BANGLADESH DELTA PLAN 2100

(Bangladesh in the 21st Century)

Volume 1: Strategy

General Economics Division
Bangladesh Planning Commission
Ministry of Planning
Government of the People's Republic of Bangladesh

Bangladesh Delta Plan 2100

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A note on this Edition

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"No plan, however well formulated, can be implemented unless there is a total commitment on the part of the people of the country to work hard and make necessary sacrifices. All of us will, therefore, have to dedicate ourselves to the task of nation building with single- minded determination".

SHEIKH MUJIBUR RAHMAN

From Foreward of the 1st Five Year Plan (1973-78)
November 1973

بسم الله الرحمن الرحيم

PRIME MINISTER
Government of the People's
Republic of Bangladesh

Message

I am delighted that Bangladesh Planning Commission is publishing the document 'Bangladesh Delta Plan 2100'. This long term visionary plan is an important step towards fulfilling our commitment of achieving a safe, resilient and prosperous Bangladesh; and would ensure bright future for generations to come.

The Father of the Nation, Bangabandhu Sheikh Mujibur Rahman, dreamt of a happy and prosperous Bangladesh. To translate his dream into reality, he established the Bangladesh Planning Commission with eminent economists and development personalities. But Bangabandhu's assassination in 1975 halted the dream and frustrated people's hope of a poverty, hunger and exploitation-free Bangladesh that was ravaged by the war in 1971.

It was Bangladesh Awami League after returning to state power in 1996, revived and restored action plan to achieve the development vision of Bangabandhu. In the past nearly 10 years, Bangladesh achieved tremendous success in many fronts of development, including record growth of social development and secured social justice.

In order to face challenges and realize the potentials of the Bangladesh Delta, we adopted the long term visionary techno-economic plan- "Bangladesh Delta Plan 2100 (BDP 2100)" with the cooperation of the Kingdom of the Netherlands. The BDP 2100 seeks to integrate the medium to long term aspirations of Bangladesh to achieve upper middle income (UMIC) status and eliminate extreme poverty by 2030, and become a prosperous country by 2041.

Bangladesh is fully committed to achieving SDGs. However, the challenge lies in integrating these sectoral, National and global targets and plans into long term coherent strategies. Effective implementation of the strategic interventions in a coordinated manner is warranted for achieving the BDP 2100.

I am happy that the Bangladesh Planning Commission has skillfully translated the political vision of the Government of Bangladesh into a long term Plan. I thank the General Economics Division of Bangladesh Planning Commission for its efforts and other Ministries/Divisions for their whole-hearted support to the preparation of BDP 2100.

I hope that our concerted efforts will realize the goals and targets of the BDP 2100 to fulfill our development aspirations of becoming a safe, resilient and prosperous country.

Joi Bangla, Joi Bangabandhu
May Bangladesh Live Forever

(Sheikh Hasina)

A H M Mustafa Kamal, FCA, MP
Minister
Ministry of Planning
Government of the People's Republic of Bangladesh

Message

I am happy to note that our government has prepared a long term visionary plan 'Bangladesh Delta Plan (BDP) 2100' for our country, Bangladesh- the largest delta of the world. BDP 2100 aims to ensure long term water and food security, economic growth and environmental sustainability while effectively reducing vulnerability to natural disasters and building resilience to climate change and other delta challenges.

Bangladesh, being a deltaic country, is highly vulnerable to climate change and water related threats and challenges. It is even more challenging in making the achieved growth sustainable in the face of extreme climate variability, storms and tidal surges, flooding and droughts. BDP 2100 has been prepared in view of the special long term challenges for development outcomes presented by climate change and natural hazards. It has, as such, set up a long term vision '**achieving safe, climate resilient and prosperous delta'** for the evolution of the country by the end of the 21^{st} century. The plan also defines short, medium and long term goals, targets and strategies as steps to reach that vision. I hope that this techno-economic plan, which is linked with resources, would contribute to the making of five year plans as well as contribute to achieving SDGs and other policy goals.

I am extremely grateful to the Hon'ble Prime Minister Sheikh Hasina for her strong commitment and guidance of preparing such a visionary plan. She has given her valuable time in reviewing this plan and made very important suggestions for its improvement. I am also grateful to my cabinet colleagues for their constructive suggestions at different stages of preparation of this mega plan. I thank the Government of the Kingdom of the Netherlands for their support and cooperation in preparing BDP 2100.

I congratulate the officials of General Economics Division (GED) of Bangladesh Planning Commission for accomplishing this challenging task of preparing such a techno-economic mega plan, which is first of its kind in the planning history of Bangladesh. This long term plan has been prepared through rigorous and extensive consultation with government ministries, divisions, agencies, development partners, experts, academia, researchers, civil societies, think tanks and NGOs. I thank all of them for their active participation in the process of formulation of the Plan.

Finally, I sincerely hope that the concerned ministries, divisions and agencies would give due attention and put their all-out efforts for implementation of BDP 2100. I am confident that proper implementation of this plan would aid us transforming our country into a happy and prosperous 'Sonar Bangla' as dreamt by our great leader Bangabandhu Sheikh Mujibur Rahman.

(AHM Mustafa Kamal, FCA, MP)

M. A. Mannan, MP
State Minister
Ministry of Finance and Ministry of Planning
Government of the People's Republic of Bangladesh

Message

It gives me immense pleasure to know that the General Economics Division (GED) of Bangladesh Planning Commission is going to publish the Bangladesh Delta Plan 2100 (BDP 2100), a long term water centric and climate change focused integrated plan for the first time in the history of Bangladesh.

Bangladesh has been experiencing rapid socio-economic development in recent times with improved per capita income, higher GDP growth rate and better performance in other social indicators such as education, health, sanitation and reducing poverty, child mortality, etc. Its economy is gradually transforming from rural and agrarian to a more urban and industrial/service oriented economy. However, making such development sustainable is more challenging due to its vulnerability to natural calamity and climate change events. Owing to the deltaic formation by the confluence of 3 (three) mighty rivers the Padma, the Meghna and the Jamuna, the country is often affected by tidal surge, flooding, river erosion, drought, cyclone and salinity intrusion, which pose continuous challenge to food security, water safety and livelihood for a large part of the population. Development of the country is also threatened by other challenges from growing urbanization, declining land availability, weak infrastructure, shortage of energy and possessing huge number of unskilled labor forces. These problems are likely to be worsening due to adverse impact of climate change.

In view of the above context, Government of Bangladesh in cooperation with the Government of the Netherlands has formulated BDP 2100, which would aid in realizing our vision to become a developed country by 2041. We hope that BDP 2100 would guide the country ensuring long term water and food security, economic growth and environmental sustainability and effectively reducing vulnerability to natural disasters and building resilience to climate change and other delta related challenges. The most significant part of the BDP 2100 is the formulation of its strategies in a short, medium and long term basis. The long term strategies will help to fulfil Delta vision of being a safe, climate resilient and prosperous delta, whereas the short and medium term strategies will help achieve benefits within the country's five year planning horizon.

We are grateful to the Hon'ble Prime Minister Sheikh Hasina for her personal initiative and guidance without which preparation of this visionary plan would not be possible. Hon'ble Planning Minister Mr. AHM Mustafa Kamal, FCA, MP, has always encouraged and contributed passionately in the formulation of this mega plan.

BDP 2100 is the culmination of a huge process that the team GED has pursued with the engagement of various stakeholders, development partners, eminent economists, social scientist, researchers, academia and civil society members, etc. I thank the GED officials and others who were involved in preparation of BDP 2100 for their immense effort and contributions.

(M. A. Mannan, MP)

Dr. Shamsul Alam
Member (Senior Secretary)
General Economics Division
Bangladesh Planning Commission

Preface

Bangladesh is one of the largest deltas of the world built by the confluence of the 3 (three) mighty rivers- the Ganges, the Brahmaputra and the Meghna. Like many other deltas of the world, Bangladesh is not bereft of challenges, many of which are closely related to its downstream location within the basins of the major sediment laden rivers, having an intense pressure on the scarce land and water resources. The country faces major inter-related delta challenges in water safety, food security and land degradation and is prone to natural calamities, such as floods, river erosion, cyclones and droughts. The challenges are both man-made and natural. The country is equally characterized by its resilience, the ability to adapt to changing climatic and economic conditions and advantage gained from the abundant natural resources available in the delta.

Management of this delta has therefore always been a key concern in both political and development agenda since long. Almost all the political movements during pre-independence period invariably included demand for flood control, disaster management and for irrigation measures, it is so because that those were the major causes of extreme poverty prevailing at that period within this delta. The election manifesto of the then United Front in 1954 advocated for protection of the country from extreme floods and famine and improving irrigation system. Father of the Nation Bangabandhu Sheikh Mujibur Rahman was always committed to develop flood control, drainage and irrigation facilities in the country and repeatedly demanded implementation of the Krug Mission report. Immediate after independence of Bangladesh, Bangabandhu established the relief ministry giving a special attention to building a disaster resilient country through minimizing losses of lives and properties caused by different natural hazards including cyclone and floods. He established Bangladesh Water Development Board (BWDB) in 1972, bifurcating the then East Pakistan Water and Power Development Board (EPWAPDA) to accelerate the implementation of the flood control, drainage and irrigation measures. He took keen interest in solving the transboundary water issues and established Joint Rivers Commission on a permanent basis in 1972. Bangabandhu had installed earthen forts locally known as ‘Mujib Killa’ in coastal regions aiming to provide shelter to coastal flood and cyclone affected people along with their livestock. The First Five Year Plan of Bangladesh (1973-1978) that was prepared under his guidance as the Chairman of the Planning Commission put strong emphasis on sound management of water resources. Many of the strategies and policies for sound management of water resources highlighted in the first five year plan are as relevant today as they were then suggesting the far-sightedness of Bangabandhu in identifying the need for holistic management of water resources and flood management.

Over the past 48 years since independence Bangladesh has achieved success in many fronts. The country has secured tremendous gains in development during the last ten years under the strong political leadership of Her Excellency Prime Minister Sheikh Hasina combined with many sound development policies and programme. GDP growth has today climbed from less than 4% in the early 1970s to around 7.86% in 2018; per capita income has surged from less than US$ 100 in 1972 to US$1751 in 2018; poverty has fallen from more than 75% in the early 1970s to less than 24%; life expectancy has increased to 72 years in 2018; and literacy has increased to 72.9% in 2017. The economy is gradually transforming from an agrarian base towards a modern manufacturing and services oriented economy. Bangladesh crossed over from a low-income economy to a lower middle income economy in 2015. The country has already fulfilled all the criteria of graduating from least developed country to a developing country for the first time in 2018. Making this growth sustainable is even more challenging in the face of extreme adverse climate variability, with frequent storm and tidal surges, flooding, and droughts. Climate change is a serious threat to sustainable development. If nothing is done by 2050, climate change impact could make an additional 14% area of the country extremely vulnerable to floods and dislocate more than 35 million people in the coastal districts. At the macro-level, the combined effects of climate change could range from a loss of 1.3% of GDP per year in a moderate climate change environment to 2.0% of GDP per year in an extreme climate change environment. Many more challenges lie ahead of Bangladesh, the most important being pressure on land use, environmental protection, globalization and macro-economic development. Given the ambition to become a developed country by 2041, addressing the expected impacts of climate change, there is a need for an integrated approach to future land and water management in relation to water safety, agricultural growth and food security. The recent and future anthropogenic changes in the hydrological cycle due to e.g. climate change, construction of dams and barrages in the upstream countries in combination with increasing water demand are expected to make future water governance and management even more challenging. A number of sectoral plans have been developed so far in Bangladesh, but they tend to be short term oriented and independently pursued by individual ministry or division. Whereas, goals and targets at the national level and climate change and natural disaster risks present major downside risks and uncertainties that require long term strategies and multi-sectoral coordinated policy management under uncertainty. In view of the above long term challenges presented by climate change and natural hazards and based on the intention of Sheikh Hasina, the Hon'ble Prime Minister of Bangladesh, General Economics Division (GED) of the Bangladesh Planning Commission has formulated 'Bangladesh Delta Plan (BDP) 2100' with support from the Government of the Netherlands. The Memorandum of Understanding (MoU) signed between Bangladesh and the Netherlands in 2012 in presence of the Hon'ble Prime Minister Sheikh Hasina to cooperate on delta planning laid the foundation of BDP 2100. The preparation of BDP 2100 was officially launched by the Hon'ble Planning Minister AHM Mustafa Kamal FCA, MP in August 2014.

BDP 2100 has been conceived as a techno-economic, long-term, holistic, water centric integrated plan. An interactive planning process has been followed comprising three major steps: i) conducting baseline studies; ii) developing delta vision, goals and management framework; and iii) formulating adaptive strategy. These steps were supported by country wide consultation processes which eventually led to the outcome of an investment plan. The formulation of BDP 2100 drew lessons from Dutch delta experiences, while at the same time adapting to the specific needs of Bangladesh and finding inspiration in country's long tradition of resilience in adversity and water management. In short, it can be said that BDP 2100 focuses on "How to enable socio-economic development under uncertain changing conditions especially regarding climate change and (trans-boundary) scarce water resources?" The plan is holistic, considering many themes and sectors and bringing together individual strategies as well as integrated ones for the whole country, considering the needs of all water-related sectors in a single plan.

BDP 2100 looks primarily at the delta agenda up to 2050 but being mindful that the decisions taken today have implications up to 2050 and beyond. It sets up a long term vision for the evolution of the Bangladesh Delta by the end of the 21st century as **'Achieving a safe, climate resilient and prosperous delta'**. As steps to reach that vision it defines short to medium term goals as to achieve upper middle income status and eliminate extreme poverty by 2030 and being a prosperous country around 2041 with the longer term challenge of sustainable management of water, ecology, environment and land resources in the context of their interaction with natural disasters and climate change. The BDP 2100, therefore, seeks to ensure long term water and food security, economic growth and environmental sustainability while effectively reducing vulnerability to natural disasters and building resilience to climate change and other delta challenges through robust, adaptive and integrated strategies, and equitable water governance.

First Volume of the BDP 2100 has been organized into 14 chapters of which first five chapters deal with context, challenges and opportunities of Bangladesh Delta, climate change, environment and ecological issues, trans-boundary water issues and approach of the planning process. The chapters from six to ten have elaborated strategies on water resources, land resources, agriculture, inland water transport and urban water management issues. Chapter 11 discusses investment and financing and chapter 12 focuses on governance and institutional issues. Chapter 13 and 14 describe monitoring and evaluation framework and delta knowledge management issues respectively. It provides long-term strategies for flood risk management, freshwater management, water supply and sanitation, river management, navigation, agriculture, fisheries, livestock, renewable energy, blue economy, earthquake. It addresses the changing dynamics of the climate change impacts and disaster risk nexus. It also includes a framework for its implementation with an investment plan phased out in short, medium and long term interventions (BDP 2100, Volume 2). The goals, associated strategies, policies, institutions and investments are moving targets and adaptive in nature. They are adaptive to changing natural events in order to respond appropriately and stay on the course to the path of the long term vision. The adaptive nature of delta management puts knowledge at a premium. BDP 2100 should be continuously science and knowledge driven. The knowledge management approach is anchored in the delta vision and goals and be updated periodically (end of every five years, preferably).

The implementation of the BDP 2100 involves total spending on delta-related interventions, through new projects and maintenance of new and old projects, which will gradually increase up to a level of 2.5 percent of GDP per annum by 2030; of which 2.0 percent of GDP would be from public funding and rest 0.5 percent would be from the private sector. The strategy for public funding involves some combination of tax financing, application of cost recovery based on 'beneficiary pays principle' and mobilizing foreign funding including tapping into the global Green Climate Fund (GCF) initiative. The BDP 2100 Investment Plan up to the year 2030, prepared in cooperation with World Bank group, consists of a total of 80 projects: 65 are physical projects, and 15 are institutional and knowledge development projects. Its total capital investment cost of the investment plan is estimated at 2,978 billion ($37 billion). The investment plan projects have been selected following multi criteria analysis and rigorous consultation with the stakeholders. This BDP 2100 took almost four years to give it a final shape to kick off. This comprehensive, techno-economic mega plan stretching a period to the end of the current century is **the best gift to the future generations by the present generation**.

The process of the BDP 2100 formulation was led by the Hon'ble Planning Minister Mr. AHM Mustafa Kamal, FCA, MP and the Deputy Chairman of Bangladesh Planning Commission, who took keen interest in making this plan happen. Hon'ble State Minister for Planning and Finance Mr. M. A. Mannan, MP has always been supportive to us while preparing this plan. We have received intimate support and contribution from the relevant Ministries/Divisions in preparing this plan. The contribution and support received from different quarters particularly the members of the Technical Advisory Committee and National Steering Committee are deeply acknowledged and appreciated. We must also record our gratitude to Sheikh Mohammad Belal, Ambassador of Bangladesh to the Netherlands for his continuous support, encouragement and the liaison he maintained between the Foreign Ministry of the Netherlands and the Government of Bangladesh relating to Delta Plan issues. The concerned officials of GED who put their best determinations and efforts in formulation of this mega plan can never be forgotten. I also acknowledge with deep sense of appreciation the cooperation and support we received from the Government of the Kingdom of the Netherlands in preparing BDP 2100.

(**Dr. Shamsul Alam)**

Summary

The Bangladesh Delta Challenge

Deft economic management and solid political leadership of Prime Minister Sheikh Hasina helped Bangladesh secure lower middle income status in 2015. Buoyed by this success, Bangladesh now aspires to reach upper middle income status and eliminate extreme poverty by 2030. The exemplary development performance under the 6^{th}FYP (FY2010-FY2015), whereby Bangladesh sharply reduced moderate and extreme poverty, improved human development and increased growth rate to an average of 6% per year, helped to achieve lower middle income status in 2015. The solid foundation laid during the Sixth Plan is a comforting factor and this progress has continued under the 7^{th} FYP (FY2016-2020); yet the government recognizes that many fundamental policy and institutional challenges remain. At the same time, Bangladesh faces substantial downside risks from the interface of its deltaic geographical configuration, high population, and regular episodes of a range of natural disasters including flooding, river bank erosion, sea level rise, salinity intrusion, cyclones and water-logging. Additional challenges in Delta Management and continued national development include: dry and wet season water shortages and surpluses; vulnerability from being a lower riparian to much of the river inflows; growing water demands from industrialization and rapid urbanization; rapid depletion of groundwater owing to over-exploitation in many areas; arsenic contamination of groundwater; and a range of water quality issues emerging from economic development.

In view of the special long term challenges for development outcomes presented by climate change and natural hazards, the Government has decided to formulate a long term Bangladesh Delta Plan 2100 (BDP 2100). The Delta Plan is not totaly a new or separate development plan. Father of the nation Bangabandhu Sheikh Mujibur Rahman envisioned a Bangladesh that was prosperous, where everybody seeking a job was gainfully employed and where economic and social justice prevailed for all citizens irrespective of gender, religion, caste or creed. In that context, he was acutely aware of the water management challenges of Bangladesh owing to geography. He understood that water was both an opportunity and a challenge. Accordingly, the First Five Year Plan of Bangladesh (1973-1978) that was prepared under his guidance as the Chairman of the National Planning Commission put strong emphasis on sound management of water resources. Many of the strategies and policies for sound management of water resources highlighted in the First Plan are as relevant today as they were then suggesting the far-sightedness of Bangabandhu in identifying the need for holistic management of water resources. Furthermore, BDP 2100 builds on the government's Sixth and Seventh Five Year plans and incorporates the government's vision for 2041.

Specifically, the BDP 2100 seeks to integrate the medium to long term aspirations of Bangladesh to achieve upper middle income (UMIC) status and eliminate extreme poverty by 2030 and being a prosporous country beyond 2041 with the longer term challenge of sustainable management of water, ecology, environment and land resources in the context of their interaction with natural disasters and climate change. The BDP 2100 looks primarily at the delta agenda upto 2050 but be mindful that the decisions taken today have implications upto 2050 and beyond. In this regard, it sets up a long term vision for the evolution of the Bangladesh Delta by the end of the 21^{st} century, but defines short and medium term goals as steps to reach that vision. These goals, associated strategies, policies, institutions and investments are moving targets and adaptive in nature. They are adaptive to changing natural events in order to respond appropriately and stay the course to the path of the long term Delta vision.

The evidence from global experience as well as the experience from Bangladesh suggest that climate change is a real threat to global and national level prosperity. Owing to the deltaic formation of the country, the configuration of the rivers and the challenges posed by natural disasters and climate change, Bangladesh has been ranked as the 5th most vulnerable country in the world in terms of risks from natural hazards. These risks have been growing over time. Unless these vulnerabilities are managed and addressed comprehensively, Bangladesh faces serious downside risks to food security, the growth momentum and poverty reduction efforts. These climate change factors work through a large number of sectors that add up to substantial losses economy wide. The most vulnerable sector is agriculture. Climate change, especially in areas of temperature, humidity and radiation, increases the incidence of insect pests, diseases, and microorganisms. Rising temperature also reduces yields of high-yielding varieties of rice. Farm productivity will fall due to increase in soil salinity caused by Sea Level Rise (SLR). Agriculture will suffer additionally from the higher incidence of flooding caused by climate change, including from inundation caused by SLR. The other highly vulnerable sectors are forestry and ecosystems. Many of the anticipated adverse effects of climate change, such as SLR, higher temperatures, and an increase in cyclone intensity, will damage the forest resources of the country, put pressure on many climate-sensitive species, and cause increased erosion and deterioration of soil quality in many upland forested areas. The world's largest mangrove forest, the Sundarbans, is extremely vulnerable to climate change. SLR will increase saltwater intrusion and negatively affect the forest.

Additional adverse effects will happen due to loss of land and physical assets from inundation. At 1 meter SLR a significant part of dryland in Bangladesh will be permanently inundated; the subsequent fall in production in all sectors of the economy would lead to a substantial fall in real GDP. Climate change and the resultant floods and cyclones will have a significant negative impact on capital stock in construction and infrastructure in Bangladesh. Health hazards will also intensify. Water-borne diseases, such as diarrhea and dysentery, and vector-borne diseases, such as malaria and dengue, are also climate sensitive.

At the macro-level, the combined effects of climate change could range from a loss of 1.3% of GDP per year in a moderate climate change environment to 2.0% of GDP per year in an extreme climate environment. In terms of loss of human welfare, district and sub-district level analysis shows that there is a strong positive correlation between incidence of poverty and the intensity of natural hazards. On average, districts that are ranked as most exposed to natural disasters also show poverty rates that are higher than the national average. Strikingly, of the 15 most poverty-stricken districts, almost 90% of the districts belong to high natural hazard risk categories.

Bangladesh Delta Plan 2100 (BDP 2100) Vision and Goals

The BDP 2100 approach to long term Vision: The BDP 2100 approach is to first develop a broad-based long term vision about the evolution of the Bangladesh Delta by the end of the 21st Century. Thus, an integrated, comprehensive and long term delta vision might be formulated as:

"Achieving safe, climate resilient and prosperous delta"

The Mission for BDP 2100 is formulated as:

"Ensure longterm water and food security, economic growth and environmental sustainability while effectively reducing vulnerability to natural disasters and building resilience to climate change and other delta challenges through robust, adaptive and integrated strategies, and equitable water governance".

BDP 2100 approach to long term goals: This long term vision needs to be translated into specific goals or targets for implementing the Delta Vision. This is done by combining longterm development outcomes in terms of country's aspirations for economic growth and poverty reduction in the perspective of 2041 with targets for reducing long-term vulnerability from water and climate change related hazards plus targets for environmental protection. The BDP 2100 proposes 3 higher level national goals which have also been considered in upcoming Perspective Plan 2041 and 6 water, ecology and land use specific goals that contribute to these higher level goals.

Higher level goals: Goal 1: Eliminate extreme poverty by 2030; Goal 2: Achieve upper middle income status by 2030 and Goal 3: Being a Prosperous Country beyond 2041.

BDP 2100 specific goals: Goal 1: Ensure safety from floods and climate change related disasters; Goal 2: Enhance water security and efficiency of water usages; Goal 3: Ensure sustainable and integrated river systems and estuaries management; Goal 4: Conserve and preserve wetlands and ecosystems and promote their wise use; Goal 5: Develop effective institutions and equitable governance for in-country and transboundary water resources management; Goal 6: Achieve optimal and integrated use of land and water resources.

BDP 2100 approach to managing uncertainties and linking short to medium to long term outcomes: Given the inherent uncertainties of the long term behavior of the natural forces that influence water, climate change and environmental outcomes, it is essential to adopt a flexible and adaptive approach to converting the long term Delta Vision 2100 to medium term strategies for moving towards this vision. BDP 2100 uses the best available information and develops short to medium term strategies and policy options under different assumptions about the external outcomes. The scenarios and strategies will need to be updated frequently as new information is available on a 5-year cycle. This adaptive approach to delta planning including selection of investment projects provides the link between the short to medium term development targets and investment programmes with the long term goals of sustained development based on climate sensitive management. This also underscores the importance of establishing a Delta Knowledge bank and doing sound monitoring and evaluation to assess delta progress and shortcomings.

BDP 2100 Macroeconomic Strategy

To evaluate the impact of climate change and natural hazards on development outcomes the BDP 2100 develops a quantitative macroeconomic framework by linking the real side (i.e. economic variables) to environment or climate change parameters. Two policy options are considered: Option 1 asks the question what happens to development outcomes if there is no Delta Plan; this is the Business As Usual (BAU) option. Option 2 develops the macroeconomic outcomes if the Delta Plan is adopted.

The results are very striking. Under the Business as Usual option, the GDP growth rate starts falling over time as the adverse effects of climate change and natural hazards gain momentum. The efficiency of capital falls. Outmigration to cities from vulnerable districts increases, adding to the urbanization pressures. Agriculture productivity falls. Land degradation and lower land productivity reduce land availability and increase land prices. Availability of urban land falls in relation to demand as growing urbanization from outmigration creates additional pressure on urban areas. Cost of urban production increases as flooding and drainage problems damage urban properties and enterprises and create infrastructure problems. Urban water shortages, water quality and sanitation risks add to health costs and reduce quality of life. The net effect is a downward slide in the growth effort. GDP growth falls from 7.2% in FY 2017 to 5.5% by FY2041, which amounts to an annual average GDP loss of about 1.1% between FY2017-FY2041 as compared with the government's target of achieving 8% of GDP. Most importantly, in this option, Bangladesh is unable to reach upper middle income status and eliminate extreme poverty by FY2031. In contrast to this, Under Option 2 that incorporates the adoption of the Delta Plan the negative effects of climate change and natural hazards are considerably reduced. This allows the Bangladesh economy to avoid a disruption of the growth effort and secure an average GDP growth rate of about 8.8% as compared with 6.9% in the BAU option. Bangladesh secures the development objectives of eliminating extreme poverty and reaching upper middle income status by 2030.

Delta plan financing needs: The implementation of the BDP 2100 involves total spending on delta-related interventions, through new projects and maintenance of new and old projects, in an amount of about 2.5% of GDP per annum. This compares with an annual spending of a mere 0.8% of GDP presently. In current prices and using the prevailing GDP, total required spending on BDP 2100 related projects (current and capital) would need to grow from the pre-BDP 2100 spending levels of about US$ 1.8 billion in FY2016 to about US$ 3.5 billion in FY2017 and will increase to US$ 29.6 billion by FY2031. The additional investment and operations and maintenance (O&M) costs for implementing the BDP 2100 of about 1.7% of GDP per year, comprising of 1.2% from the Budget and 0.5% from private sector, more than pays for itself in terms of recovery of GDP growth.

Public sector financing: Finding an additional 1.2% of GDP for public financing of the BDP 2100 will not be easy. The strategy for public funding involves some combination of tax financing, application of cost recovery based on beneficiary pays principle and mobilizing foreign funding including tapping into the global Green Climate Fund (GCF) initiative. International experience of good practices with Delta management shows the strong role of the application of the beneficiary pays principle in financing water investments. For example, in the Dutch Delta much of the funding of flood control, irrigation, water supply, sanitation and waste management investments is financed through the application of the beneficiary pays principle. The O&M is fully funded through cost recovery. In the Netherlands, water management is heavily decentralized. Some 80% of water spending including 100% of O&M is done by lower levels of government. The bulk of this spending is done by the local water authorities that are managed and run as private cooperative enterprises with 100% application of the beneficiary pays principle, with some degree of cross-subsidies to the recognized poorer communities.

Beneficiary pays principle: The scope for application of the beneficiary pays principle in Bangladesh Delta management is huge. In Bangladesh O&M funding of urban water and sanitation is prevalent in significant ways. However, full cost recovery of O&M does not happen. Moreover, the cost recovery of O&M of waste management is negligible. By default, there is no cost recovery of capital cost of urban water supply, sanitation and waste management. Regarding flood control and irrigation, there is no cost recovery of either capital cost or O&M in Bangladesh. This is mainly because of the absence of local water management bodies/authorities. Once these local water authorities are created the application of beneficiary pays principle will gradually become a reality. Regarding urban water and sanitation, the institutions and regulations are in place. They need to be applied more rigorously. A time bound policy should be adopted whereby all public urban water and sanitation services must be required to cover 100% of the O&M cost. Over time, consideration may be given to recovering capital costs, starting with the relatively well-off service areas of the 4 WASAs. Regarding solid waste, cost recovery can happen through an annual service charge linked with the setting up of a modern property tax system.

Resources from Green Climate Fund: Additional international grant financing for BDP 2100 can be secured by effectively tapping resources from the global Green Climate Fund (GCF). Bangladesh has had significant success in using its public sector intermediaries to incentivize the private sector, particularly in the renewable energy industry. As such, it is well placed to tap this important source of grant funding to scale up delta investments. While a lot more needs to be done to ensure private enterprises fulfil their crucial role in the fight against climate change, if Bangladesh can pursue her case effectively, there is bright possibility that Bangladesh may receive funds as large as US$ 2 billion per year from the GCF. However, this might probably materialize only after 10 to 15 years from now when GCF is fully running and all parties involved in GCF have taken their full responsibilities and effectively pledging their agreed funds in time (year by year).

Private sector financing: Effective engagement of the private sector will generate sizable resources to finance the Delta Plan. The BDP 2100 projects that on average Bangladesh should be able to mobilize at least 0.5% GDP per year for private financing of water and related infrastructure. International experience shows that the prospects for attracting private investments including through public-private-partnerships (PPP) in water treatment, water supply and sewage treatment are excellent. Another prospective area is irrigation. A third area is dredging. There is strong private sector interest in undertaking dredging contracts. The cost of dredging may be significantly offset by the sale proceeds from sand, making dredging costs quite low. Bangladesh can learn from good international experiences in developing proper contracting arrangements for dredging. A fourth area for PPP role concerns land reclamation. Combining land reclamation with dredging of rivers in a PPP concession framework would make very good sense. Finally, PPP initiative is also possible in establishing river port infrastructure for inland water transport (IWT). However, as mentioned before this level of 0.5% from the private sector might only be reached after 10 to 15 years from now, due to its slow development over time.

BDP 2100 Sectoral Strategies

Water: Water remains an indispensable resource and is used in diversified ways. It is used for production purposes such as, agriculture, industrial, commercial, forestry, fisheries, etc. and also for community services like use of water for domestic consumption and sanitation. The nation-wide demand for water is growing every day which is being intensified by several socio-technical drivers such as, high demographic changes, rapid and unplanned urbanization, high sectoral demand (such as agriculture, fisheries, transportation, industries, etc.), climate change, etc. On the other hand, the essentiality of water for the rich but vulnerable ecosystem of the country, and the variability of water availability in dry and wet seasons complicates the issue of water resources management in Bangladesh. The management of water resources is further complicated by the fact that the flow generated from 93% of the area of the Ganges- the Brahmaputra- the Meghna is lying outside the border of Bangladesh and is drained out to the Bay of Bengal.

The BDP 2100 develops an adaptive, holistic and long term strategic plan to steer the opportunities and vulnerabilities created by the interface of water, climate change, natural disasters, environment, ecological balance, agriculture, land use and inland water management for national development. The sustainable use of water resources and prevention of water-related natural disasters provides the backbone to the Delta Plan. The strategies for managing water resources in wet and dry seasons that have been formulated are **flexible** in respect of measures and actions with its timeframe and uncertainties. The strategies are **adaptive** in the sense that they need periodic review and update in a Five Year Planning cycle on the basis of situation and development needs. These are **'no regret' strategies** in a sense of effectiveness and maximum benefit and offers integrated implementation with innovation, advanced information technology and strengthened institutional capacity.

The water challenges and proposed strategies in BDP 2100 are built around addressing the fundamental problem of flooding that is a nation-wide challenge and addressing "hotspot" specific challenges of water shortage in Barind and drought prone areas; river erosion problems of the river systems and estuaries; coastal inundation and salinity problems of the Coastal Zone; flash-flooding and wetland management issues of the Haor and flash flood areas; water shortage, sanitation and drainage problems of the urban region; and the water shortage problem of the Chattogram Hill Tracts (CHT).

The proposed water management strategies recognize the transboundary issues and associated constraints imposed by upstream country water management activities. The implications of this for river basin management of the Ganges and the Brahmaputra are developed. The water strategy also builds in the implications of prospective river course changes and related river bank erosion, land accretion and land losses. The inter-linkages between land, water and environmental management are emphasized in the relevant water management strategies. A particular emphasis is placed on the proper management of the "char" areas that have specific implication for poverty alleviation. The strategy notes the importance of creating room for river in flood control and embankment projects, which has also been a key feature of the Dutch Delta management. The strategy emphasizes that flood control and embankment projects must not create problems of land inundation downstream or elsewhere but be based on the principle of creating room for river to flow its natural course and move on to the sea. The Delta Plan notes the importance of addressing the salinity problems in the coastal areas of Bangladesh and provides specific approaches to addressing water management and salinity control for these areas. The Plan also underscores the need to address water logging in all areas and flash floods in Haor areas. It provides comprehensive strategies to address these concerns including alternative livelihoods, such as fishery resources in Haor areas.

Environment, ecology and bio-diversity: Wetlands are precious for the environment, ecology, and biodiversity. They are an integral part of the local ecosystem and closely related with local cultures, and also support the livelihoods of millions of people based on diverse activities such as fishing and agriculture. There is an urgent need to take action against wetlands degradation and maintain them through proper management. Strategic considerations include: conservation and preservation of wetlands and ecosystems through institutional capacity building, research and awareness raising programs; restoration of the Chalan Beel and the Halda River; establishing greenbelt around the hills of the Kaptai Lake; preserving the Sundarban mangrove forest and parts of the Haor Basin wetlands, planting of artificial mangrove forest, development of greenbelt, and development of the islands. As a part of strategy for preservation of the Sundarban, the BDP2100 puts emphasis on restoring the Gorai river to allow fresh water inflow that will wash away the adverse effects of saline intrusion in the Sundarbans and also the regular dredging and maintenance of of Ghasikhali and other channels in the Sundarbans.

For improving the urban environment and water quality management, the BDP 2100 calls for a major expansion of piped water supply, improved urban drainage, preventive measures for control of river and other water body pollution, and strong management of urban solid and liquid wastes. Special attention should be given to proper disposal of medical wastes and other hazardous materials.

Agriculture, fisheries and livestock: Agriculture sector is most vulnerable to climate change. Considerable adaptation efforts of the past have helped lower the cost of agriculture. Nevertheless, several additional initiatives are necessary to cope with the growing risk of climate change for agriculture and livelihood. The implementation of water strategies and interventions are a major part of protecting agriculture from the adverse effects of natural disasters and climate change. Other strategic elements relate to the adoption of proper technology to combat salinity and rising temperature, and strengthen drought tolerance, and the institution of proper land management. Diversification of agriculture and preservation of food security requires stronger policy attention to non-crop agriculture that provides essential nutrition and balanced diet choices including fruits and vegetables, fisheries, dairy farming and livestocks. In particular, the delta location with multitude of rivers, lakes and ponds open access to sea provides Bangladesh with rich opportunities to develop and benefit from a prosperous fisheries industry. Preserving the forest cover to maintain bio-diversity and ecological balance also allows protection from natural hazards. Sustainable forestry can also provide livelihood support to poor people when combined with a broad-based livelihood support strategy.

Land management: Land resource management is integrally linked to water resource management. Given the location and topography of Bangladesh, its land resources management are constrained by floods, drainage congestion and water logging, drought, coastal/tidal surge, soil salinity, river bank erosion, land degradation, soil erosion, soil fertility depletion, decrease of land productivity, siltation on river beds and canals, rise of sea water due to climate change, increase of population, urban and rural settlements, decrease of crop land creating different challenges. With population growth and declining per capita availability of land, Bangladesh also faces land degradation. Deforestation, cultivation on steep slopes, shifting cultivation, over-exploitation of groundwater, unbalanced use of fertilizers, improper crop rotations are responsible for land degradation induced by humans. All these phenomena mean that availability of land for crop agriculture will continue to decline calling for policies, reforms, and technological innovations for not only raising productivity and reducing soil degradation, but also diversifying the crops to better respond to food security needs.

Bangladesh in the past adopted many land reform initiatives but effectiveness was limited due to the inadequate attention to land governance, institutions and land markets. So, the main priorities under BDP 2100 are: undertake a comprehensive public sector reform involving Ministries/ Institutions dealing with land administration; modernization of land management through the Digital Land Management System (DLMS); computerization of processes and use of ICT for all land transactions; comprehensive review and reform of the National Land Use Policy to make it applicable for all land uses throughout the country; reform of the regulatory policies for land accretion and reclamation to counter land grabbing and other predatory practices; adoption of a comprehensive land zoning policy that is sensitive to climate change and water hazard risks; and adoption of water-sensitive spatial land use planning. Land reclamation is an important strategy in the BDP 2100 and will become an integral part of land management in the country.

Inland water transport: Being a land of rivers, inland waterway transport (IWT) has always been a natural, environment friendly and relatively cheap mode of transport for Bangladesh. An estimated 25% of the rural population has access to inland navigation. Inland waterways have continued to be important, sometimes the only transportation mode not only for maintaining transport link between various remote parts of the country; it is a means of transporting export-import cargo as well. It provides cheaper transit of passengers and goods. Despite being the cheapest mode of transport, the popularity of IWT as a mode of passenger and cargo transportation has been on decline. IWT has suffered because many rivers of the country have been deteriorating both for natural, morphological processes and for withdrawal of water from the rivers beyond the border and within the country caused by decreased dry season navigability. This was further aggravated by poor or no maintenance of navigability, weak regulations and safety standards, low allocation of budgetary funds and general under-investment by both public and private sectors. In recent years, given the rapid GDP growth and associated demand for passenger and cargo services along with constraints in developing road and railway transport (owing to land and financial scarcity), the prospects for inland waterway look brighter. There is now a growing appreciation that with proper investments, policies, regulations and institutional development IWT can be a major low-cost transport alternative to the high-cost of land transport. The positive effects of this strategy for income, employment and poverty reduction are large. Looking forward, the IWT strategy will need to focus on the following main priorities: systematically and substantially address the river morphology and climate change issues affecting IWT; select priority routes and maintain them adequately; develop and modernize priority route infrastructure as an integral part of multimodal connectivity; substantially increase public and private investment in IWT; improve IWT governance, administration and safety standards; strengthen cross-boundary river traffic through joint investments in infrastructure and proper cost recovery policies. Effective sediment management is also an important contributor to dynamizing the inland water transport sector.

Strategic dredging of major river routes to enabling proper navigation is a key element of the BDP 2100. In particular, the capital and maintenance dredging of the rivers Padma, Meghna, Jamuna, Brahmaputra, Dharla, Arial Khan, Kushiyara, Gorai and Manu are high priority items for investment programme of the BDP 2100. Related to dredging, efficient and equitable management of the sand obtained from dredging is essential . Sand reovered from dredging is a valuable resource and should be managed as such. The place for 'Balu-mahal' (sand quarry) should be shifted regularly and the local administration should take necessary steps accordingly. Specific guidelines for the management of soil/sediment management resulting from dredging should be developed.

Blue Economy: With the settlement of maritime border disputes with neighboring states Myanmar and India in 2014, the Government of Bangladesh can unlock the potentials from better access to sea and ocean resources. The blue economy is now considered as a new 'development space' in Bangladesh. Shipping, sea ports, ship building and recycling, marine fisheries, sea salt, coastal tourism, ocean energy, land reclamation, maritime surveillance, human resources development and governance have been identified as key priority issues for the development of blue economy.

Renewable Energy: Bangladesh is expected to have enormous potentiality in renewable energy development. Solar photovoltaic (PV) panels are gaining acceptance for providing electricity to households and small businesses in rural areas. Development of off-grid solar home solutions has achieved international benchmark. However, potential of other renewable resources is still at the exploration stage. Strategies cover the following aspects: institutional, hydropower, harnessing tidal power, solar power energy and financing.

Earthquakes: Bangladesh and the northeastern part of India have long been one of the seismically active regions of the world, and have experienced numerous large earthquakes during the past 200 years. Strategies in BDP 2100 include: strengthen earthquake management and enhance the capacity to cope with earthquakes; design earthquake proof water resources structures in conformity with the Bangladesh National Building codes or other approved standards; formulate a proper land use plan for building construction in municipal areas; and conduct further research on identification of geological faults and epicentres.

BDP 2100 Investment Plan

The Investment Plan consists of a total of 80 projects: 65 are physical projects, and 15 are institutional and knowledge development projects. Its total capital investment cost is BDT 2,978 billion ($37 billion). All projects can be started within the next eight years, though given the scale and programmatic nature of some investments, construction in some cases will extend over decades.

Development of the Investment Plan followed a rigorous, consultative, and inclusive process, using the principles of ADM. As part of the BDP 2100 formulation process, the General Economics Division (GED) of the Planning Commission asked over 20 agencies involved in work in the Delta to submit their priority investment projects. This generated 133 candidate projects with total capital costs of BDT 3,753 billion ($47 billion).

The candidate projects were screened, grouped, then sequenced following an ADM methodology. Candidate projects were included in the Investment Plan if their expected benefits exceed expected costs; if they contribute to at least one of the six BDP 2100 goals; and if they are compatible with the ADM approach. Of the 133 candidate projects, 80 met these criteria.

BDP 2100 Governance and Institutions

The BDP 2100 agenda is essentially cross-sectoral and implementation arrangements involve multiple line ministries, local government institutions, communities and private sector. Clarity of role, interdependence of actions and a coordinated approach are essential requirements of the institutional set up for BDP 2100 implementation. Institutions are dynamic in the sense that they evolve over time. Starting with a thoughtful design that involves pragmatic solutions based on the present socio-political realities of Bangladesh and working within the umbrella of the overall capacity constraints in public administration, institutional changes can further evolve as implementation progress is made. The immediate challenge is to develop a basic minimum core arrangements now without which the implementation of the BDP 2100 will falter.

Some of the broad principles and features of the global institutional practices in delta management can be summarized as follows: importance of integrated water management; need for effective regional water cooperation; strong and participatory institutions for internal water cooperation; focus on knowledge for adaptive delta management; emphasis on public-private partnerships; coordinated approach to delta financing with emphasis on beneficiary pays principle; and effective monitoring and evaluation

Bangladesh has 50 plus years of experience in managing water resources that is reflected in numerous water policies and water programmes. Despite this rich history and the enactment of the 2013 Water Act and the high powered coordinating committees (NWRC, ECNWRC), effectiveness of the implementation of integrated water management is weak. Integration of water with other challenges of the Bangladesh Delta including a clear link to development outcomes does not exist. The governance and institutional gap with principles of good practice international experiences listed above is large. Successive governments have engaged in detailed technical studies with international technical experts, but implementation has suffered owing to political, financing and institutional constraints. At the institutional level, the main problem is the weak capacity of all water and water related institutions. A second problem is the absence of local water authorities and therefore the absence of key-stakeholders (beneficiaries) in water decision making. A third problem is the lack of integration of water issues with climate change, environment, land management and other delta-related challenges owing to inadequate institutional coordination.

Clearly, in addition to substantial new investments and adequate financing arrangement, a substantial overhaul of the Delta governance and institutional arrangements is needed to implement the BDP 2100.

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Acronyms and Abbreviations

ΔDIEM	Delta Development Integrated Emulator Model
4S	Steps for Sustainable Sanitation Services Project of the Water Supply Program of the World Bank
A1B	Climate Change Scenario developed by the IPCC
A1FI	Climate Change Scenario developed by the IPCC
A2	Climate Change Scenario developed by the IPCC
A2i	Access to Information
ADB	Asian Development Bank
ADM	Adaptive Delta Management
ADP	Annual Development Programme
AIS	Agriculture Information Service
AOGCM	Atmosphere-Ocean Global Circulation Models
AR5	Fifth Assessment Report of IPCC
ASLR	Accelerated Sea Level Rise
ATP	Adaptation Tipping Points
B1	Climate Change Scenario developed by the IPCC
BADC	Bangladesh Agricultural Development Corporation
BAEC	Bangladesh Atomic Energy Commission
BAPA	Bangladesh Poribesh Andolon
BAPEX	Bangladesh Petroleum Exploration & Production Co. Ltd
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Business as Usual
BBIN	Bangladesh, Bhutan, India and Nepal
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Centre for Advance Studies
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BCCTF	Bangladesh Climate Change Trust Fund
BCM	Billion Cubic Meters
BDHS	Bangladesh Demographic and Health Survey
BDP2100	Bangladesh Delta Plan 2100
BECA	Bangladesh Environment Conservation Act
BEMP	Bangladesh Environmental Management Project
BEZA	Bangladesh Economic Zone Authority
BFD	Bangladesh Forest Department
BFRI	Bangladesh Fisheries Research Institute
BFoRI	Bangladesh Forest Research Institute
BIDS	Bangladesh Institute of Development Studies
BIGD	BRAC Institute of Governance and Development
BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation

BIP	Bangladesh Institute of Planners
BIP	Barind Irrigation Project
BIRDEM	Bangladesh Institute of Research and Rehabilitation in Diabetes, Endocrine and Metabolic Disorders
BIWTA	Bangladesh Inland Water Transport Authority
BIWTC	Bangladesh Inland Water Transport Corporation
BMD	Bangladesh Meteorological Department
BMDA	Barind Multi-purpose Development Authority
BMDF	Bangladesh Municipal Development Fund
BNBC	Bangladesh National Building Code
BoB	Bay of Bengal
BoBLME	Bay of Bengal Large Marine Ecosystem Project
BOD	Biochemical Oxygen Demand
BORI	Bangladesh Oceanographic Research Institute
BOT	Built-Operate-Transfer
BQ	Blackquarter
BR	Bangladesh Railway
BRRI	Bangladesh Rice Research Institute
BRT	Bus Rapid Transit
BSCIC	Bangladesh Small and Cottage Industries Corporation
BTM	Bangladesh Transverse Mercator
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
BWFMS	Bangladesh Water and Flood Management Strategy
CA	Conservation Agriculture
CAG	Comptroller and Auditor General
CASE	Clean Air and Sustainable Environemnt
CBA	Community Based Adaptation
CBD	Convention on Biological Diversity
CBN	Cost of Basic Needs
CBOs	Community Based Organizations
CBRMP	Community-Based Resource Management Project
C–C	Copenhagen-Cancun
CCC	Chattogram City Corporation
CCNR	Central Commission for the navigation of the Rhine
CDA	Chattogram Development Authority
CDM	Clean Development Mechanism
CDMP	Comprehensive Disaster Management Programme
CDR	Crude Death rate
CDSP	Char Development and Settlement Project
CEGIS	Center for Environmental and Geographic Information Services (CEGIS)
CEIP	Coastal Embankment Improvement Project
CEP	Coastal Embankment Project

CETP	Centralized Effluent Treatment Plant
CFAB	Climate Forecast Applications in Bangladesh
CHT	Chattogram Hill Tracts
CHTDB	Chattogram Hill Tracts Development Board
CIP	Country Investment Plan
CIS	Corrugated Iron Sheet
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CIWTC	Central Inland Water Corporation Limited
CLO	Certificate of Land Ownership
CMS	Convention on Migratory Species
COD	Chemical Oxygen Demand
COP21	Conference on Parties 21
CoZ	Contiguous Zone
CPA	Chattogram Port Authority
CPHEEO	Central Public Health and Environmental Engineering Organization
CPI	Consumer Price Index
CR	Critically Endangered
CREL	Climate-Resilient Ecosystems and Livelihoods
CSA	Climate-Smart Agriculture
CSICRD	Climate Smart Integrated Coastal Resource Database
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSOs	Combined Sewer Overflows
CUS	Centre for Urban Studies
CWASA	Chattogram Water Supply and Sewerage Authority
CWBMP	Coastal and Wetland Biodiversity Management Project
CWU	Canal Water Uplifting
DAE	Department of Agriculture Extension
DAM	Department of Agriculture Marketing
DANIDA	Danish International Development Agency
DAP	Detailed Area Plan
DBHWD	Directorate of Bangladesh Haor & Wetlands Development
DD	Data Deficient
DDM	Department of Disaster Management
DEM	Digital Elevation Model
DEM	Disaster Emergency Management
DEPTC	Deck Engine Personnel Training Center
DFID	Department for International Development
DGC	Delta Governance Council
DHV	Daily Hourly Volume
DIEM	Delta Dynamic Integrated Emulator Model
DIP	Delta Investment Plan
DIS	Digital Information System

DKRZ	Helmholts Centre and the German Climate Computing Centre
DL	Danger Level
DLDD	Desertification, Land Degradation and Drought
DLMS	Digital Land Management System
DLRS	Directorate of Land Records and Surveys
DLS	Department of Livestock Services
DMA	Dhaka Metropolitan Area
DMFRM	Digital Marine Fisheries Resource Mapping
DMTCL	Dhaka Mass Transit Company Limited
DNCC	Dhaka North City Corporation
DND	Dhaka-Narayanganj-Demra
DO	Dissolved Oxygen
DoE	Department of Environment
DoF	Department of Fisheries
DoS	Department of Shipping
DP	Delta Plan
DPs	Development Partners
DPHE	Department of Public Health Engineering
DRAS	Drought Assessment framework
DRF	Development Results Framework
DSCC	Dhaka South City Corporation
DSSAT	Decision Support System for Agrotechnology Transfer
DTWs	Deep Tubewells
DWASA	Dhaka Water Supply & Sewerage Authority
DWT	Deadweight Tonnage
ECAs	Ecologically Critical Areas
ECNEC	Executive Committee of National Economic Council
ECNWC	Executive Committee of the National Water Council
ECNWRC	Executive Committee of the National Water Resources Council
ECR	Environment Conservation Rules
EEF	Equity and Entrepreneurship Fund
EEZ	Exclusive Economic Zone
EGPP	Employment Generation Programme for the Poorest
EH	Eastern Hills
EKN	Embassy of The Kingdom of the Netherlands
EN	Endangered
EPR	Extended Producer Responsibility
EQS	Environmental Quality Standard
ERD	Economic Relations Division
ERRRP	Earthquake Risk Reduction and Recovery Preparedness Programme
ERWR	Externally Renewable Water Resources
ESPA	Ecosystem Services for Poverty Alleviation

ETPs	Effluent Treatment Plants
EU	European Union
EXT	Extreme Scenario
EXIM	Export-Import
EWS	Early Warning Systems
FAO	Food and Agriculture Organization
FAP	Flood Action Plan
FCD	Flood Control and Drainage
FCDI	Flood Control, Drainage and Irrigation Projects
FD	Forest Department
FDI	Foreign Direct Investment
FEWS	Flood Early Warning Systems
FGT	A Measure of Poverty
FMD	Foot and Mouth Disease
FMDI	Flood Management, Drainage and Irrigation
FPMU	Food Planning and Monitoring Unit
FRERMIP	Flood and Riverbank Risk Management Investment Program
FRM	Flood Risk Management
FRSS	Fisheries Resource Survey System
FSM	Faecal Sludge Management
FY	Financial Year
FYP	Five Year Plan
FW	Freshwater
GBM Basins	The Ganges, the Brahmaputra and the Meghna Basins
GCF	Green Climate Fund
GCM	General Circulation Models
GCM	Growth Center Markets
GCRI	Global Climate Risk Index
GDA	Ganges Dependent Area
GDP	Gross Domestic Product
GED	General Economics Division
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GIS	Geographic Information System
GIZ	Gesellschaft für Internationale Zusammenarbeit
Gm	Gram (weight)
GMO	Genetically Modified Organism
GNI	Gross National Income
GNP	Gross National Product
GoB	Government of Bangladesh
GoN	Government of the Netherlands
GPS	Global Positioning System

GTF	Green Transformation Fund
GW	Groundwater
Ha	Hectare
HDRC	Human Development Research Centre
HEIS	Health Emergent International Services
HH	Household
HIC	High Income Country
HIES	Household Income and Expenditure Survey
HRA	Hard to Reach Area
HRD	Human Resources Development
HS	Hemorrhagic Septicaemia
HtR	Hard to Reach Area
HYSAWA	Hygiene, Sanitation and Water Services
HYVs	High-yielding Varieties
IBA	Important Bird Areas
IBD	Infectious Bronchities
ICD	Inland Container Depot
ICDDR,B	International Centre for Diarrhoeal Disease Research, Banglades
ICM	Integrated Coastal Management
ICOR	Incremental Capital Output Ratio
ICRD	Integrated Coastal Resources Database
ICS	Improved Cook Stoves
ICT	Information Communication Technology
ICTL	Inland Container Terminal
ICZM	Integrated Coastal Zone Management
ICZMP	Integrated Coastal Zone Management Planning
IDA	International Development Asspciation
IDCOL	Infrastructure Development Company Limited
IEDCR	Institute of Epidemiology, Disease Control and Research
IFI	International Financial Institutions
IHO	Intergovernmental Oceanographic Commission
IHWRD	Integrated Haors & Wetlands Resources Database
IMED	Implementeation, Monitoring and Evaluation Division
IMME	Integrated Management of the Marine Ecosystem
IMF	International Monetary Fund
INBF	Implementation of the National Biosafety Framework
INDC	Intended Nationally Determined Contributions
INGER	International Network for Genetic Evaluation of Rice
IORA	Indian Ocean Rim Association
IPCC	Inter-Governmental Panel for Climate Change
IPM	Integrated Pest Management
IPNS	Integrated Plant Nutrient Management System

IPPC	Integrated Pollution Prevention and Control
IPTT	Immovable Property Transfer Tax
IRP	Iron Removal Plant
IRRI	International Rice Research Institute
IRWR	Internal Renewable Water Resources
ISSA	Inland Ship Safety Administration
ISWM	Integrated Solid Waste Management
ITN	International Training Network
ITO	International Terminal Operators
IUCN	International Union for Conservation of Nature
IWAI	Inland Waterways Authority of India
IWFM	Institute of Water and Flood Management
IWSM	Integrated Water Supply Management
IWM	Institute of Water Modeling
IWMI	International Water Management Institute
IWP	India Water Partnership
IWRM	Integrated Water Resources Management
IWT	Inland Water Transport
IWTP	Inland Water Transport Protocol
JCE	Joint Committee of Experts
JICA	Japan International Cooperation Agency
JMP	Joint Monitoring Programme
JRC	Joint Rivers Commission
JTC	Joint Technical Committee
JTST	Joint Technical Study Team
JWG	Joint Working Group
KCC	Khulna City Corporation
KJDRP	Khulna-Jashore Drainage Rehabilitation Project
km	Kilometre
kWh	Kilowatt Hours
LAD	Least Available Depth
LCC	Lambert Conformal Conic Projection
LDCs	Least Developed Countries
LED	Light-Emitting Diodes
LFS	Labour Force Survey
LGD	Local Government Division
LGED	Local Government Engineering Department
LGI	Local Government Institutions
LGRD	Local Government and Rural Development
LIS	Land Information System
LLP	Low Lift Pumps
LME	Large Marine Eco-system

LMI	Lower Middle Income
LNG	Liquefied natural gas
LOA	Length Overall
LPCD	Litres per Capita per Day
LPL	Lower Poverty Line
LPG	Liquefied petroleum gas
LUCF	Land Use Change and Forestry
M	Metre
M&E	Monitoring and Evaluation
MAC	Middle-class and Affluent Consumers
MACH	Management of Aquatic Ecosystem through Community Husbandry
MBR	Madaripur Beel Route
MCSP	Multi-purpose Cyclone Shelter project
MCP	Municipal-Community Partnership
MDGs	Millennium Development Goals
MFI	Micro Finance Institutions
MGC	Mongla-Ghashiakhali Channel
MHRP	Million Hectare Reforestation Program
MICCA	Mitigation of Climate Change in Agriculture
MICS	Multiple Indicator Cluster Survey
MIE	Multilateral Implementation Entity
MIS	Management Information System
MLD	Million Litres per Day
MMT	Million Metric Tonnes
MoA	Ministry of Agriculture
MoDMR	Ministry of Disaster Management and Relief
MoEF	Ministry of Environment and Forest
MoFA	Ministry of Foreign Affairs
MoFL	Ministry of Fisheries and Livestock
MoHFW	Ministry of Health and Family Welfare
MoL	Ministry of Land
MoLGRD&C	Local Government, Rural Development and Cooperatives
MoLJ	Ministry of Law and Justice
MoP	Ministry of Planning
MoSIWT	Ministry of Shipping and Inland Water Transport
MoU	Memorandum of Understanding
MoWR	Ministry of Water Resources
MPA	Mongla Port Authority
MPA	Marine Protected Area
MPO	Master Planning Organization
MRA	Microfinance Regulatory Authority
MRC	Mekong River Commission

MRT	Mass Rapid Transit
MSL	Mean Sea Level
MSP	Maritime Spatial Planning
MSY	Maximum Sustainable Yield
MT	Metropolitan Thana
$MtCO_2e$	Mega tonne of Carbon Dioxide equivalent (measure for emissions of GHGs)
N/A	Not Applicable
NABAR	National Bank for Agriculture and Rural Development
NAP	National Action Program
NARS	National Agriculture Research System
NBSAP	National Biodiversity Strategy and Action Plan
NC	North-Central
NCA	Net Cultivable Area
NCD	Non Communicable Disease
NCS	National Conservation Strategy
ND	New Castle Disease
NDA	National Designated Authority
NDC	Nationally Determined Contributions
NE	Northeast
NEDECO	Netherlands Engineering Consultants
NEMAP	National Environment Management Action Plan
NGOs	Non-governmental Organization
NIE	National Implementation Entity
NILG	National Institute for Local Government
NIMTP	National Integrated Multimodal Transport Policy
NLUP	National Land Use Policy
NMC	Nuclear Medicine Centres
NMI	Nuclear Medicine Institute
NMTPF	National Medium Term Priority Framework
NORAD	Norwegian Agency for Development Cooperation
NORI	National Oceanographic Research Institute
NRLP	National River Linking Project
NSB	National Seed Board
NSDS	The National Sustainable Development Strategy
NSP	Nishorgo Support Project
NW	Northwest
NWA	National Water Act
NWFP	Non-Wood Forest Produce
NWMP	National Water Management Plan
NWPo	National Water Policy
NWRC	National Water Resources Council
NWRD	National Water Resources Database

O&M	Operations and Maintenance
OCS	Outer Continental Shelf
OM	Organic Matter
PAs	Protected Areas
PCNs	Project Concept Notes
PDO-ICZM	Program Development Office for Integrated Coastal Zone Management
PET	Potential Evapotranspiration
PGA	Peak Ground Acceleration
PGI	Poverty Gap Index
PHC	Primary Health Care
PIWTT	Protocol on Inland Water Transit and Trade
PM	Particulate Matter
PMU	Project Management Unit
POPs	Persistent Organic Pollutants
PPA	Payra Port Authority
PPP	Public Private Partnerships
PPR	Peste de Petits Ruminants
PRI	Policy Research Institute
PRIF	Pre-Investment Feasibility
PSF	Pond Sand Filter
PW	Production Well
PWD	Public Works Department
PWM	Participatory Water Management
PWSS	Pourashavas Water Supply Sections
R&D	Research and Development
RAJUK	Rajshahi Unnayan Kartripakkha
RAMSAR	Convention on Wetlands
RBM&E	Results-Based Monitoring and Evaluation
RBOs	River Basin Organizations
RCM	Regional Climate Models
RCP	Representative Concentration Pathway
RE	Rivers and Estuaries
REB	Rural Electrification Board
REDD	Reduced Emissions from Deforestation and Degradation
RHD	Roads and Highways Department
RHF	Relatively Hazard Free
RMG	Ready Made Garments
ROR	Record of Rights
RRI	River Research Institute
RSV	River Sea Vessel
RTI	Right to Information
RWH	Rainwater Harvesting

SAARC	South Asian Association for Regional Cooperation
SC	South-central
SCA	Seed Certification Agency
SDGs	Sustainable Development Goals
SDP	Sector Development Plan
SE	Southeast
SEMP	Sustainable Environment Management Program
SEZ	Special Economic Zone
SHS	Solar Home Systems
SIDS	Small Island Developing States
SIP	Sector Investment Plan
SL	Safety Level
SLR	Sea Level Rise
SMA	Statistical Metropolitan Area
SME	Small Medium Enterprise
SoB	Survey of Bangladesh
SPGI	Square of Poverty Gap Index
SPI	Schedule Performance Index
SRDI	Soil Resource Development Institute
SREDA	Sustainable and Renewable Energy Development Authority
SRES	Special Report on Emissions Scenarios
SRF	Sundarbans Reserved Forests
SST	Sea Surface Temperature
STP	Sewage Treatment Plant
STW	Shallow Tube-wells
SW	Southwest
SWM	Solid Waste Management
SWR	Southwestern Region
SWTP	Surface Water Treatment Plant
TAR	Third Assessment Report 2001
TBF	Transboundary Flow
TDS	Total Dissolved Solids
TEU	Twenty Feet Equivalent Unit
TFR	Total Fertility rate
Tk.	Taka
TLCCs	Three Lower Counties Community Services Inc.
ToR	Terms of Reference
TP	Treatment Plant
TRM	Tidal River Management
TRWR	Total Renewable Water Resources
TS	Territorial Sea
UDD	Urban Development Directorate

UDDP	Urban Dredging and Demonstration Project
UFW	Unaccounted for Water
ULBs	Urban Local Bodies
UMIC	Upper Middle Income Country
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Emergency Fund
UNPCA	UN Permanent Court of Arbitration
UPL	Upper Poverty Line
USAID	United States Agency for International Development
USP	Urban Sector Policy
UTM	Universal Transverse Mercator
VGD	Vulnerable Group Development
VGF	Vulnerable Group Feeding
VTMS	Vessel Tracking and Monitoring System
VU	Vulnerable
WARPO	Water Resources Planning Organization
WASAs	Water Supply and Sewerage Authorities
WASH	Water Supply, Sanitation and Hygiene
WATSAN	Water Supply and Sanitation
WB	World Bank
WDF	Washing, Dyeing, Finishing
WDI	World Development Indicators
WEO	World Economic Outlook
WFP	World Food Programme
WHC	World Heritage Convention
WHO	World Health Organization
WHS	World Heritage Site
WMC	Waste Management Cost
WMIP	West Midlands Institute of Psychotherapy
WRG	Water Resources Group
WRM	World Rainforest Movement
WSDP	Water Sector Development Plan
WSP	Water and Sanitation Program
WSS	Water Supply and Sanitation
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

Glossary

Adaptation Tipping Point: Threshold conditions under which an action or strategy will no longer meet a set of predefined policy or strategic goals or standards

Adaptation Pathway: A sequence of measures to achieve a set of predefined goals under changing external conditions, such as climate, socio-economic factors or other developments

Adaptation (pathways) Map: Visualization of a set of adaptation pathways showing options for transferring from one pathway to another, and the timing and/or conditions under which an adaptation tipping point of a policy action occurs.

Delta: A delta is a geo-morphological area, largely defined by its low lying surface form and location in landscape and coastal area that forms at the mouth of a river. Deltas form from deposition of sediment carried by a river as the flow leaves its mouth. Over long periods, this deposition builds a dynamic and characteristic geographic, ecological and social pattern of the delta and its features

Delta Atelier: Delta Ateliers are one or two-day workshops in which the issues at stake are discussed, ideas and views are generated and presented while interests of the stakeholders are identified and linked with the discussed issues and are elaborated in visualized and supported results These results have a certain status as building blocks in de BDP 2100 formulation process. The Delta Ateliers form an interactive strategy making concept which will be used for important issues to the BDP2100 formulation process

Flexible or Adaptive Actions: Actions can be adapted (e.g. intensification of the action), abandoned (switch to a different action) or extended (add an action) at low cost or having small societal impact. Flexible actions do not result in lock-ins and have little influence on potential future options (i.o. have less path-dependencies).

Gini Coefficient: Measure of income inequality in a country.

Haor: A haor is a deep flooded area during monsoon, which dries up after monsoon. These wetland ecosystems are found in the northeastern part of Bangladesh. They are also characterized by one or more deep area called *beel*, that retains water throughout the year.

Holistic: 'Holistic' refers to viewing and understanding a system and its properties as they happen as whole, not as a collection of elements. This includes the view that systems cannot be fully understood solely in terms of their component elements. A delta forms an interesting application of holism; as a whole it includes e.g. social, biological, physical, chemical, and economic aspects in a given area. The complexity grows with the area, so that it is necessary to reduce the characteristic of the view by studying a) events in the behaviour of the delta, b) behaviour of elements, their emergence and interconnectedness and c) in other ways, for example studying the system during a specific episode

Holistic planning: This is a type of planning to address problems of a system in a comprehensive way, viewing the system as a whole in relation with its interdependent elements. Multiple policy domains may be involved requiring coherent governance and budget allocation

Integrated approach: Combination of relevant elements in a comprehending approach to understand more of the total system

Learning cycle: A learning cycle is a concept of how people learn from experience. A learning cycle will have a number of stages or phases, the last of which can be followed by the first: 1. Doing something, having an experience; 2. Reflecting on the experience; 3. Concluding from the experience, developing a suitable approach; 4. Planning the next steps, to apply or test this approach

Lock-in: Situation where future action in a pathway can only be implemented against high costs or high societal impact because of earlier choices and investments.

Measure or action: Individual intervention, which may be infrastructure but also institutional, legal, economic, knowledge / capacity development and may be at specific spatial, sector- or national-general level. Measures can be part of one strategy but can also fit in multiple strategies

No Regret and Win-Win actions: No-regret actions are useful and cost-effective on the short term and under a range of future conditions and do not involve hard trade-offs with other policy objectives. Win-win actions contribute to a central objective whilst also having other, e.g. social, economic and environmental, policy impacts and benefits

Path-dependency: Extent to which a policy action (in a pathway) is limited by actions implemented in the past or by actions planned anterior in the pathway.

Plan: A coherent framework of targets (expected results), approach, methods and resources as well as actions and time schedule to be worked out beforehand for the accomplishment of one (or more) objective(s)

Robust actions: Actions that result in acceptable indicator values under a wide variety of futures.

Scenario: Coherent descriptions of alternative hypothetical futures that reflect different perspectives on past, present and future developments, which can serve as a basis for action (Van Notten, 2005). In this study, scenario is used for 'external context' scenarios that describe developments that cannot be influenced and are thus policy-free.

Sector: A sub-division within the government, focused on a policy domain with its discourse and instruments

Sectoral planning: Planning to address problems within a sector or policy domain, e.g. by a ministry mandated to act on it

Sell-by year of an action or strategy: Point in time, in a given external scenario, when an action or strategy will no longer meet a set of predefined policy or strategic goals or standards

Showcase: A showcase is an illustrative local scale design exercise. In these exercises the Delta Ateliers' participants apply the more conceptual design principles and adaptation measures on the local scale, which is more tangible

Signposts: Information that should be tracked in order to determine whether implementation of action or reassessment of the plan is needed.

Strategy: A from Delta Vision point of view coherent combination of measures that contributes to reaching the Delta Goals.

Tipping point: A situation when a particular policy or strategy is no longer feasible to change in circumstances, e.g. increasing embankment height to protect from climate induced sea level rise no longer possible due to land, costs or other constraints. Also see adaptation tipping point.

Touch Table: A Touch Table is an interactive surface computing platform that – in combination with specific software – allows for the visualization of different climate and policy maps. The software combination of several maps helps exploring different developments and effects and allows for the identification of problem areas and use of arising opportunities. Special drawing and calculation tools allow for new design plans to be evaluated on the spot.

Chapter 1
Opportunities and Challenges of the Bangladesh Delta

Chapter 1: Opportunities and Challenges of the Bangladesh Delta

1.1 Bangladesh Development Prospects and Constraints

Over the past 48 years, since independence, Bangladesh has secured tremendous gains in development. Annual GDP growth has climbed from less than 4% in the early 1970s to over 7% in 2017; per capita income has surged from less than US$ 100 in 1972 to US$ 1,751 in FY2018; poverty has fallen from 82% in 1971 to 24.3% in 2016; fertility rate has decelerated from 7.3 in 1974 to 2.1 in 2016; life expectancy has increased from 55 years in 1974 to 72 years in 2017; child mortality has declined from 240 per thousand in 1974 to 31 in 2017; and adult literacy has increased from 22% to 72.9% over the same period. Bangladesh has achieved food self-sufficiency and the economy is transforming from an agrarian base towards a modern manufacturing and services economy. In 2015, Bangladesh crossed over from a World Bank classified low-income economy to a lower middle income economy. The country has also fulfilled all the criteria of graduating from least developed country to a developing country.

These indicators of an exceptionally strong development record have inspired the country to aim even higher. The country now aspires to reach the Upper Middle Income (UMIC) status by 2030. The development progress accelerated over the past 10 years under the strong political leadership by Prime Minister Sheikh Hasina combined with many sound development policies and taking advantage of the hugely abundant supply of labor, a very fertile land and plenty of water and monsoon rains. The Bangladesh Delta, the largest delta of the world, along with a large and growing population base presented many advantages that the people and policy makers converted into opportunities to secure the above development gains.

Yet, the same delta and high population density presents many development challenges. With a population of about 160 million crammed into a total space of 1,47,570 km^2 including rivers, Bangladesh at 1,200 people per km^2 is the most densely populated country in the world, excluding some small island economies with less than 2 million people and the city states of Hong Kong and Singapore. Owing to the deltaic formation of the country, the configuration of the rivers and climate change, Bangladesh has been ranked as the 5th most vulnerable country in the world in terms of risks from natural hazards. Tidal surge, salinity, flooding, river erosion and cyclones are regular features of the country. These features pose a continuous challenge to food security for the country and livelihood for a large part of the rural population. Growing risk of sea level rise threatens to engulf a considerable area of the coastal belt that could displace millions of people living in the coastal districts. Sea level rise along with drying up of upstream fresh water flows in rivers in the Southwest is causing problems for agriculture and fresh water supply. Increasing temperature threatens to increase monsoon rains causing river overflow and higher incidence of flooding; temperature rise also threatens to damage crops and contribute to health problems. In parts of the country over-exploitation of groundwater with low rain owing to climate change threatens to weaken the surface aquifers that could create water-shortage problems for irrigation-led agriculture in the Northwest dry zone of Bangladesh. In the urban areas, the water tables in many parts have already fallen very low owing to over-exploitation of groundwater. Arsenic contamination threatens many rural water supply sources. Assuring adequate water supply to a growing urban population and expanding industrial and commercial activities will be a major challenge. At the same time strengthening the access of the rural population to safe water will be a major task.

These delta related challenges are just one source of challenges. The country faces other challenges from growing urbanization, declining land availability, infrastructure shortages, energy supply constraints and labor skills. The interface of these multiple challenges with limited public resources and a heavily constrained public sector capacity define the policy and institutional challenges of an aspiring upper middle income Bangladesh. Past track record gives comfort that the country has the capability of making concerted efforts to attack these challenges with strong determination and vigor.

Good planning and strategies are necessary to move coherently and in an organized fashion. Vision 2021, the 10-year perspective plan (2010-2021) and the 7th FYP (FY2016-FY2020) are all parts of the government's ongoing national development strategies. In view of the special long term challenges presented by climate change to the Bangladesh delta, the Government has decided to develop a long term Bangladesh Delta Plan 2100 (BDP 2100). The BDP 2100 seeks to integrate the short to medium term aspirations of Bangladesh to achieve Upper Middle Income (UMIC) status and eliminate extreme poverty by FY2031 with the longer term challenge of sustainable management of water, ecology, environment and land resources in the context of their interaction with natural disasters and climate change. In view of the best practice of Dutch delta management experience, the Government requested technical assistance from the Government of Netherlands to help Bangladesh develop this BDP 2100.

The formulation of BDP 2100 involved a large volume of baseline studies as special background papers, large number of stakeholder consultation meetings, and interaction with experts and government officials. In addition, there exists a large volume of literature on water management and water analysis based on past technical assistance and national and international research. The BDP 2100 draws on this rich volume of technical knowledge to develop the Bangladesh Delta Plan. A full list of consulted research is provided in the bibliography section.

Chapter 1 provides an overview of the delta opportunities and challenges with a view to identifying the main elements of these opportunities and concerns for fuller development in the remaining chapters of the report. In order to ground these risks and opportunities to the specific context of the Bangladesh Delta, the chapter starts by defining an analytical framework for describing the main delta related constraints in as much specificity as possible that then helps lay the basis to develop proper strategies, policies, institutions and investment priorities. It describes the interaction of climate change with development including ecological balance and environmental protection that is critical for the long term sustainability of development. It then lays out the broad contours of the analytical framework to provide the basis for detailed analysis of the various delta challenges in the later chapters.

1.2 Need for a Delta Plan

Management of this delta had always been a key concern in both development and political agenda since long. Almost all the political movements during pre-independence period invariably included demand for flood control, disaster management and irrigation measures, it is so because that those were the major causes of extreme poverty prevailing at that period in this delta. The election manifesto of the then United Front in 1954 advocated the protection of the country from flood and famine by means of digging canals and improving irrigation system. Father of the Nation Bangabandhu Sheikh Mujibur Rahman was always committed to develop flood control, drainage and irrigation facilities in the country and repeatedly demanded implementation of the Krug Mission Report. Immediate after independence of Bangladesh, Bangabandhu established the relief ministry giving a special attention to building a disaster resilient country through minimizing losses of lives and properties caused by different natural events including cyclone and floods. He established Bangladesh Water Development Board (BWDB) in 1972, bifurcating the then East Pakistan Water and Power Development Board (EPWAPDA) to accelerate the implementation of the flood control, drainage and irrigation measures. He took keen interest in solving the transboundary water issues and established Joint Rivers Commission on a permanent basis in 1972. Bangabandhu had installed earthen forts locally known as Mujib Kella in coastal regions aiming to provide shelter to coastal flood and cyclone affected people along with their livestocks.

A lot of initiatives and plans for water sector and agricultural development have been prepared and adopted in Bangladesh since 1960. IECO Master plan (1964) for water resources sector, National Water Plan-I (1986) followed by National Water Plan-II (1991), The Flood Action Plan (FAP) after the devastating floods in 1987 and 1988, etc. have been adopted in the country. The FAP studies were very elaborate, and one of the outcomes of the study was the Bangladesh Water and Flood Management Strategy (1995), based on which the National Water Policy (NWPo, 1999) and National Water Management Plan (NWMP, 2004) were formulated. The National Water Policy provides a useful basis for the Delta Framework, as it outlines an integrated approach towards sustainable water resources management. The NWMP is meant as an operationalization of the NWPo. It is a comprehensive water resources plan in which 13 ministries and more than 30 agencies are involved. It is primarily a management plan. Within the existing institutional context, however, the NWMP shows many implementation issues, which are important to analyze and to consider as "lessons learnt". The good thing that came out of these various phases of water resources planning is that the planning approach has undergone many stages and refinement, responding to the socio-economic needs of the people.

Other ministries and departments of the government have also devised their own plans and strategies. The Master Plan for Haor areas was prepared for the Northeast region of the country by Directorate of Bangladesh Haor and Wetland Development (DBHWD) in 2010. The Master Plan for Agricultural Development in the Southern region of Bangladesh was prepared by the Ministry of Agriculture (MoA) and FAO in 2013. The National Plan for Disaster Management (2008) was prepared by the Ministry of Disaster Management & Relief (MoDM&R) to reduce the risk of people, especially the poor and disadvantaged, from the effects of natural, environmental and human induced hazards. Most recently, the Local Government Engineering Department (LGED) has prepared the District Development Plan and Upazilla Development Plan. The Ministry of Local Government, Rural Development and Cooperatives (MoLGRD&C) has prepared the National Policy for Safe Water Supply and Sanitation (1998) for providing safe drinking water and sanitation.

Bangladesh is a signatory of the historic Paris Climate Agreement. It is committed to combat climate change reaffirming the government's readiness to continue to work towards mobilizing greater international efforts in support of comprehensive implementation of the Paris deal. Bangladesh has also taken various proactive initiatives, with its own resources and international cooperation, to adapt to climate change. The Ministry of Environment and Forest (MoEF) formulated the National Adaptation Programme of Action (2005) and the Bangladesh Climate Change Strategy and Action Plan (2009) to address adverse impacts of climate change including variability and extreme events and to promote sustainable development of the country.

Furthermore, national-level strategic plans such as the Five Year Plans and Perspective Plan have been formulated by the General Economics Division (GED) of Planning Commission. More recently, the 17 Sustainable Development Goals with 169 targets, is a new global agenda and Bangladesh is highly committed to meeting these goals. However, the challenge lies in integrating these sectoral, national and global targets and plans into long term coherent strategies taking climate change and future demands into account, as well as in effective implementation of the needed interventions in a well-coordinated manner.

Notwithstanding this rich historical background, a comprehensive integrated approach to water managemet in the overall development context of Bangladesh did not emerge until now. First, typically, the sectoral plans tend to be short term oriented and independently pursued by the formulating ministries or departments. Whereas, goals and targets are at the national level and climate change and natural disaster risks present major downside risks and uncertainties that require long term strategies and multi-sectoral coordinated policy management under uncertainty. For example, the national challenge to maintain food sufficiency in the face of increasing population and decreasing agricultural land as well as the threat posed by climate change requires coordinated policy actions involving MoA, MoEFCC, Ministry of Land (MoL), Ministry of Fisheries and Livestock (MoFL), Ministry of Water Resources (MoWR), Ministry of Local Governent, Regional Development and Cooperatives (MoLGRD&C), Ministry of Finance (MoF) and Ministry of Planning (MoP). Similarly, to meet the higher water demand for achieving a greater standard of living and to protect the ever increasing level of investment in housing and industry from disasters, Bangladesh needs a long term vision, planning and implementation involving all government agencies and ministries that contribute to this objective.

Second, due to the large uncertainties with respect to climate change and socio-economic development, planning is being enriched with adaptive strategy making in several deltas in the world. Rather than providing linear recipes, robust and flexible strategies and measures have been taken, with strong institutions and a good knowledge base that allows policy makers and stakeholders to anticipate and decide on the most appropriate investments. Learning from these international experiences, BDP 2100 has been similarly developed in light of the many possible future paths that are possible, and is designed to be changed over time as new information becomes available or policy priorities change. So instead of only focusing on short term 'trial and error' actions and projects, the idea is to keep the long term vision in mind while prioritizing short term 'no regret' actions.

Finally, sound manafgement of water resources requires a balanced combination of investments, policies and institutions. Earlier sectoral plans were mostly investment and proect centric. Policies and institutions for sustainable management of water resources have been generally overlooked. Historically, this factor was recognized as early as the First Five Year Plan prepared under the guidance of Bangabandhu in his capacity as the Chairman of the Planning Commission. The First Plan put major emphasis on policies and instutions for sustainable management of water resources. These included decentralized managementof water resources through involvement of beneficiaries, importance of O&M, the need for cost recovery (beneficiary pays principle) and balanced combination of flood control with irrigation schemes. These sound principles of water management were not well integrated in practice but have been recognized as some of the core principles of the Bangladesh Delta Plan 2100.

1.3 Bangladesh Delta Definitions, Hydrological Regions and Hotspots

The Bangladesh Delta is variously defined in the literature. The different names include the Ganges Delta; the Ganges- the Brahmaputra Delta; the Ganges- the Brahmaputra- the Meghna Delta; the Padma-Jamuna-Meghna Delta; the Sundarbans Delta; or the Bangladesh Delta. The various names derive from the geographical congregation of the three mighty transboundary rivers (the Ganges, the Brahmaputra and the Meghna) and name changes that happen once the concerned river crosses boundary. The flow of three rivers meet together near the Chandpur district of Bangladesh and then flow into the Bay of Bengal from around the district of Bhola. In the proper sense of the term, the delta would actually begin with the distributaries flow southwards to the Bay of Bengal; strictly speaking, the Bangladesh Delta would comprise the lower delta and coastal zone; most narrowly conceived, the geographic delta forms the combined Sundarbans region of India and Bangladesh. In terms of location in Bangladesh, this would comprise roughly the three districts of Satkhira, Khulna and Bagerhat. A more meaningful conception of the Delta Region from a policy perspective is the districts of the Southern coastal belt of Bangladesh. A third and more inclusive definition comprises the combined areas of the Southern coastal belt and the areas surrounding the flows of the three rivers (the Ganges- the Brahmaputra- the Meghna). Finally, the most expansive definition of the Delta is the Bangladesh Delta that includes all districts that face various natural hazards owing to the deltaic formation of Bangladesh and the related interface with the vast river networks, the Bay of Bengal and climate change.

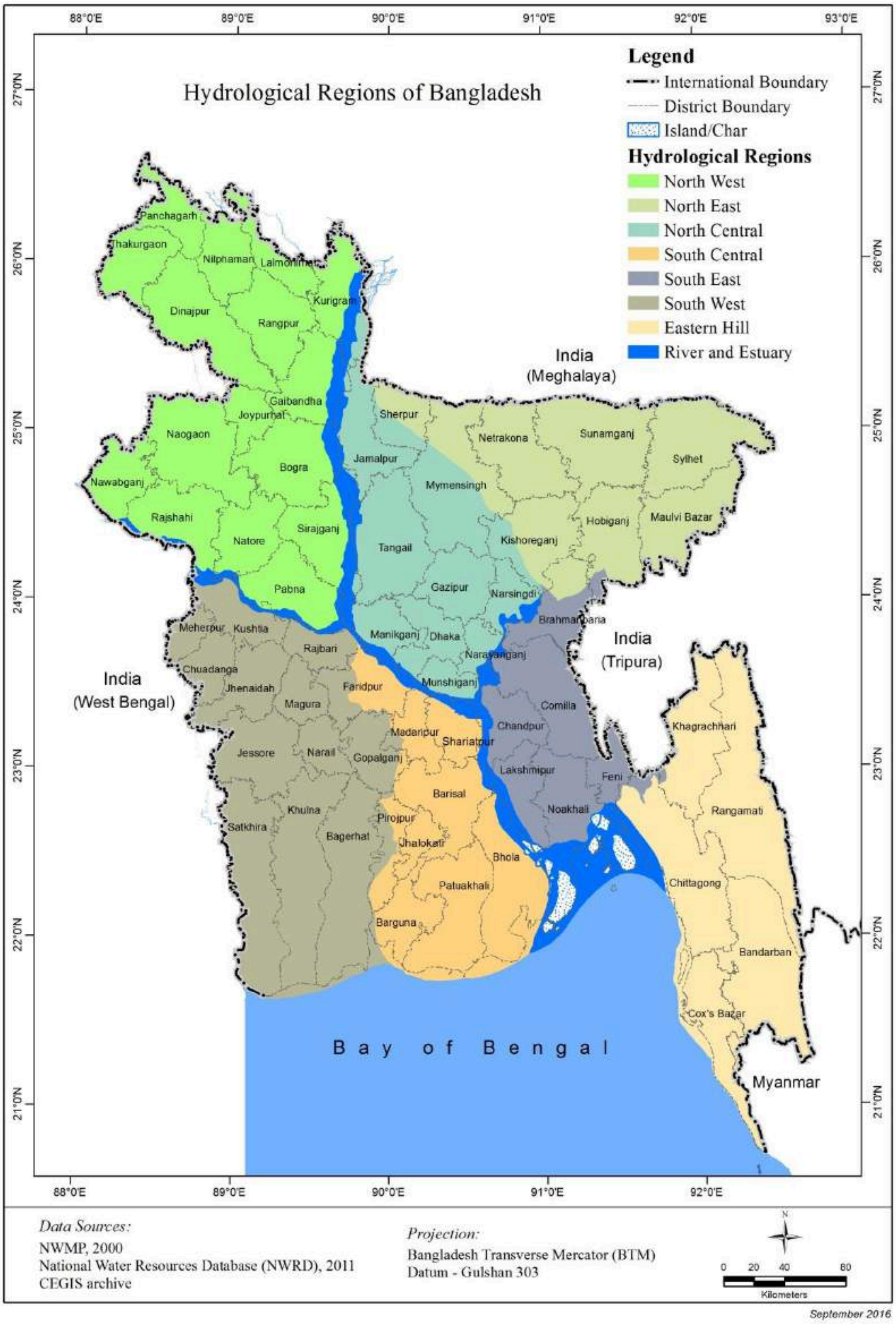
Since natural hazard and climate change risks affect almost the entire Bangladesh owing to its Deltaic formation and since integrated water resources management in the context of its interaction with climate change, environment, ecology, biodiversity, agriculture and land management is an integral part of the BDP 2100, the Plan has adopted the most expansive definition of the Delta Region. For water resource planning purposes, Bangladesh has been divided into 8 hydrological regions, which are the Northwest (NW), Northeast (NE), North-central (NC), Southeast (SE), South-central (SC), Southwest (SW), Eastern Hills (EH) and the main Rivers and Estuaries (RE). The 8 hydrological regions are shown in **Map 1.1**. Using the 8 hydrological zones as the starting point, the BDP 2100 sharpens the focus on the magnitude of the natural hazard vulnerabilities facing each of the hydrological regions. This has led to a modified grouping of districts and areas facing similar risks of natural hazards. These groups are called "Hotspots" that simply define a broad grouping of districts and areas facing similar natural hazard risks. Dictionery meaning of Hotspot is-a place of significant activity or danger. Hotspots are prototypical areas where similar hydrological and climate-change vulnerability characteristics and problems converge (such as sea level rise, river erosion, intensity of flooding, water shortages, siltation constraints, etc.). This is a broad definition and the intensity of hazard and underlying risks can vary considerably among districts and sub-districts within the hotspot zone.

The aggregate hotspot grouping provides a convenient analytical tool to summarize certain broad socio-economic and common risk profile. They are only a first step of analysis. The risk profile and magnitude of vulnerabilities facing a district within each hotspot and between hotspot districts vary considerably. In some cases, a further disaggregation to the subdivision/ thana level may be necessary to understand in detail the risk profile. Accordingly, a risk profile at the district level, and where necessary at the sub-district level, is developed and discussed in considerable detail in **Chapter 2**, while at same time maintaining the thematic focus on hotspot areas. Needless to say the hotspots are strongly correlated to the hydrological regions.

The six Hotspots are[1]:

1. The Coastal Zone. (27,738 sq. km)
2. The Barind and Drought Prone Areas. (22,848 sq. km)
3. The Haor and Flash Flood Areas. (16,574 sq. km)
4. The Chattogram Hill Tracts (CHT). (13,295 sq. km)
5. The River Systems and Estuaries. (35,204 sq. km)
6. The Urban Areas. (19,823 sq. km)

[1] The urban areas are defined to include the six major urban cities and metropolis only. The Delta-related urban challenges are well represented by these cities and metropolis and the findings/strategies can apply to other urban centers.



Map 1.1: Hydrological Regions of Bangladesh

Source: CEGIS, 2016

The logic of hotspot grouping has significant analytical merit. The climate risks on coastal districts are broadly similar and should be grouped as such rather than distribute them across three regions that also include non-coastal districts. Similarly, the water and climate change problems of CHT are significantly different from Chattogram and Cox's Bazar. The latter two face the hazards of being a part of the coastal districts. Furthermore, the urban metropolitan divisional headquarter districts face common water challenges and it makes sense to group them together.

Needless to say, there is nothing water-tight about the hotspot definition and there is little gain from applying a microscopic view to this analytical construct. The more important point is to focus on the associated vulnerabilities, i.e. whether they have been captured adequately, and link these vulnerabilities to the suggested strategies and policy interventions. The main point is that unless all delta major vulnerabilities are identified and strategies and policies address these specific vulnerabilities, the BDP 2100 will be an incomplete plan.

By definition, the hotspots are strongly correlated to the hydrological regions. The interface between these two classifications is summarized in **Table 1.1**.

Table 1.1: Relationship between Hotspots and Hydrological Regions

Hotspots	Hydrological Zones
Barind and Drought Prone Areas	North West
Chattogram Hill Tracts	Eastern Hills excluding Chattogram and Cox's Bazar
Coastal Zone	The coastal districts of South West, South Central and South East
Haor and Flash Flood Areas	North East
River Systems and Estuaries	Rivers and Estuary; Districts of North Central and South Central that lie along the major rivers.
Urban Areas	No Specific Grouping

Source: BDP 2100 Analysis, GED (2015)

While the entire Bangladesh faces some kind of natural disaster risks, there are some six districts that are geographically located in a way that they are considered relatively safe from the natural hazard risk point of view (Relatively Hazard Free, RHF). These are: Nilphamari (Northwest); Sherpur, Mymensingh and Gazipur (North-Central); and Jhenidah and Magura (Southwest Region). They typically lie outside a major river course and far from the coastal belt. They are also further away from the drought-prone dry zone of the Northwest or the CHT area of Southeast Region.

The basic characteristics of the Six Hotspots are provided in **Table 1.2** below. The district mapping of hotspots is shown in **Table 1.3**

Table 1.2: Bangladesh Delta Hotspots - Basic Socio-Economic Indicators 2011

Hotspots	Area (km^2)	Population (million)	Literacy Rate (%) (7 years and above)	Population Density ($person/km^2$)
Haor and Flash Flood Areas	16,574	15	42.56	906
Coastal Zone	27,738	22.4	42.03	807
Chattogram Hill Tracts (CHT)	13,295	1.7	55.55	128
Urban Areas	19,823	31.5	43.90	1588
Barind & Drought Prone Areas	22,848	22.8	58.40	999
River Systems & Estuaries	3,5204	41.4	48.35	1177
Relatively Less Hazard Prone (RLHP) Areas	12,089	15	47.79	1238
Total	***147,570***	***149.8***	***48.37***	***1015***

Source: BDP 2100 Analysis, GED (2015) & Bangladesh Bureau of Statistics (BBS), 2011

Table 1.3: Mapping of Districts to Hotspot Areas

Hotspots	Number of Districts	Name of District
Haor and Flash Flood Areas	7	Brahmanbaria, Habiganj, Kishoreganj, Moulvibazar, Netrokona, Sunamganj, Sylhet
Coastal Zone	19	Bagerhat, Barguna, Barishal, Bhola, Chandpur, Chattogram, Cox's Bazar, Feni, Gopalganj, Jashore, Jhalkati, Khulna, Lakshmipur, Narail, Noakhali, Patuakhali, Pirojpur, Satkhira and Shariatpur.
Chattogram Hill Tracts	3	Bandarban, Khagrachhari, Rangamati
Urban Areas	7	Barishal, Chattogram, Dhaka, Khulna, Rajshahi, Rangpur, Sylhet
Barind and Drought Prone Areas	18	Bogura, Chuadanga, Dinajpur, Gaibandha, Joypurhat, Kushtia, Meherpur, Naogaon, Natore, Nawabganj, Nilphamari, Pabna, Panchagarh, Rajshahi, Rangpur, Satkhira, Sirajganj, Thakurgaon
River Systems & Estuaries	29	Barguna, Barishal, Bhola, Bogrua, Chandpur, Cumilla, Faridpur, Feni, Gaibandha, Gopalganj, Jamalpur, Kurigram, Lakshmipur, Lalmonirhat, Madaripur, Manikganj, Munshiganj, Narayanganj, Natore, Chapai Nawabganj, Noakhali, Pabna, Potuakhali, Rajshahi, Rajbari, Shariatpur, Sirajganj, Tangail, Khulna
RLHP Area	6	Gazipur, Jhenaidah, Magura, Mymensingh, Nilphamari, Sherpur

Source: BDP 2100 Analysis, GED (2015) and Coastal Zone Policy 2005

The river and estuaries districts constitute the majority share of Bangladesh's population. The CHT area is sparsely populated. The urban areas have the highest population density. They also have the highest per capita income and highest literacy rates. On average the CHT and Hoar and flash flood areas tend to have the lowest per capita income and literacy rates, closely followed by the Barind and drought prone areas. The detailed socio-economic characteristics and poverty profile of hotspots are described in **Chapter 2**.

1.4 Bangladesh Delta Opportunities

The delta opportunities are many. The soil and water combination makes Bangladeshi land highly fertile with multiple cropping opportunities. Bangladesh has wisely combined this natural advantage with HYV seed-fertilizer irrigation technology to intensify land cultivation and expand food production, primarily rice. This has allowed Bangladesh to increase rice production from 12 million tonnes in 1973 to 35.2 million tonnes in 2017. Along with a very successful population control policy, Bangladesh has now met food self-sufficiency requirements with prospects for rice exports. This amazing achievement despite the multiple risks posed by the delta and climate change is a remarkable feather in the hat of the Bangladesh policy makers.

The plentiful of rivers, fresh wetlands, and lakes provide ample scope for fisheries resources. More recently, Bangladesh has been increasingly exploiting the open access to sea. Marine fishing has become a potentially important source of fish. Owing to the growing importance of fishing, the structure of agriculture is slowly changing as the share of crop agriculture is falling and that of fisheries increasing. Consequently, the value-added and employment shares of fisheries are increasing. The role, importance and challenges of the agriculture sector including fisheries are discussed in detail in **Chapter 8**.

The plentiful of rivers in Bangladesh provide another huge comparative advantage. Almost all districts of Bangladesh are connected with each other and with the growth centers of Dhaka, Chattogram and Khulna through river ways. The inland waterways provide an environment friendly and low-cost transport option for both passengers and cargo for the country as a whole but especially for the rural poor. Inland water transport is one of the important sources of rural employment. Unfortunately, this comparative advantage has not been properly exploited by Bangladesh. More focus on river transport can provide a major opportunity to lower the cost of production, reduce environmental degradation, conserve budgetary resources and add to employment prospects for the poor. The inland water transport issues are discussed in depth in **Chapter 9**.

The open access to sea is a huge advantage to Bangladesh. In addition to the port facilities that could serve the needs of the growing internal trade and commerce needs of Bangladesh. With proper investments, Bangladesh can become a regional hub for sea transportation. Examples of dynamic port cities like Rotterdam, Singapore and Hong Kong show dramatically how proper planning and investments can convert this natural advantage to a huge development gain for Bangladesh. Increasingly, the open access to sea is becoming a major opportunity in another way. The rapidly growing demand for energy in Bangladesh owing to increasing GDP growth led by the expansion of manufacturing sector is facing a huge challenge of primary energy shortage. The rapid depletion of natural gas has led to a search for other primary fuels. The Government has rightly decided that sole reliance on imported fossil fuel cannot be the answer. In addition to the fluctuations and uncertainties of global oil prices that cause tremendous fiscal and balance of payments uncertainties, Bangladesh is acutely aware of the need to adopt cleaner energy option to oil. This search has led to a strategy of procuring clean imported coal, LNG and LPG. All these primarily require port facilities to handle these bulky cargoes. Bangladesh is slowly capitalizing this open access to sea by establishing new ports, in addition to Chattogram and Mongla ports. The ongoing Payra port construction in Patuakhali is an example of this. There are many other opportunities that could boost Bangladesh trade and commerce by reducing the cost of trade logistics through easier and lower cost access to ports in terms of time and money.

In addition to ports, the prospects for converting the open access to sea to a major source of growth and development are also being viewed from the point of developing the blue economy of Bangladesh. Marine fishing is already emerging as one of the major sources of domestic food, exports, income and employment. There is also an emerging demand for coastal tourism and alternative areas to the traditional Cox's Bazar coastal resorts are emerging. An example of such coastal tourism is Kuakata of Patuakhali. The judicial utilization of the blue economy opportunities is just emerging and the potential is huge. Other potential areas are exploration of petroleum and other marine resources, beach mineral sand, renewable energy by wave, land reclamation by sediment management, etc.

1.5 Bangladesh Delta Challenges

1.5.1 *Climate Change*

In the Fifth Assessment Report of the International Panel for Climate Change (IPCC), the globally averaged combined land and ocean surface temperature data, as calculated by a linear trend, show a warming of 0.85 (0.65 to 1.06) °C, over the period 1880 to 2012. The total increase between the average of the 1850-1900 period and the 2003-2012 period is 0.78 (0.72 to 0.85) °C. For the longest period where the calculation of regional trends is sufficiently complete (1901 to 2012), almost the entire globe has experienced surface warming. In addition to robust multi-decadal warming, global mean surface temperature exhibits substantial decadal and inter-annual variability. For the future, the IPCC projected global warming for selected time slices for different Representative Concentration Pathways (RCPs). For 2046-2065, mean temperature rise projections range from 1.0 to 1.4°C whereas it ranges from 1.0 to 3.7°C for the period 2081-2100 (**Table 1.4**).

Table 1.4: Projected Global Mean Surface Warming (°C) for Different RCPs

Scenario	2046-2065	2081-2100
RCP2.6	1.0	1.0
RCP4.5	1.4	1.8
RCP6.0	1.3	2.2
RCP8.5	2.0	3.7

Source: International Panel for Climate Change (IPCC), 2013

There is considerable debate and variations in projected future global climate change and parameters for Bangladesh. However, there is consensus that global warming will increase and so will be the case for Bangladesh. The IPCC used the RCP instead of previous Special Report on Emission Scenarios (SRES) to project global warming. But the available impact study results for Bangladesh are mostly from SRES scenarios. So, in this report, similar characteristics scenario is used to analyze the possible future conditions. In this report, two future situations are considered. These are: Business As Usual scenario (BAU) and Extreme scenario (EXT). The BAU considers the moderate climate change scenario that assumes that the global and national efforts to reduce the GHG emissions are maintained. The BAU includes the similar scenarios SRES A1B, B1 and RCP 4.5, which are mostly similar in nature for the end of the century temperature projections. On the other hand, the EXT considers the extreme climate change scenario with no global and national efforts to reduce the GHG emissions and assumes continued pursuit of fossil fuel based economic development. The EXT includes the similar scenarios SRES A1FI, A2 and RCP 8.5, which are mostly similar in nature.

The region-wise seasonal changes in temperature and rainfall during 2030 and 2050 under BAU scenario are presented in **Table 1.5** and **Table 1.6** respectively. **Table 1.5** shows that the temperature will rise in all regions in future in a similar trend with the global pattern. So, it is projected that due to climate change annual temperature might rise in the country in the range of 1.4 to 1.7°C for BAU by 2050. Further rise in temperature is expected in the latter half of the century.

Table 1.5: Projected Seasonal and Annual Surface Warming (°C) for BAU

Region	Seasonal Temperature change (°C) for 2030				Annual	Seasonal Temperature change (°C) for 2050				Annual
	DJF	MAM	JJAS	ON		DJF	MAM	JJAS	ON	
Maximum Temperature (°C)										
NW	1.5	-0.1	1.3	1.1	1.0	2.3	0.6	1.9	1.9	1.7
NC	1.4	-0.3	1.3	1.0	0.9	2.3	0.5	1.9	1.6	1.6
NE	1.4	0.0	1.3	1.1	1.0	2.2	0.5	1.9	1.6	1.6
SW	1.2	0.0	1.0	0.8	0.8	2.2	0.9	1.6	1.2	1.5
SC	1.1	0.4	1.0	0.8	0.8	2.0	1.1	1.5	1.2	1.5
SE	1.2	-0.1	1.2	0.9	0.8	2.1	0.6	1.7	1.3	1.4
EH	1.0	0.4	1.0	0.8	0.8	1.6	0.9	1.5	1.2	1.4
Minimum Temperature (°C)										
NW	1.4	0.6	1.2	1.4	1.1	2.3	1.3	1.7	2.3	1.9
NC	1.5	0.6	1.2	1.4	1.1	2.4	1.2	1.7	2.3	1.8
NE	1.6	0.8	1.2	1.6	1.3	2.4	1.2	1.8	2.4	1.9
SW	1.3	0.6	1.1	1.1	1.0	2.4	1.3	1.6	1.9	1.8
SC	1.3	0.7	1.0	1.0	1.0	2.3	1.3	1.5	1.7	1.7
SE	1.4	0.6	1.1	1.3	1.1	2.4	1.2	1.6	2.0	1.8
EH	1.3	0.9	1.1	1.2	1.1	2.2	1.5	1.7	1.9	1.8

Source: IPCC, 2013

DJF stands for December, January & February; MAM: March, April & May; JJAS: June, July, August & September; ON: October, November.

The rainfall pattern is going to be more variable and erratic in the future. There is an indication that pre monsoon and monsoon rainfall will increase under BAU scenario (**Table 1.6**). On an annual basis, the rainfall is expected to increase in most regions during 2030. However, during 2050, southern parts of the country along with the eastern hills might get reductions in rainfall. Under the EXT scenario, as temperature rise will be higher, more erratic behavior of rainfall along with changes in rainfall amounts is expected.

Table 1.6: Projected Seasonal and Annual Change in Rainfall for BAU

Region	Seasonal Rainfall change (%) for 2030				Annual	Seasonal Rainfall change (%) for 2050				Annual
	DJF	MAM	JJAS	ON		DJF	MAM	JJAS	ON	
NW	134.0	19.9	-6.1	116.1	-0.1	119.3	-18.6	5.6	28.8	4.5
NC	107.6	34.1	14.8	47.7	19.0	31.2	-5.1	20.6	12.6	16.9
NE	32.0	7.1	15.0	8.1	13.1	12.1	-0.9	17.9	9.8	13.2
SW	68.8	11.9	1.4	76.4	6.0	58.2	-20.3	0.7	-7.8	-1.5
SC	-6.7	15.7	3.4	45.4	6.3	0.2	-1.5	-2.1	-11.4	-2.5
SE	-5.1	26.6	10.9	6.6	12.3	7.2	9.6	5.0	0.6	5.4
EH	-32.9	-20.1	1.8	-35.4	-2.8	45.0	2.2	-1.3	-33.7	-1.6

Source: IPCC, 2013

DJF stands for December, January & February; MAM: March, April & May; JJAS: June, July, August & September; ON: October, November.

1.5.2 *Floods*

Flood is a recurrent phenomenon of Bangladesh, occurring almost every year. Three mighty rivers the Ganges, the Brahmaputra and the Meghna meet together in central Bangladesh forming the largest delta of the world. As a consequence, most of the country consists of huge flood plain and delta, of which around 70% of the total area is less than 1 meter above sea level and 10% of the land area is made up of lakes and rivers. Bangladesh experiences heavy monsoon rains, especially over the highlands along with frequent tropical storms in coastal zone. All of these phenomena trigger frequent flood occurrence in Bangladesh. On average, an estimated 20-25% of the country becomes inundated due to river spilling and drainage congestion. Extreme situation arises when the three major rivers (the Ganges, the Brahmaputra and the Meghna) reach their flood peak at same time. In general, 55-60% of the country is inundated during extreme flood events. Recent evidence reveals that the magnitude and frequency of mega floods is increasing (**Figure 1.1**) as a consequence of climate change. Other human causes like construction of dam in upper riparian countries, unplanned urbanization in illegally encroached floodplains, lack of combination of structural and non-structural measures etc. are aggravating the situation.

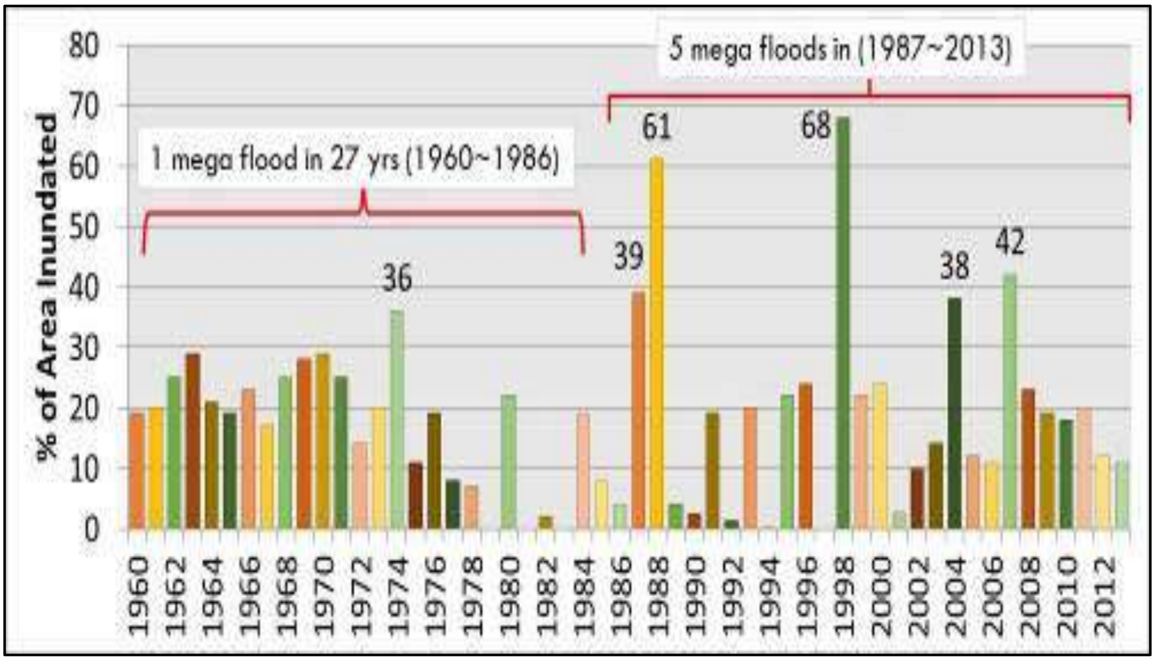
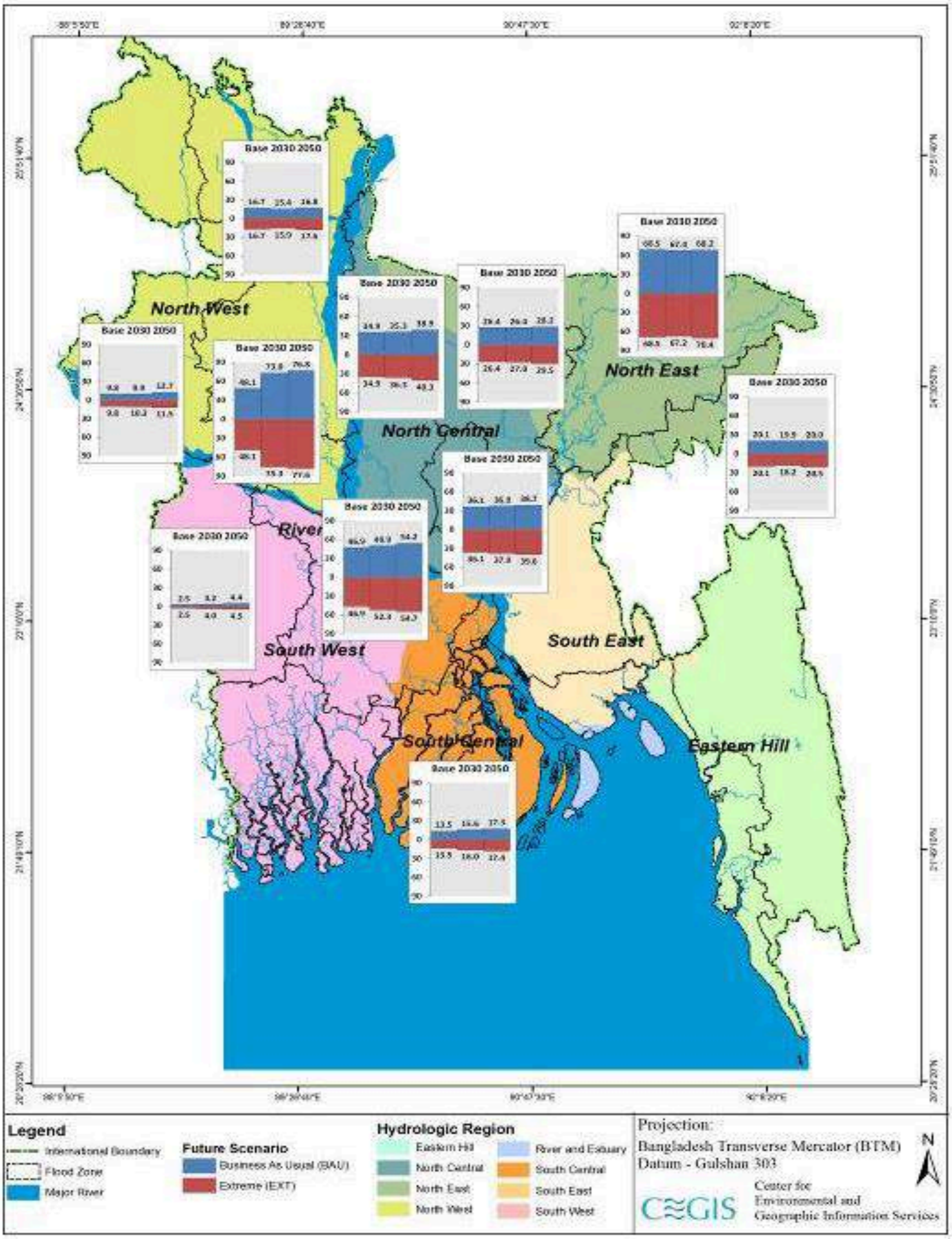


Figure 1.1: Increased Frequency of Mega Floods due to Climate Change

Source: CEGIS, 2013

Projections suggest that the flood extent will increase for all areas of the country by mid-century (2050) based on the extreme scenario. Both left and right side of the Brahmaputra- the Jamuna River will be worst affected in this scenario. On average, 3-9% additional area will be inundated from the base (1978-2007) on the left side of the Jamuna River. On the other hand, some portion of the Barind and drought prone areas adjacent to right bank of Jamuna river will be more inundated (around 30%) from the base by 2050 due to flooding in the extreme scenario. **Map 1.2** shows percentage of flooded area for future in different parts of Bangladesh under BAU and EXT scenarios. Sea facing portion of the coastal zone is mainly prone to coastal flooding.

The health impacts of flooding have been well documented for a long time (Durkin et al, 1993). However, Non communicable diseases (NCDs) are emerging as major issues. With children it is related mainly to the long term effects on brain development, which can be transmitted during pregnancy and also the pre and post effects of floods on childhood disability (Khan et al 2016).



Map 1.2: Percentage of Projected Flooded Area in Bangladesh in 2030s and 2050s

Source: CEGIS, 2014

1.5.3 *Drought*

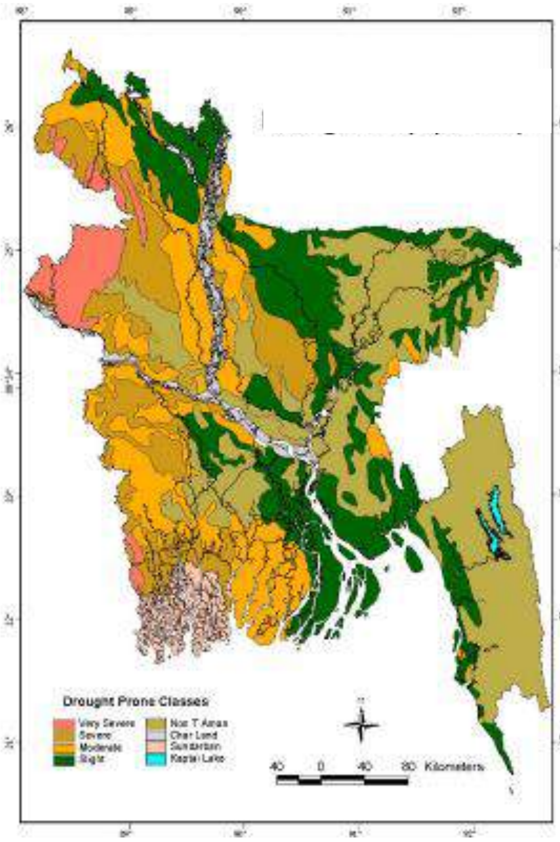
The droughts occurring in Bangladesh are not meteorological droughts but mainly agricultural droughts, which could be also termed as severe moisture stress. In the Bangladesh context, drought is defined as the period when soil moisture content is less than the required amount for satisfactory crop-growth during the normal crop-growing season. The mean annual rainfall in Barind and drought prone area is 1,250-1,750 mm, falling mainly in 4 to 5 wet months (BDP 2100 Water Resources Baseline Study, 2015). The drought situation of the area becomes severe during April-May due to the cumulative effect of presence of soils with low moisture holding capacity (<200 mm available moisture), increasing number of dry days (precipitation <0.5 PET) and occurrence of extreme summer temperature of more than 40°C.

In the drought prone agro-ecological zones of Bangladesh, period of dry days range between 32-48 days, starting from 24 March to 21 May (BDP 2100 Agriculture and Food Security Baseline Study). During this period the temperature also rises more than 40°C for 5 to 15 days within the same agro-ecological zones. In addition, some soils have low moisture holding capacities, which show different degrees of droughtiness.

Rabi and pre-Kharif drought (January/May) occurs due to the cumulative effect of dry days, higher temperatures during pre-Kharif (>40°C in March/May) and low soil moisture availability (BDP 2100 Agriculture and Food Security Baseline Study). Kharif drought occurs from June/July to October, created by sub-humid and dry conditions in the highland and medium highland areas of the country (in addition to the west/northwest). The Madhupur tract in the central parts of the country is also drought prone.

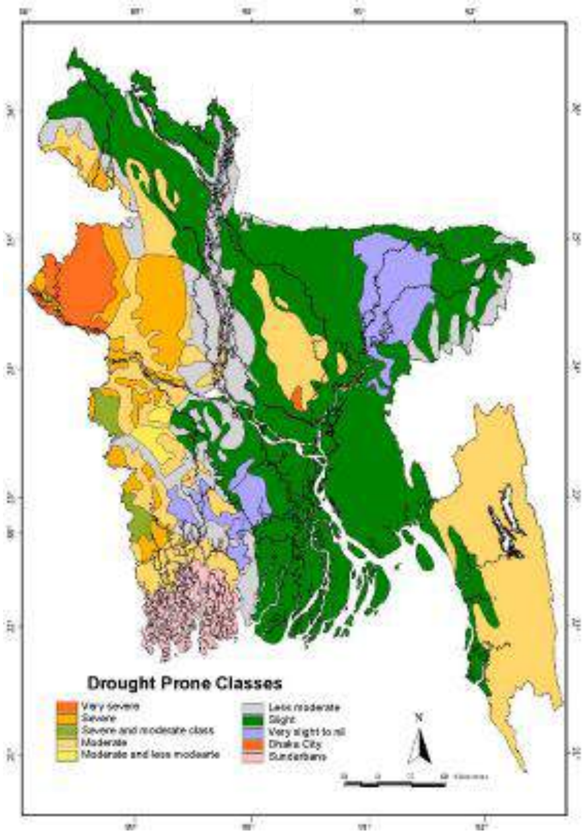
The Government's intervention to address drought with the Barind Region Irrigation Project has changed the profile of the Barind region with a rapid transformation of the area into an agrarian green field with a diversified agriculture based on rice, fruits and vegetables. This has contributed substantially to lowering poverty in the Northwest part of Bangladesh. Yet, the drought risk has been shifted forward as surface water reduction from the diversion of river water upstream in India and inadequate rainfall in the dry season continues to lower the water table. So, erratic rainfall in the wet season and less rainfall in the dry season due climate change will further hurt agriculture in the Barind tract.

The geographical distribution of drought prone areas for different seasons (shown in **Map 1.3** and **Map 1.4**) illustrates that the western parts as well as Barind and drought prone areas of the country will be at greater risk from droughts during both the Kharif and pre-Kharif seasons. It is estimated that under a moderate climate change scenario, Aus production would decline by 27% while wheat production would be reduced to 61% (BDP 2100 Agriculture and Food Security Baseline Study). Under a severe climate change scenario (with 60% moisture stress), yield of Boro might reduce by 55-62%. Moisture stress might force farmers to reduce the area of Boro cultivation. In case of a severe drought (moisture stress) forced by a change of temperature by +2°C and a reduction in precipitation by 10%, runoff in the Ganges, the Brahmaputra, and the Meghna rivers would be reduced by 32%, 25% and 17% respectively (BDP 2100 Climate Change Baseline Study). This would limit surface irrigation potential in Barind and drought prone areas and challenge the food self-sufficiency of the country.



Map 1.3: Barind and Drought prone (Kharif) areas of Bangladesh

Source: Soil Resource Development Institute (SRDI, 2013)

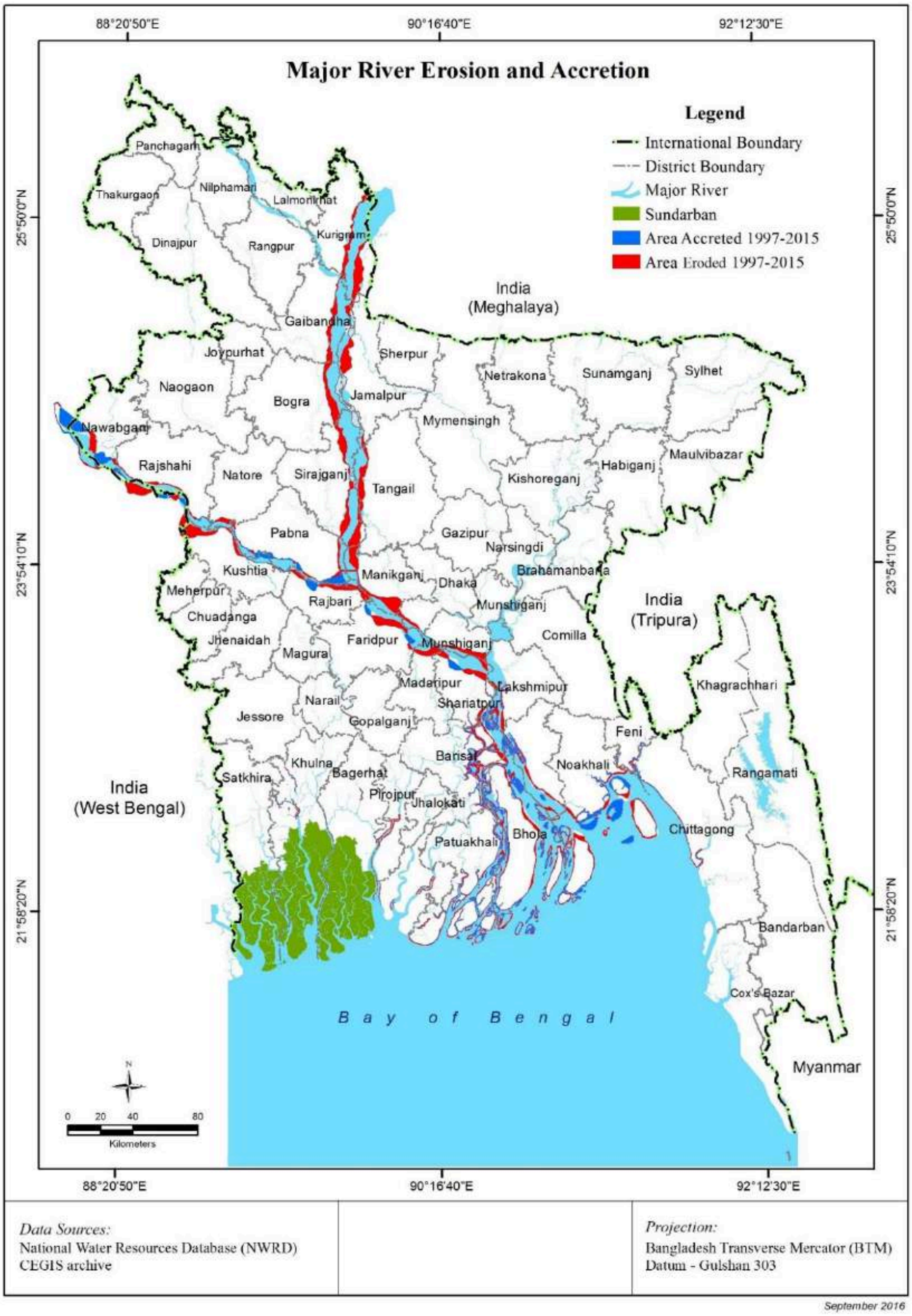


Map 1.4: Barind and Drought prone (Rabi and Pre Kharif) areas of Bangladesh

Source: Soil Resource Development Institute (SRDI, 2013)

1.5.4 River Bank Erosion

Bangladesh is a riverine country. The morphology of the country's rivers is highly dynamic and river bank erosion is also a regular phenomenon, particularly along the banks of the main rivers. Erosion in the three major rivers (the Jamuna, the Padma and the lower Meghna) can be considered as proxies for riverbank erosion in Bangladesh (Map 1.5). The present rate of the Jamuna bank erosion is about 1,770 ha per year while bank erosion by the Padma River is about 1,298 ha per year and the lower Meghna (erodes at a rate of 2,900 ha per year (BDP 2100 Water Resources Baseline Study).



Map 1.5: River Bank Erosion in Bangladesh

Source: CEGIS, 2016

The Jamuna River is widening over time. This means that the river is eroding its banks. The river has been widening at an average rate of about 130 m per year, which corresponded to a loss of about 70,000 ha in 23 years, while only 11,000 ha had been accreted (BDP 2100 Water Resources Baseline Study). Changes in the river flow and sediment transport due to multi-faceted impacts of climate change are expected to increase the dynamics of these rivers even more. During 1973-2015, a total 52,313 ha land has been accreted due to river bank erosion (BDP 2100 Water Resources Baseline Study).

A major reason for the erosion is that the discharge in the rivers is increasing. Flow records over 50 years long for the station Bahadurabad (the Brahmaputra/the Jamuna rivers) show that peak discharge is increasing and is peaking earlier. The average timing of the peak was in the middle of August but is now in the first week of August (BDP 2100 Water Resources Baseline Study).

At Hardinge Bridge station on the Ganges, peak discharge is increasing but the time of peak is advancing. The date is advancing by about one day in a decade. If the present trend of advancing of the peak prevails, the chances of coincidence of the Ganges and the Brahmaputra peaks will be less, reducing the probability of catastrophic and long duration floods.

At Bhairab Bazar (the Meghna), peak discharge is decreasing and its occurrence is delayed slightly. The time of peak has moved to the last week of September from mid-July in the late 1970s (BDP 2100 Water Resources Baseline Study).

On balance land accretion is significantly lower than river bank erosion for all three major rivers, although net erosion is the largest for the Brahmaputra/Jamuna river. Changes in the river flow and sediment transport due to multi-faceted impacts of climate change are expected to increase the dynamics of these rivers even more.

1.5.5 Sea Level Rise and Salinity Intrusion

Sea Level Rise (SLR) and consequently, salinity intrusion are the most prominent issues now in the Bangladesh Delta for its complex geographical position. IPCC (2013) predicts SLR between 0.2 to 1.0 m for low to high emission scenarios in 2100 for the Bay of Bengal. For the future, the IPCC projections for very high emissions (red, RCP 8.5) and very low emissions (indigo, RCP 4.5) are shown in **Figure 1.2**.

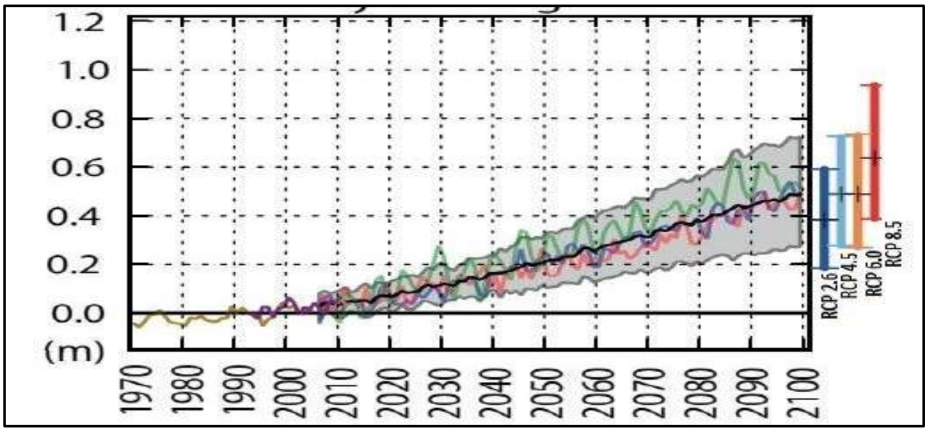
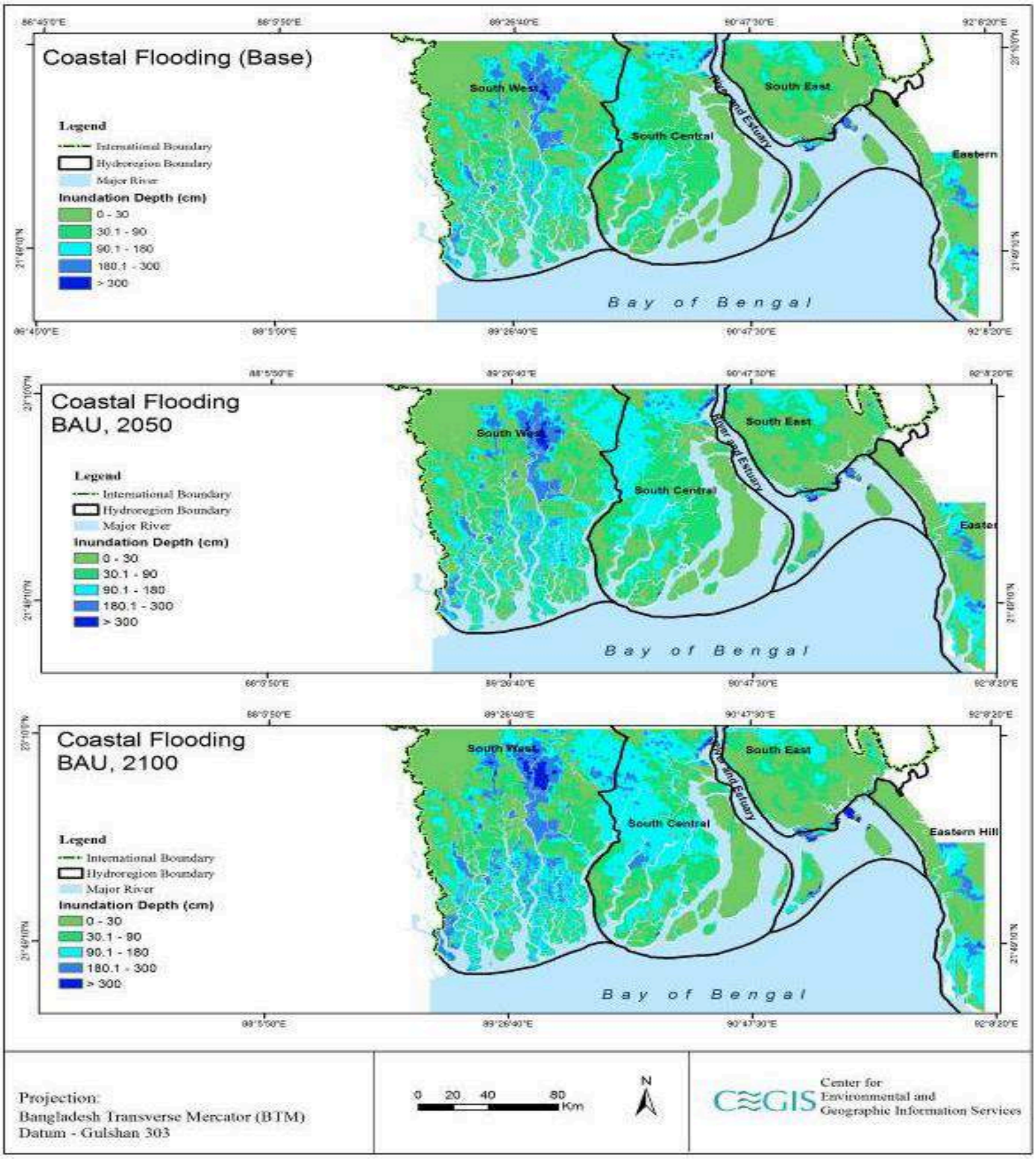


Figure 1.2: SLR Predictions for different RCPs in Bay of Bengal

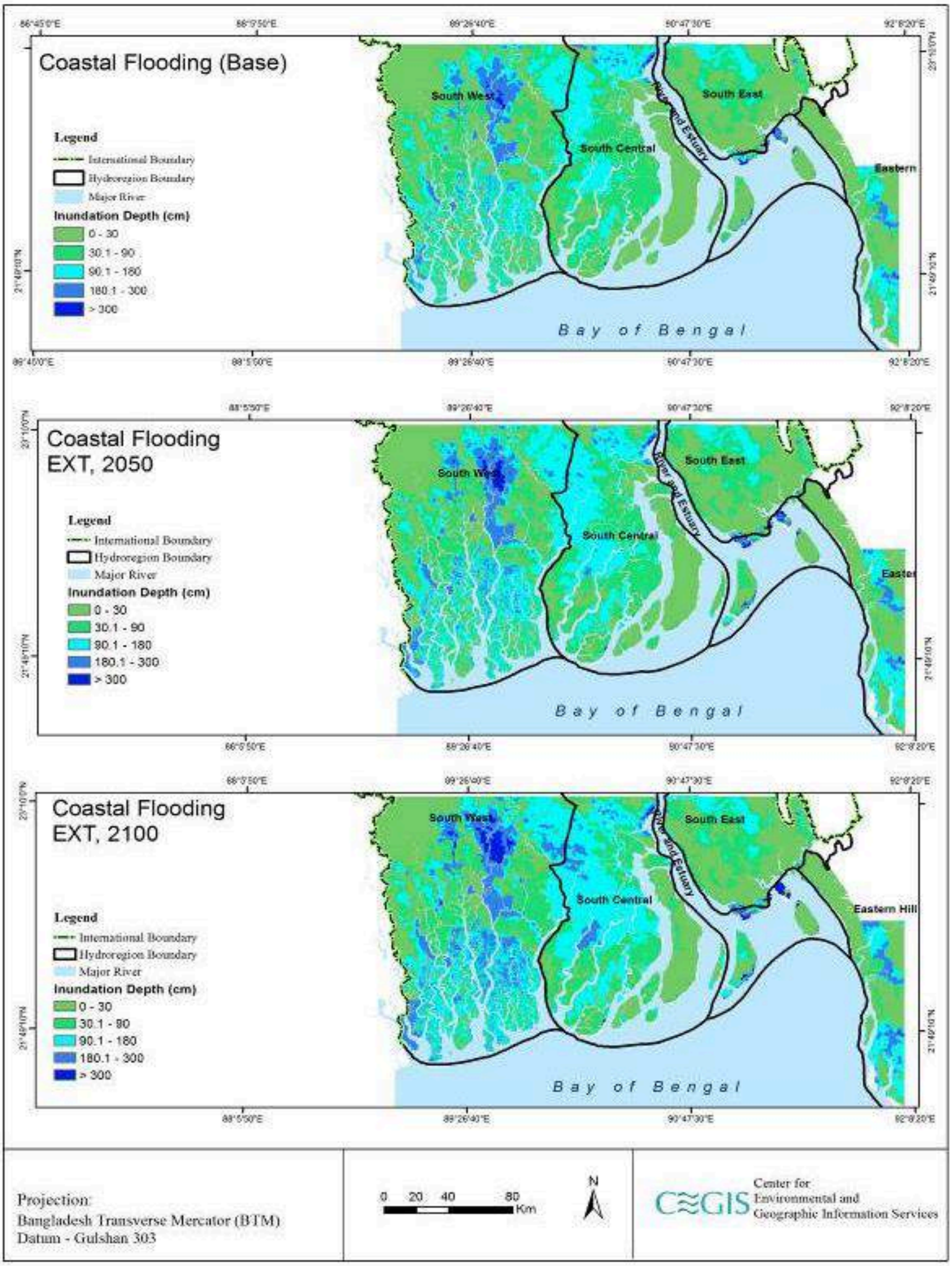
Source: IPCC, 2013

The overall trend of SLR in the coastal zone is 6-20 mm/year and this trend is much higher in the Chattogram coastal plain area than the Ganges and the Meghna subzones (BDP 2100 Climate Change Baseline Study). This uprising water level trend forms possibilities of increased intensity and extent of coastal flooding, particularly for the sea facing Coastal zone. **Map 1.6** and **Map 1.7** show coastal flooding situation for BAU and EXT scenarios.



Map 1.6: Coastal Flooding under BAU Scenario

Source: CEGIS, 2014

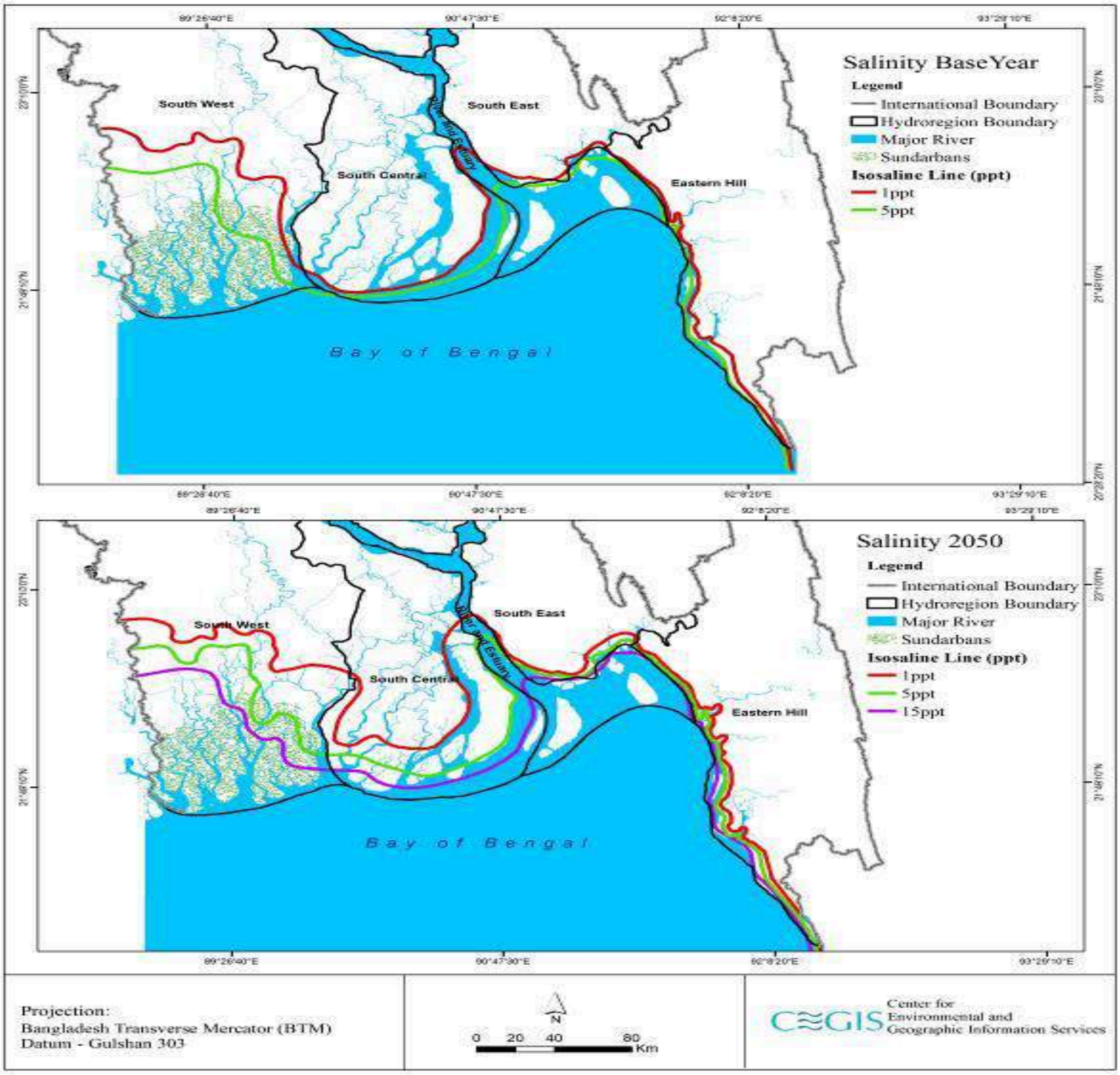


Map 1.7: Coastal Flooding under EXT Scenario

Source: CEGIS, 2014

Analyses indicate that flooding extent might increase up to 6% and 8% from base (2005) in the central part of the Coastal zone following EXT scenario by 2050 and 2100 respectively, which is highest among other parts of coastal zone. The west portion of coastal zone will face 5% and 6% more coastal flooding than the base situation following extreme scenario by 2050 and 2100 respectively. No significant changes have been found in the eastern portion of the coastal zone.

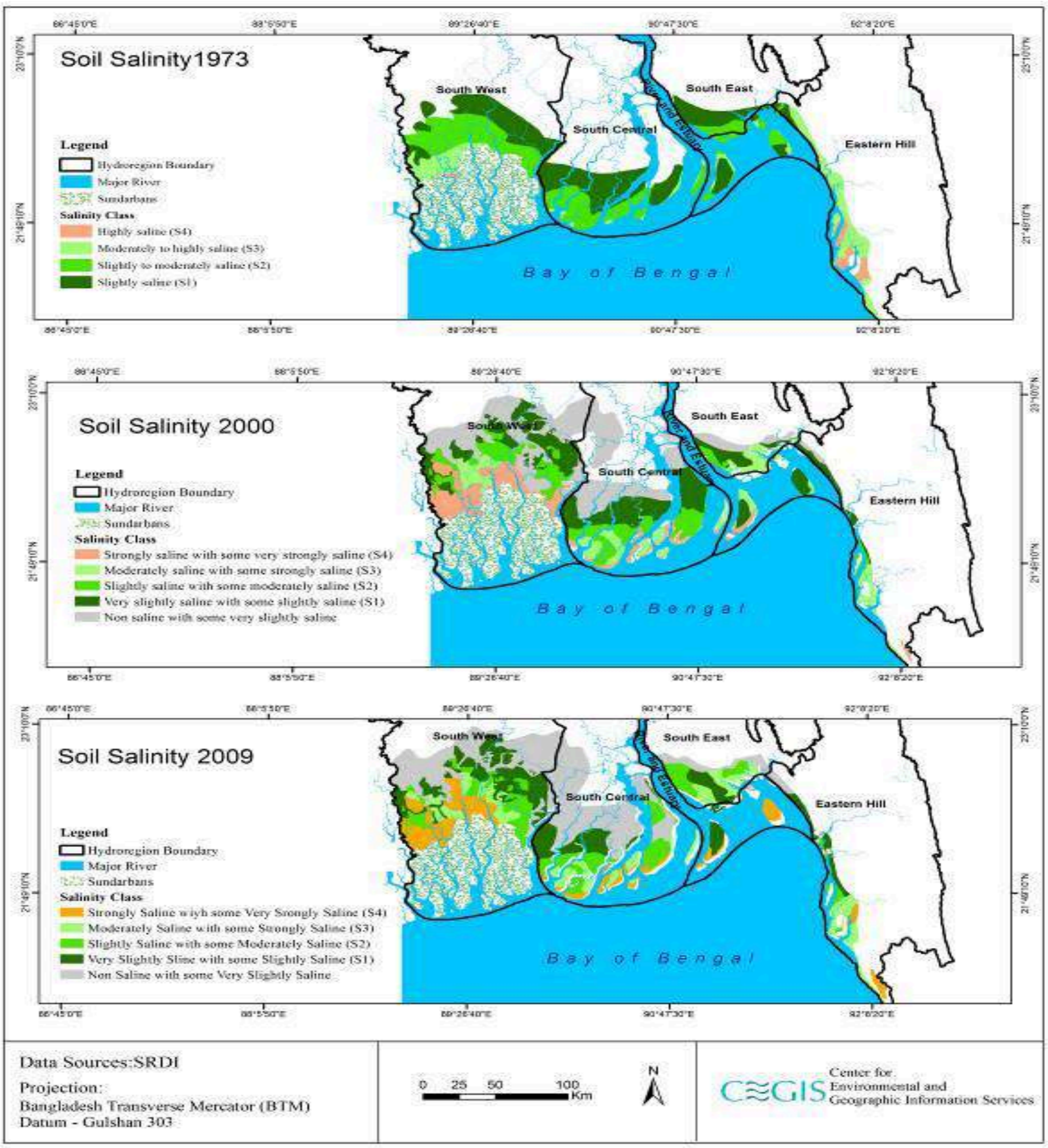
The rising sea level impedes fresh water availability in the coastal zone, expediting intrusion of salinity front. Both surface water and soil salinity along the coast may increase with the rising sea level (**Map 1.8**).



Map 1.8: Soil Surface Salinity Extents in 2005 and 2050

Source: CEGIS, 2014

The isosaline lines of 1, 5 and 15 ppt have been drawn for base (2005) and 2050 conditions to show changes in salinity in the coastal zone of Bangladesh. **Map 1.8** indicates that in base (2005) condition about 10% area is under 1 ppt salinity and 16% under 5 ppt salinity; these areas will increase up to 17.5% (1 ppt) and 24% (5 ppt) by 2050 in the EXT scenario. So, there will be around a 7% increase in area under 5 ppt salinity levels. The salinity front will move towards inland from the south of Bangladesh with SLR and it will be further aggravated if the fresh water flows from upstream declines.



Map 1.9: Soil Salinity and Water Salinity Condition in Coastal Zone, 1973-2009

Source: SRDI, 2013

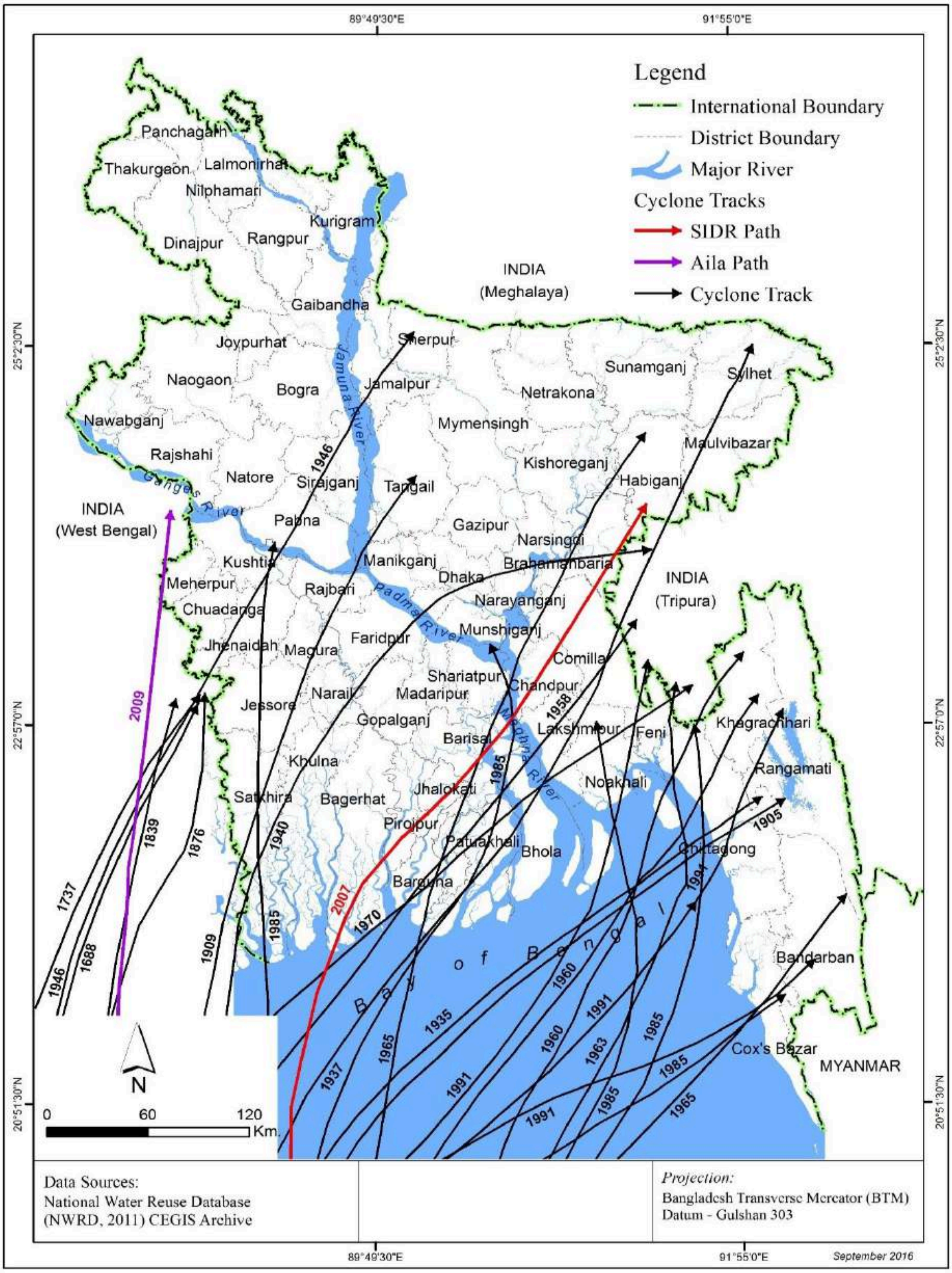
A soil salinity map for the period of 1973, 2000 and 2009 (**Map 1.9**) produced by Soil Resources Development Institute (SRDI) shows that the problem is already increasing and severity of salinity is also increasing. The map shows that soils of Jashore, Magura, Narail, Faridpur, Gopalganj and Jhalokati were newly salinized over 24 years. The coastal zone of Bangladesh covers about 20% of the country and more than 30% of the cultivable land. Out of 2.86 Million Hectare (Mha) of coastal and offshore lands about 1.056 Mha of lands are affected by different degrees of soil salinity. Of the 151 upazillas in 19 coastal districts, 93 upazillas under 18 districts are affected by soil salinity (BDP 2100 Baseline Coast and Polder Issues Baseline Study).

1.5.6 Cyclones and Storm Surges

Low lying areas of coastal zone are highly vulnerable to cyclones, which pose serious threat to lives and properties of the region. Nearly every year, cyclones hit the country's coastal zone and a severe cyclone strikes the country every three years, on average. Intensity of cyclonic storm surges as well as depth and extent of storm surge induced coastal inundation are likely to increase in changing climate through rising Sea Surface Temperature (SST) and sea level. The IPCC further indicates that future cyclonic storm surges and related coastal floods in Bangladesh will likely become more severe as future tropical cyclones increase in intensity.

Recurvature of tropical cyclones in the Bay of Bengal, the wide, shallow continental shelf, especially in the eastern part of the country and the high tidal range are the major reasons for this disproportionately large impact of cyclones. Low lying topography like nearly sea-level geography of the coastal land, high-density population and inadequate coastal protection system are aggravating the situation. Furthermore, triangular shape at the head of the Bay of Bengal, which helps to funnel sea water pushed by the wind towards the coast, causing further surge amplification; Meghna-estuarine region is facing the most surge amplifications.

In general, it has been observed that the frequency of a 10 m high wave (surge plus tide) along the Bangladesh coast occurs about once every 20 years, while a wave with a 7 m height occurs about once in 5 years (BDP 2100 Baseline Coast and Polder Issues Baseline Study).



Map 1.10: Risk from Major Cyclones in 1960–2009

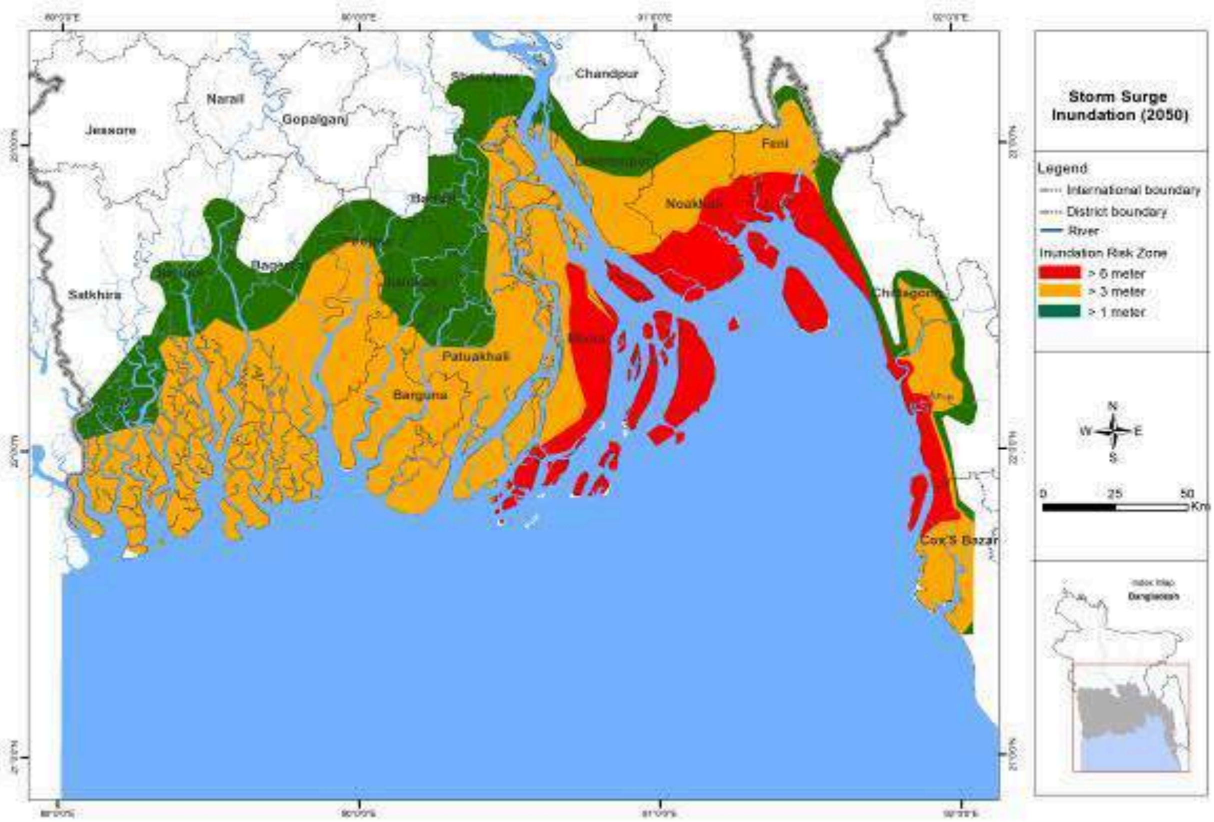
Source: CEGIS, 2016

Previous records indicate that the greatest damage during cyclones has resulted from the inundation caused by cyclone-induced storm surges. **Table 1.7** shows the relationship between wind velocity, strong surge height and the inundation span from coastline. Though time-series records of storm-surge height are scarce, existing literature indicates a 1.5 m to 9 m height range during various severe cyclones.

Table 1.7: Typical Storm Surge Inundation Characteristics for Cyclones of Varying Strength in Bangladesh

Wind Velocity (km/hr)	Storm Surge Height (m)
85	1.5
115	2.5
135	3.0
165	3.5
195	4.8
225	6.0
235	6.5
260	7.8

Source: Multi-purpose Cyclone Shelter project (MCSP), 1993



Map 1.11: High-risk Storm Surge Inundation Area for 2050 EXT Scenario

Source: Adopted from IWM, 2014

Table 1.8: Vulnerable Areas in Bangladesh due to Storm Surge Induced Inundation

Inundation depth (m)	Baseline scenario (km^2)	Climate change scenario (km^2)	Change (%)
>1	20,876	23,764	+14
3	10,163	17,193	+69

Source: IWM, 2014

Summary of major vulnerabilities from climate change: Bangladesh faces major climate change challenges. The key vulnerabilities from climate change are summarized in **Table 1.9**.

Table 1.9: Key Vulnerabilities from Climate Change and Impacts

Climate Change Impact	Current State	Expected Change	Consequences under a BAU scenario
1. Accelerated Sea Level Rise (ASLR)	2.0 mm/year SLR	1 m or more by 2100; increase in tidal flooding; with monsoonal rainfall and river discharge increase in flooded area	Inundation of between 17-21% (up to 30,000 km^2) of total area; increased saline land area; loss of farmland; loss of livelihoods; out-migration; destruction of infrastructure; destruction of mangroves
2. Temperatures	Increase in minimum temperatures by 0.85 °C between 1948 – 2011; maximum temperatures increased by 0.5 °C	Increases in temperatures of up to 2.0 °C or more	Reduced rice yields; increase in pests and insects; extinction of some species
3. Dry periods / drought	Long period of consecutive dry days	Increase in number of dry days and drought	Further reduction in groundwater table; water scarcity for irrigation and household consumption, land degradation and impeded ecosystem functioning.
4. Precipitation	Increase in total annual rainfall by 10% between 1948-2011	Increase between 300 mm in southeast to 800 mm in northwest with increase in intensity	Increases in mean annual discharge in the the Ganges- the Brahmaputra- the Meghna rivers; may cause flash floods, extensive area under flooding, damage to infrastructure, destruction of crops
5. Cyclones	Number of cyclones decreasing but intensity increasing	Increased intensity of cyclones with high wind speeds up to and over 250 km per hour	Devastating effects on homesteads, crops, livestock; salt water intrusion; water logging;
6. Storm surge	Current storm surge heights are over topping polder embankments (Sidr and Aila cyclones)	Future storm surge heights will increase due to higher wind speeds	All current polders will be flooded with prolonged water logging

Note: BAU = business as usual (i.e. no concerted adaptation or mitigation investments)

Source: BDP 2100 Technical Team Analysis, GED, 2015

Knowledge gap: While future trends are becoming clear there is need for more quantified spatial specific information, especially on future changes in extremes. This information is needed for improved flood and drought risk analysis. Climate scenarios have to be used for an integrated climate change impact assessment and there is a need to analyze changes in water demand, availability, salt-intrusion and flood risks. To further quantify the possible changes in extreme rainfall events and better understand future changes in the onset of the monsoon, there is a need for further downscaling of the climate change scenarios. In addition, there is a need to develop improved scenarios on basin wide changes in rainfall and water resource availability. There is a gap between climate change science, the use of the knowledge and climate scenarios for adaptation efforts. There is need to improve this link to ensure that adaptation plans are developed based on detailed knowledge of climate change at national and local level.

1.6 Maintaining the Ecosystems: Forests, Wetlands, Coastal, Marine and Biodiversity

1.6.1 Ecosystem Diversity

A tremendous natural asset for Bangladesh is its rich and diverse ecosystem that not only provides it with the many advantages noted before, it also provides for a high quality of life in terms of the eco balance. This ecosystem has come under stress from climate change as well as human interventions from settlements and unsustained exploitation of the natural resources. Preserving this ecosystem is a major development challenge moving forward.

The ecosystems of Bangladesh can be categorized into two major groups (i) Terrestrial and (ii) Aquatic. The terrestrial ecosystems include homestead, forest, and crop field; while seasonal and perennial wetlands, rivers, lakes, coastal mangroves, coastal mudflats and chars, and marine fall into the aquatic category. Each of the ecosystems has many sub-units with distinct characteristics as well.

Terrestrial ecosystem: According to National Forest and Tree Resources Assessment 2005-07, homesteads cover about 20% (2.767 million ha) of the total land, of which 10% is covered with trees and the rest is covered with homestead vegetation, which is important for its wild shrubs and herbs as well as locally cultivated plants and as wildlife refuge. The site lower than homesteads but a little higher than the adjoining agricultural fields is locally called 'kanda'. Long ago, the kandas were occupied by swamp forest, reed swamps and grass. The village roads, highways and embankments provide a good habitat for woody and fruits yielding plants. Coastal embankment plantation has long been in practice in southern Bangladesh.

In Bangladesh, forests are distributed on the eastern hills, central and northwestern terraces and the mangroves facing the Bay of Bengal. In addition to embankment/roadside plantations, there are rubber plantations. The Madhupur Sal Tract, extending across the districts of Gazipur, Tangail and Mymensingh, contains important timber species; however, 70% of the sal forest area is either already degraded or encroached. The southeastern hill-range in the Chattogram Hills and the Chattogram Tracts is composed of tropical evergreen and semi-evergreen forests. The majority of the species in the lower canopy are evergreen, and the upper canopy of the forest is deciduous type. Tropical evergreen forest is found in the valleys of this zone. This zone possesses the richest avifauna population of the country. While the hills are not very high, generally about 600 m, they are ragged and often steep; these hill forests are the most important watershed areas of the country. The tropical evergreen and semi-evergreen forests are not very distinct, and are often intermingled and merged into one another in this zone. The undergrowth is usually a tangle of shrubs, in which cane, bamboo and wild banana are the prominent species. In comparison, the Sylhet hillocks average round 40-60 m, with the highest peak around 170 m. Tropical semi evergreen forest is found in this zone, particularly in the valleys. The Lalmai-Tipperah hills enjoy tropical semi-evergreen forests. This expanse remains largely evergreen with various species. The diversity of bird and mammal species is still considerably high but these species are increasingly under threat of extinction due to unhindered loss of habitats.

Aquatic ecosystem: These consist of seasonal and perennial wetlands, rivers, lakes, coastal mangroves, coastal mudflats and chars, and marine areas are important habitats for aquatic plants, birds, mammals, fish and animals." The majority of the natural ecosystems of Bangladesh are wetlands (Haors). Intricate networks of rivers that drain into and inundate Bangladesh have created many riverine ecosystems in the country. Bangladesh is a land of many small and large rivers densely crisscrossing like a net covering almost the entire country. The Tanguar Haor, Aila Beel, Hakaluki Haor and Hail Haor are considered as Important Bird Areas (IBA). Remnant swamp forest patches are now restricted to sloping areas, helping to protect homesteads from wave erosion, while some are recently replanted areas. The Chalan beel is an extensive low land area at the lower Atrai basin in the northwestern region of Bangladesh spread across the districts of Natore, Pabna and Sirajganj. It consists of a series of beels connected to one another by various channels to form more or less a continuous water body during the rainy season. As long as the Jamuna remains flooded during the monsoon months, the beel area expands into a vast water body with dense aquatic vegetation. It, however, dries out in the winter leaving only patches of 'water-holes' in the central part of this zone. The area of Chalan Beel has been reduced and land use has been changing.

The rivers are the most important component for any ecosystem sustainability. Many species of fish, invertebrates, algae and birds depend on riverine ecosystem. The floodplains (the Teesta, the Ganges, the Brahmaputra-the Jamuna, the Surma-the Kushiari, and the Meghna floodplains) are landforms, which are inundated in each monsoon. Except for the Barind Tract, Hill Tracts, Madhupur Shal Tract, and Akhaura Terrace, the rest of Bangladesh is under the floodplain ecosystem. The composition of plant and wildlife is almost same in the floodplain ecosystem. Vegetation of the floodplains changes with fluctuation of water levels; this type of seasonal wetland is dominated by grass and rooted floating plants. In the dry season, floodplains are converted into agricultural fields. The floodplains, situated close to the coasts, are more influenced by the saline waters of the Bay of Bengal. The Gopalganj-Khulna Peatlands occupy a number of low-lying areas between the Ganges river floodplain and the Ganges tidal floodplain in the south of Faridpur region and the adjoining parts of Khulna and Jashore districts. Thick deposits of peat occupy perennially wet basins, but they are covered by clay around the edges and by calcareous silty sediments along the Ganges tributaries crossing the zone. Most of the layers harden irreversibly into coal-like lumps when dry. The soil, in this zone, is potentially strongly acidic and low in essential plant nutrients. The basins are deeply flooded by rainwater during the monsoon season. However, in the basin area close to Khulna, the flooded water is somewhat brackish. Understandably then, the floral diversity in this zone is quite limited.

The river channel is continuously shifting within its active floodplains, eroding and depositing large areas of new char lands in each flooding season. A good succession of plants and animals in new char lands has been observed. Chars are good habitats for some of the avian fauna and amphibians because of noise and disturbance-free condition. Char lands support a good number of avifauna like cisticola, prinia, warblers, grassbirds, larks, pipits and munias. Char lands also support numerous mollusks, which are the feed for water birds, fishes and other aquatic faunal species. The pattern of succession depends on how long the char land has been permanent. A major part of these char lands are seasonally inundated in monsoon and deposit more sand on land surface. During dry season, large portions of the land are used for paddy, maize, sugarcane and groundnut cultivation.

Mangroves are a unique ecosystem hosting incredible biodiversity: migratory birds, marine creatures and reptiles; in addition to associated species of flora function as natural water treatment system, as spawning grounds for fish, and provide several resources to local communities who directly or indirectly depend upon them for their livelihoods and sustenance. The Sundarbans, a national treasure shared with India, is of global importance as the largest mangrove forest in the world. Intact mangroves form a natural coastline buffer against floods, storms or other natural disasters such as tsunamis and hurricanes protecting the coasts from erosion. The Bangladesh part of the Sundarban extends over an area of about 6,017 km^2, of which 4,142 km^2 is island and 1,875 km^2 is water. About 62% of the forest lies in the administrative districts of Bagerhat, Khulna and Satkhira. This mangrove tract constitutes 44% of the total forest area in Bangladesh and contributes about 50% of the total revenue derived from the forestry sub-sector. This area was declared as Reserved Forests in 1875 and handed over to the Forest Department (FD) for management; the FD manages this area as the Sundarbans Reserved Forests (SRF). A part of the Bangladesh Sundarbans (about 139,700 ha) is under three wildlife sanctuaries, designated as a World Heritage Site (WHS) by UNESCO in 1997 and classified as a natural heritage. The floristic composition of the Sundarbans is rich compared to many other mangrove areas of the world. The Sundarbans is the habitat of the Royal Bengal Tigers and according to the Tiger Census 2015, there are 106 tigers residing in the Sundarbans of Bangladesh whereas in 2004 the population was 440. Wildlife poaching and illegal trade of wildlife and their organs remain a challenge.

Bangladesh is situated at the head of the Bay of Bengal. The coast is characterized by a vast network of rivers covering an area of 9,380 km^2, a large number of islands between channels, a submarine canyon (Swatch of No Ground), the funnel shaped part of the northern Bay of Bengal. The area of the sea that makes up the Bangladesh Exclusive Economic Zone (EEZ) is estimated to be about 118,813 km^2 and spreads up to 200 nautical miles (370 km). A huge number of offshore islands are scattered in the Bay of Bengal. The Saint Martin’s Island (Narikel Jinjira) is the only coral bearing island of Bangladesh, and therefore it is of significance in the context of coastal and marine ecosystems. Estuarine flood plains, sand dunes and beaches characterize the coastal ecosystems of Bangladesh. The Meghna flood plains of Noakhali and Lakshmipur districts are inundated seasonally attracting a wide variety of birds, including the migratory ones. Rare species of birds including the Globally Critically Endangered Spoon-bill Sandpiper and Indian skimmer (Rhynchops albicollis) visit this ecosystem including Sonadia Island, which is a global hotspot of Spoon-billed Sandpiper. The beaches and sand dunes also attract sea turtles.

This extensive open water ecosystem extends southwards into the Bay of Bengal. The coastline of Bangladesh is 580 km long and can be broadly divided into three regions: the eastern region (Pacific type), the active delta of the central region, and the stable deltaic western region (Atlantic type). The shallower part of southern continental shelf off the coast of the Sundarbans, Patuakhali and Noakhali is covered by silt and clay; and extensive muddy tidal flats have developed along the shoreline. Some of the shoals and sand ridges present on this part of the continental shelf, show an elongation pattern pointed towards the Swatch of No Ground.

1.6.2 *Major Challenges to the Ecosystems from Climate Change*

The major challenges emerge from pressures that bring changes in land use in both terrestrial and aquatic environments. These include demand for increased agricultural lands, collection of fuel wood, and non-timber forest products by the local communities, natural habitats converted into human habitations, ecosystem fragmentation and loss of habitat. Additionally, there is degradation of habitats in all ecosystems and landscapes, change in hydrological regimes, pollution, poorly managed and unsustainable tourism (St. Martin's Island, Lawachara National Park, Ratargul Swamp Forest, Madhabkundu Eco-park and Sundarban), unsustainable agricultural practices, urban expansion, invasive alien species, and impacts of climate change including SLR. Unchecked challenges will cause irreparable losses of ecosystem services relating to: (a) provisioning services such as food and water; (b) regulating services such as flood and disease control; (c) cultural services such as spiritual, recreational, and cultural benefits; and (d) supporting services, such as nutrient cycling, that maintain the conditions for life on Earth. Climate change would cause shifting in composition of agro-ecological zones as well as species in ecosystems.

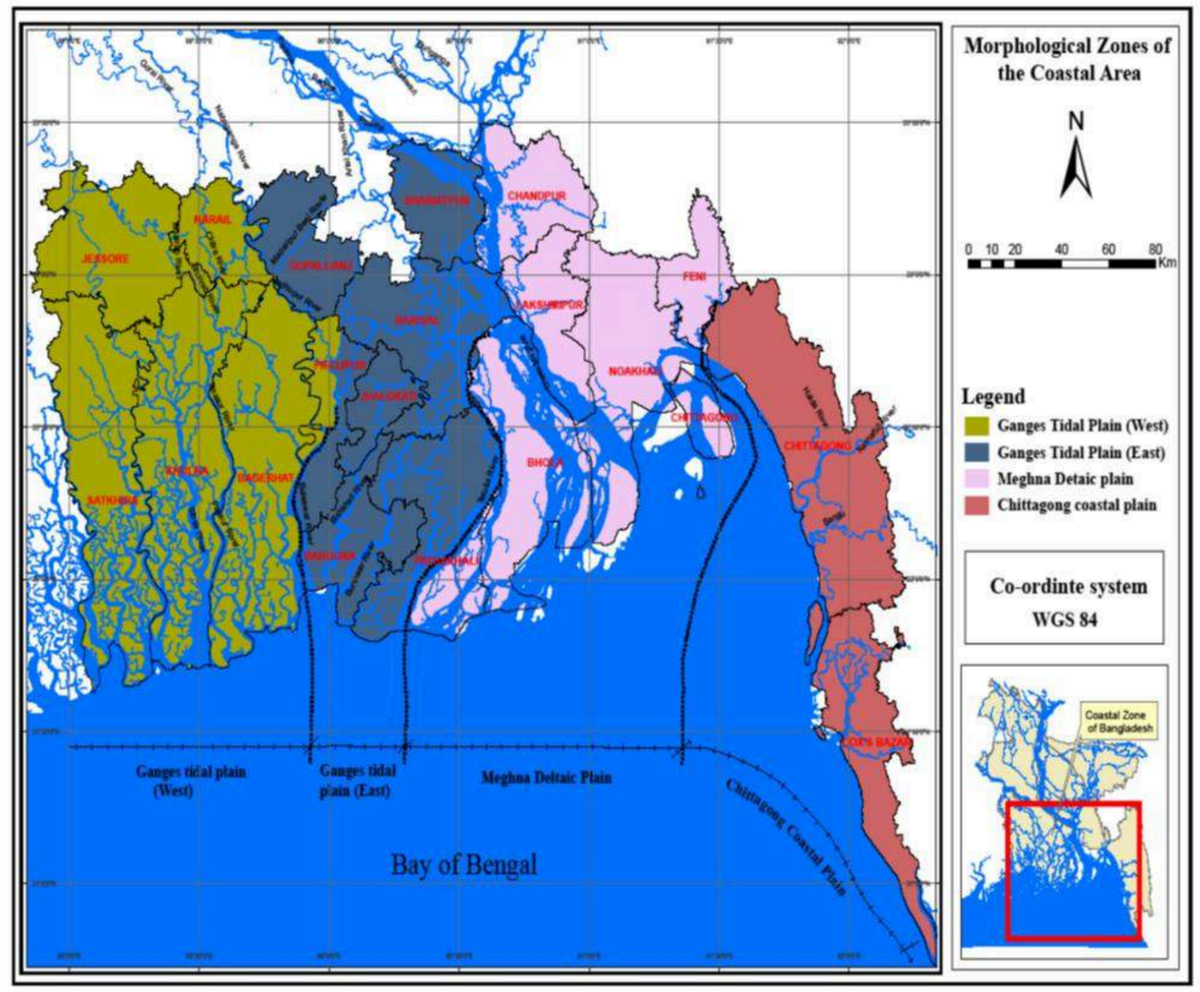
The predicted rise in sea level may inundate up to 75% of the Sundarbans; highly specialized plants and animals will migrate to the north or disappear while less specialized organisms may be in a position to adapt in the newly created environment. Higher future CO_2 levels could benefit forests with fertile soils in the Northeast. However, increased CO_2 may not be as effective in promoting growth in the West and Southeast, where water is limited. Warming temperatures could also increase the length of the growing season as well shift the geographic ranges of some tree species. Habitats of some types of trees are likely to move northward or to higher altitudes. Other species may be at risk locally or regionally if conditions in their current geographic range are no longer suitable. For example, species that currently exist only on mountaintops in some regions may die out as the climate warms since they cannot shift to a higher altitude. Climate change will likely increase the risk of drought in some areas and the risk of extreme precipitation and flooding in others. Increased temperatures would alter the timing of snowmelt, affecting the seasonal availability of water. Although many trees are resilient to some degree of drought, increases in temperature could make future droughts more damaging than those experienced in the past. In addition, drought increases wildfire risk, since dry trees and shrubs provide fuel to fires. Drought also reduces trees' ability to produce sap, which protects them from destructive insects such as pine beetles.

Preservation of the ecosystem from the adverse impacts of climate change is very important to reduce the negative consequences of natural disasters on human welfare. Forests and trees can reduce wind velocity and storm surges; thick vegetation diminishes the tidal height, thus arresting the magnitude of devastation. Not only mangrove afforestation, social forestry can also be important in cyclone mitigation. It may be advisable to create a green belt of 3 to 4 km width depending on the position and configuration of the coast for protective purpose. The current height of the embankment is not consistent with the maximum height attainable by storm surges. Coastal embankment can be raised and planted with mangrove and mesophytic species (suitable to the coastal zone) on both sides of the embankment to prevent sea water intrusion. The Sundarbans with a width of 80-100 km from the sea is very effective in minimizing the intensity of cyclone speed before it reaches human habitation. Unfortunately, the Chokoria Sundarbans in the East has been completely cleared for shrimp farming. In 1991, more than 1,35,000 people were killed due to the cyclone. Had there been a vegetation barrier, the loss could be much lower. The cyclone ravaged the Chattogram coastal belt but the people of Mirsrai and Sitakunda suffered least casualties primarily due to protection provided by 1-2 km wide plantation buffer along the shore. In coastal zone, foreshore afforestation is a proven cost-effective method to dissipate wave energy and reduce floods on embankments during storm surges. This was also evident during the 2007 Sidr and 2009 Aila cyclones. Even scattered and unplanned afforestation on the embankments affected by the cyclone Sidr substantially broke the storm surge velocity, reducing damages and losses.

1.7 Natural Hazard Risks and Challenges by Hotspots

1.7.1 Coastal Zone Hotspot

The Coastal Zone of Bangladesh is covered under the existing Coastal Zone Policy and Coastal Development Strategy. Three hydrological indicators characterize the Coastal Zone Hotspot: salinity intrusion, tidal fluctuation, and risk of cyclones and storm surges. The prospects of climate change impacts such as sea level rise further exacerbates these problems adversely affecting habitation, economic activity and livelihoods of the poor and vulnerable. Across the coastal zone tidal amplitude ranges from approximately 1.5 m in the west to over 4 m in the east and up to 8 m at spring tide near Sandwip. The coastal zone can be subdivided into four areas because of the diversity of conditions (**Map 1.12**). Each of the four areas has a distinct typical set of conditions and problems: i) South West (Ganges Tidal Floodplain- West); ii) South Central (Ganges Tidal Floodplain-East); iii) South East (Young Meghna Estuarine Floodplain); and iv) East and Hill (Chattogram Coastal Plains). (**Table 1.10**)



Map 1.12: Morphological Zones of Coastal Area of Bangladesh

Source: Bangladesh Water Development Board(BWDB), 2000

Ganges Tidal Floodplain (West): This covers the Sunderbans (mangrove) forest covers the first 60 to 80 km inland from the coastline, thus providing the hinterland to the north with a considerable degree of protection from cyclonic surges. This area has long drainage routes of low gradient and very little fresh water flow from the parent river (the Ganges). Except for Jashore and Narail, all other districts are at risk from cyclone and storm surges. There is salinity in all districts and all districts have tidal fluctuations.

Ganges Tidal Plain (East): The area is characterized by a younger stage of estuary development; the land is intersected by a number of rivers receiving water from the Lower Meghna river and from the Padma river via the Arial Khan river. There is no substantial forest area, and polders extend about 60 km inland from the coastline. Those facing the sea are subject to erosion and migration of rivers is eroding some polder embankments. Siltation of some rivers is causing navigation problems. River floods are not a major problem in this area, most of which is primarily subject to tidal effects. This zone is vulnerable to cyclonic storm surges and eventual damages of infrastructures, agriculture and aquaculture.

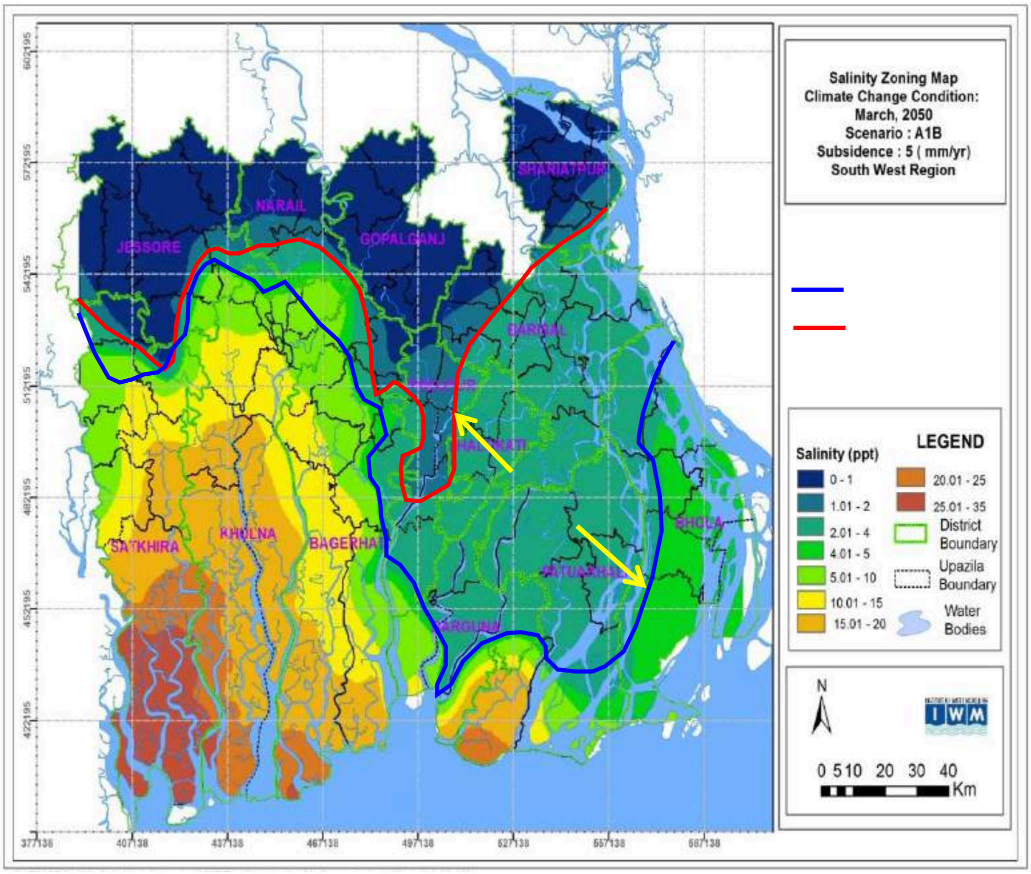
Meghna Deltaic (Estuary) Plain: Most of the islands are vulnerable to cyclone storm surges and erosion. The land accretion is higher than erosion. New land is being formed at a rate faster than the erosion of older land in this area. The newly accreted areas are initially too low and vulnerable for human settlement and agricultural use. Population pressure and urgent need for land is, nevertheless, leading people to settle on these recent deposits, and sometimes people demand to empolder them before the natural deposition process has built them high enough for adequate drainage. The northeast and east sides of Bhola island, north and west sides of Hatia, west side of Manpura, and west side of Sandwip islands have been experiencing severe erosion. Some areas are also increasingly subject to prolonged water-logging due to encroachment and land reclamation by closing the tidal channels. River floods are severe in some parts of the mainland near the Meghna estuary, especially in the districts of Chandpur, Lakshmipur, Noakhali and Feni.

Chattogram Coastal Plain: This is directly exposed to vulnerable cyclone and storm surges. A problem that is not seen in the other three areas is flash floods from the hills immediately to the east: the steep gradients, and the usual tendency of hills to generate intense rainfall, produce rapid increases in discharge, which the rivers and other drainage channels across the flat coastal plain cannot convey safely.

Coastal polders built by Bangladesh Water Development Board (BWDB) enabled bringing 1.2 million ha of land under agriculture or aquaculture and provided protection of lives and properties of coastal communities against flood, storm surge and salinity intrusion. However, there have been unintended consequences such as river sedimentation and water-logging that has become increasingly problematic in the last three decades in certain parts of the coastal zone.

SLR is likely to cause significant changes in river salinity in the southwest coastal zone of Bangladesh during the dry season (October to May) by 2050, which will likely lead to significant shortages of drinking water in the coastal urban areas, scarcity of water for irrigation for dry-season agriculture and significant changes in the coastal aquatic ecosystems. Changes in river salinity and the availability of freshwater may affect the fish habitat and productive freshwater fisheries.

Salinity challenge: Simulation of salinity intrusion with SLR of 52 cm in 2050 shows that the freshwater zones in Bagerhat, Barguna, Barishal, Bhola, are likely to be lost. Khulna, Jhalokati, Pirojpur, and Satkhira districts will also be most adversely affected by the increase in river salinity (BDP 2100 Climate Change Baseline Study). An area of 7,000 km^2 is likely to be affected by more than 1 ppt and about 8,400 km^2 would be affected by more than 2 ppt salinity in the southwest and south central zones by 2050 with a 52 cm sea level rise. The 2 ppt salinity front moves about 65 km into Barishal division as shown inMap 1.13. As a consequence, many farmers have to choose a new farming strategy. The number of people in the southwest coastal zone affected by salinity is likely to increase from 2.9 to 5.2 million mainly the poor. Salinity may thus become the biggest problem in the coastal zone for the next 50 to 100 years, due to Accelerated Sea Level Rise (ASLR) and uncertainty in river flows.



Map 1.13: Effect of Sea Level on 2 ppt Salinity contour (A1B, 2050)

Source: IWM, 2014

Land use loss due to sea level rise and flooding: As noted earlier, the projected land loss from a 1 meter increase in SLR ranges from a low of 3% (4,400 km^2) to a high of 21% (30,000 km^2). Additional problems for land use will be created by growing risk of flooding from higher rainfall and river overflows.

Water logging will become a major problem. The combined effect of SLR and increased precipitation in the changing climate, subsidence inside polders and sedimentation of peripheral rivers will deteriorate the drainage condition. Restoration of tidal plain for tidal inundation in increasing the tidal prism of the tidal river, sediment management allowing free movement of tide into polders for certain periods of the year to raise the low lying land are very likely measures for solving water logging problems. In order to obtain faster drainage in times of climate change, pumping might be required in addition to gravity drainage of polders. It is important to assess where this tipping point lies.

Cyclones can have a devastating impact on Bangladesh both in human and economic terms. Changes in cyclone frequency, paths and intensity can therefore have a large impact on the country. The analyses of historic changes on cyclones showed that the number of cyclones is decreasing but the intensity is increasing. For the future, this trend is likely to continue. Polders were overtopped in the recent cyclone Sidr and Aila. The estimated cost of damage of Sidr is at US$ 1.7 billion (World Bank, 2010).

In summary, the Coastal Zone Hotspot is most vulnerable to Accelerated Sea Level Rise (ASLR), increasing salinity and water logging, tidal fluctuation, and increasing intensity of cyclones and storm surges which will ultimately lead to huge losses of farming land, homesteads, livelihoods accompanied by severe health impacts (due to scarce freshwater and salinity in drinking water) and out-migration of people from coastal zone into urban centers. The key vulnerabilities are summarized in **Table 1.10**.

Table 1.10: Key vulnerabilities of the Coastal Zone Hotspots

Vulnerability from	Current State	Expected Change	Consequences under a BAU scenario
1. Tidal fluctuation	ranges from approximately 1.5 m in the west to over 4 m in the east and up to 8 m at spring tide near Sandwip	Tidal height expected to increase with ASLR	Will affect at least 50% of coastal zone and increased salinity and destruction of polder embankments.
2. Accelerated Sea Level Rise (ASLR)	2.0 mm/year sea level rise.	1 m or more by 2100; likely to cause significant changes in river salinity in the southwest coastal zone of Bangladesh during the dry season (October to May) by 2050	Inundation of between 17-21% of total area; significant shortages of drinking water in the coastal urban areas, scarcity of water for irrigation for dry-season agriculture and significant changes in the coastal aquatic ecosystems; loss of farmland; loss of livelihoods; out-migration; destruction of infrastructure; change in mangrove pattern; will affect fish habitat and productive freshwater fisheries.
3. Salinity intrusion with sea level rise	Out of 2.86 million ha of coastal and offshore lands about 1.0 million ha (SRDI 2000) of arable lands are affected by varying degrees of salinity.	salinity intrusion increase with SLR of 52 cm in 2050	7,000-8,400 km^2 likely to be affected; Loss of freshwater zones in Bagerhat, Barguna, Barishal, Bhola; salinity will affect 2.9 to 5.2 million people

Vulnerability from	Current State	Expected Change	Consequences under a BAU scenario
4. Cyclones	Number of cyclones decreasing but intensity increasing	Increased intensity of cyclones with high wind speeds up to and over 250 km per hour	Devastating effects on homesteads, crops, livestock; salt water intrusion; water logging.
5. Storm surge	Current storm surge heights are topping over polder embankments (Sidr and Aila cyclones); estimated cost of damage of Sidr alone was at US$ 1.7 billion (World Bank, 2010).	Future storm surge heights will increase due to higher wind speeds.	All current polders will be flooded with prolonged water logging; damages to infrastructure, agriculture and aquaculture.

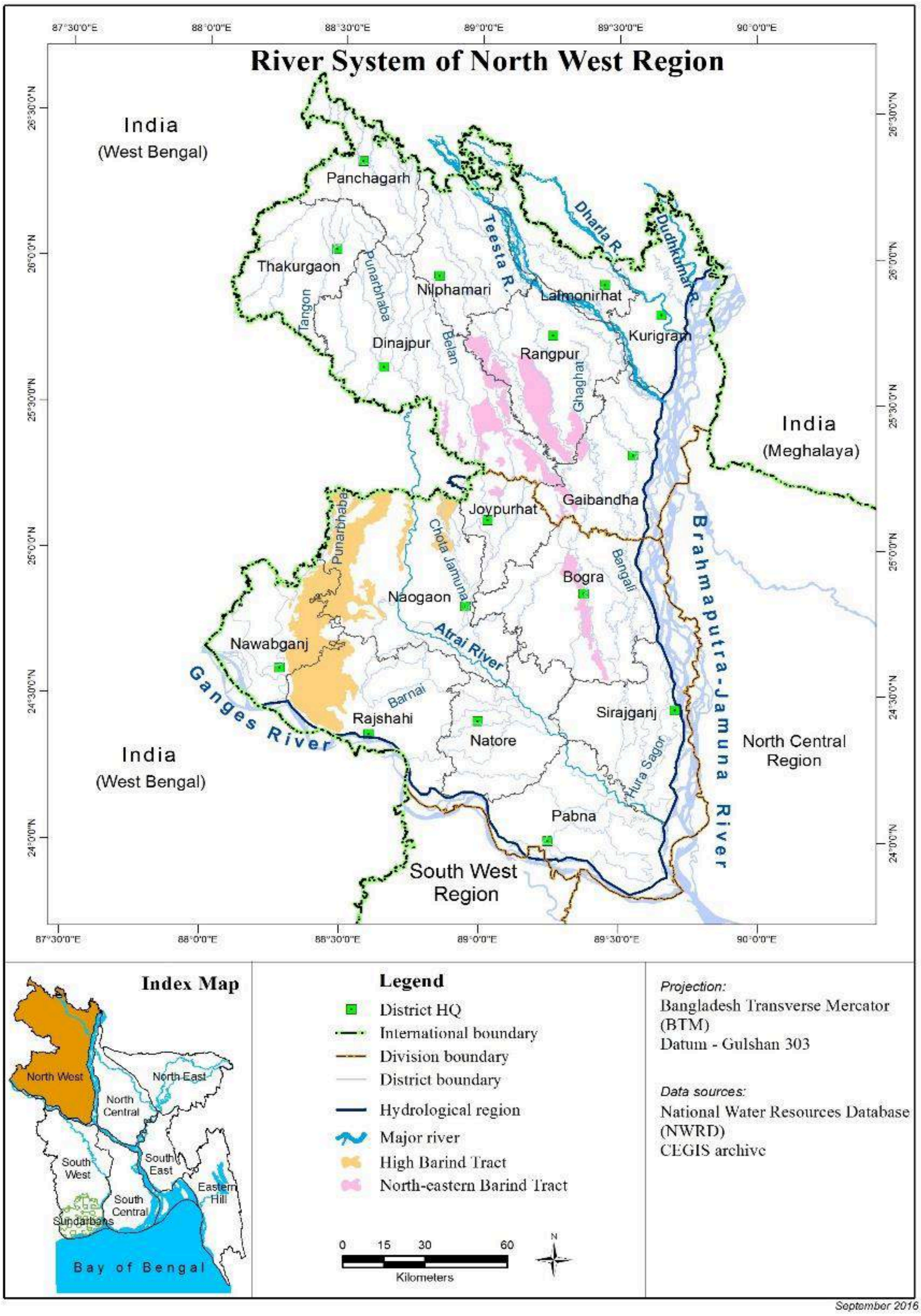
Note: BAU Scenario (i.e. no concerted adaptation or mitigation investments)

Source: BDP 2100 Technical Team Analysis, GED, 2015

1.7.2 *Barind and Drought Prone Areas Hotspot*

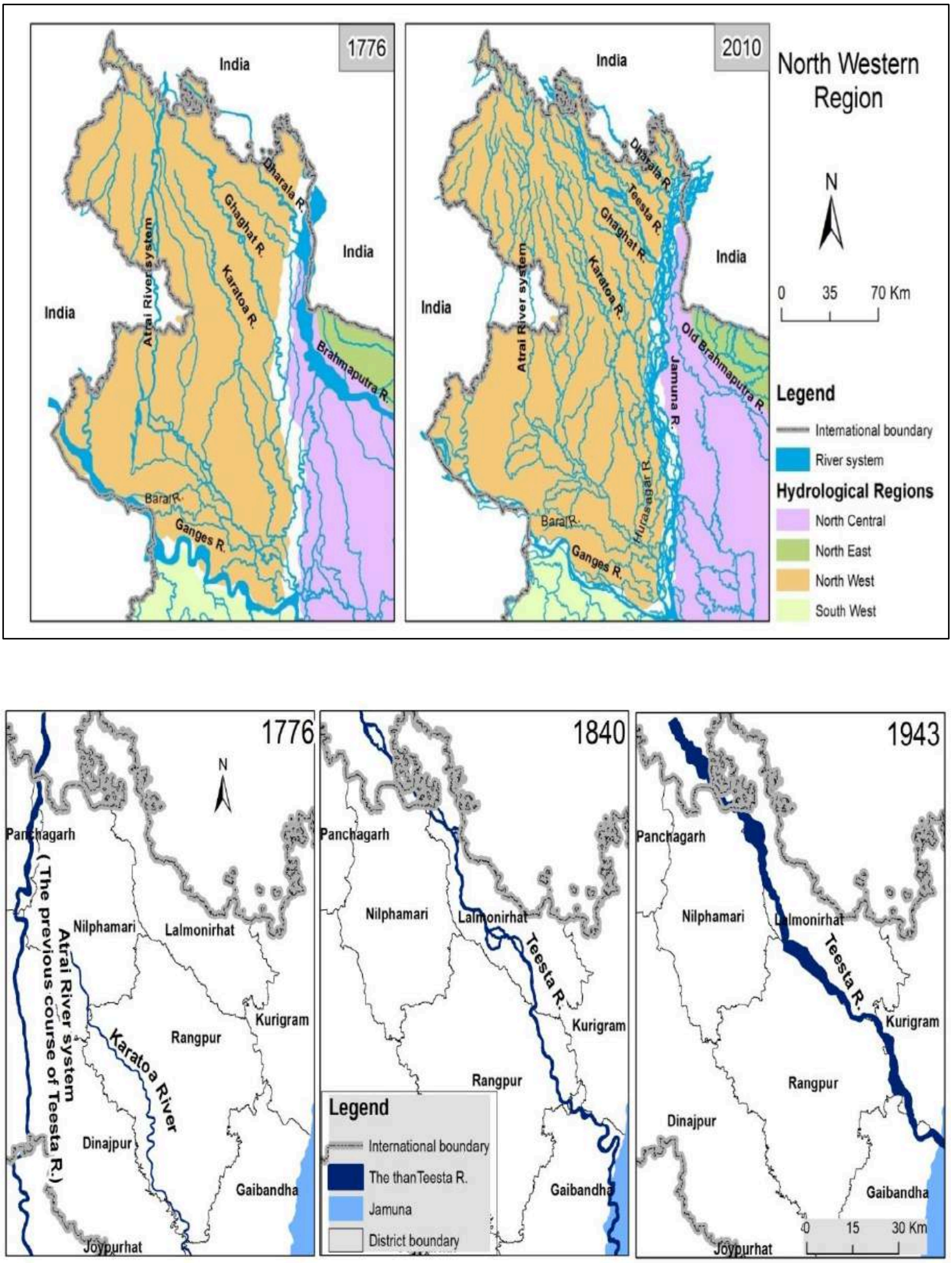
Most characteristically, the Barind Tract at the west side of Rajshahi Division makes the area elevated, and the elevated riverbanks of the Jamuna and the Ganges make the region basin-shaped where Chalan Beel is located. Most of the rivers of this area come from the Ganges River and Barind Tract and outfall into the Brahmaputra-the Jamuna River. During the last few decades, there were a number of human interventions such as the Teesta Barrage in India (at Gazaldoba in 1985) and in Bangladesh (at Dalia in 1990), which have severe consequences on the availability of water during the dry season.

The greater part of the Barind Tract is almost plain and is crisscrossed by only a few minor rivers. This tract is considered an ecologically fragile ecosystem with extremely low vegetation cover. Though the zone was rich with faunal diversity in the past, it has now noticeably reduced mostly due to various pressures like expansion of human habitat, agricultural extension, unwise use of agrochemicals, and illegal hunting.



Map 1.14: River System of Northwest Region

Source: CEGIS, 2016



Map 1.15: River system of Northwest Region in 1776 and 2010 and Historical Changes of the Teesta River

Source: CEGIS, 2015

Upstream human intervention and natural events, like the Teesta avulsion or shifting due to heavy rainfall in 1787, have had profound impact on the river system changes and development in the Northwest Region (**Map 1.15**). In the Northwest Region, intensive agriculture is being practiced, especially boro crops, for which intensive irrigation is required. On the other hand, westward migration of right bank of the Jamuna River since 1830 was about 8 km, which caused the net loss of about 2,000 km^2 of floodplain. Erosion often breaches flood embankment causing widespread flooding in the adjacent floodplain. The barrages do not permit enough water to flow through it during the dry season. As a result, water scarcity for irrigation recurs. Water level analysis indicates that more water is being stored in the dry season at the upstream of the Teesta barrage on the Indian side but during monsoon flood, the gate of the barrage remains open. In spite of many erosion protection structures along the river bank, erosion remains a major problem and sand carpeting in this river due to flood is very harmful for the cultivation of land in the floodplain. High temperature, low and erratic rainfall appeared to be a major challenge for crop production. Heavy dependency on groundwater for irrigation causes lowering of groundwater table and land degradation, adverse impacts on human health, animal and plant production.

Long term challenges: The socio-economic prospects of the Barind and Drought Prone Areas have improved dramatically in the last few years owing to the large-scale adoption of mechanized tube well based irrigation. The program was introduced by the government as a part of its Barind and Drought Prone Areas development strategy, but private irrigation took over and expanded the availability of water that revolutionized food and other farm production including fruits and vegetables. However, this improvement has come at a large future cost. This region is characterized by the tendency of high extraction of groundwater and diversion of river water for irrigation purpose. Groundwater extraction occurs at high rate particularly in the Barind Tract area. The reduction of the Ganges water during the dry period and inadequate surface water is further creating problems as underground aquifers do not get adequately recharged. In the northwest region the existing water scarcity may be intensified due to effects of climate change. There will be longer dry season and shorter wet season and discharge will increase only in the wet season. This could seriously affect the lives of nearly 39 million (2011) people living in the Barind and Drought Prone Areas Hotspot with farmland being affected by water scarcity. High temperature, low and erratic rainfall appeared to be a major challenge for crop production. Heavy dependency on groundwater for irrigation causes lowering of groundwater table and land degradation, adverse impacts on human health, animal and plant production. Fluctuation in diurnal temperatures, low humidity and wind speed will cause changes in flowering phenology of agronomic and forest crops that may lead to decline in yield reduction.

In summary, the vulnerabilities affect the Barind and Drought Prone Areas Hotspot are contained in **Table 1.11.** This hotspot poses a major challenge for managing water availability during the dry season. Continued reliance on groundwater based mechanized irrigation without efforts to augment the supply of surface water in the dry season is not sustainable and presents a major risk to food security.

Table 1.11: Key vulnerabilities of the Barind and Drought Prone Areas Hotspot

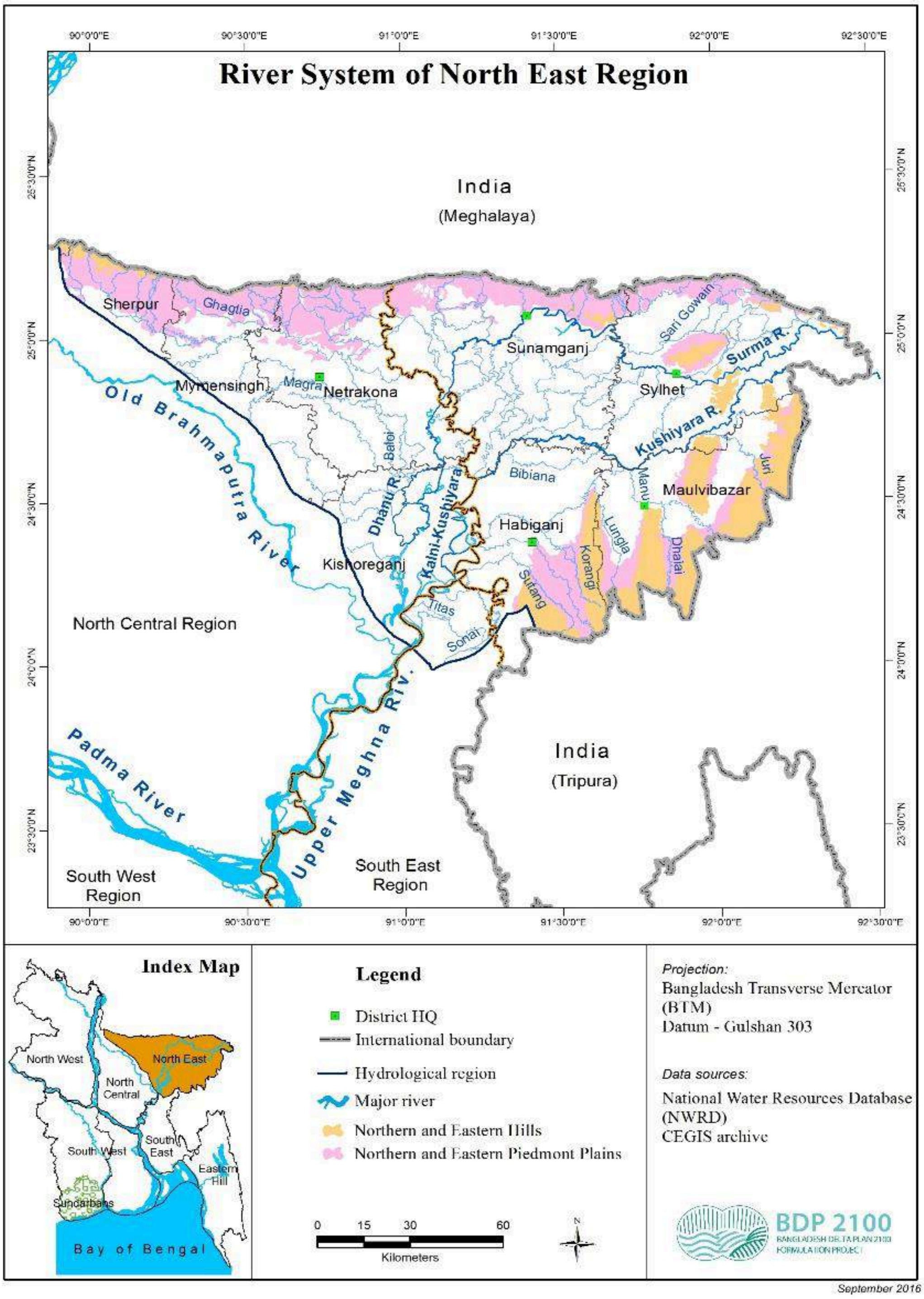
Vulnerability from	Current State	Expected Change	Consequences under a BAU scenario
1. Temperatures	Increase in minimum temperatures by 0.85 °C between 1948 – 2011; maximum temperatures increased by 0.5 °C	Increases in temperatures of up to 2.0 °C or more	Reduced crops and livestock production; increase in disease and pest infestation; extinction of some flora and fauna.
2. Dry periods / drought	Long period of consecutive dry days	Increase in number of dry days and drought	Further reduction in groundwater table; water scarcity for irrigation and household consumption; up to 39 million people could be affected; landuse pattern, plan species composition in the Barind ecosystem may change and also increase in top soil erosion
3. Reduced groundwater levels	Uncontrolled abstraction of groundwater for irrigation and consumption	Falling groundwater tables; poor re-charging of groundwater due to prolonged dry spells and drought	Crop failures, reduced agricultural output; water scarcity; increase in water, sanitation and hygiene problems and related diseases
4. Reduced wetlands	Number of water bodies, their area and water holding capacity reducing	Low water holding capacity, reduction in ecosystem goods and services	Reduce water availability for domestic and irrigation purpose, rise in temperature due to low evapo-transpiration, affect food security and nutrition, disease and pests outbreak, land degradation and loss of biodiversity.

Source: BDP 2100 Technical Team Analysis, GED, 2015

1.7.3 Haor and Flash Flood Areas Hotspot (Northeast Region): Freshwater Wetlands

Haors are important bowl or saucer-shaped depressions or natural reservoirs of freshwater wetlands with renewable and non-renewable natural resources in the Sylhet Basin in the northeastern region of Bangladesh. They are the back swamps or bowl shaped depressions between the natural levees of rivers. They are flooded to a depth of as much as 4-6 m during the rainy season, and in most cases during monsoon two or more Haors become linked and form large water bodies. During the dry season most of the water drains out except some shallow lakes locally called Beels. Surface water is likely to be the most severely impacted natural resource in Bangladesh due to climate change; an increase in the risk of extreme precipitation and flooding is likely; warming temperatures could also increase the length of the growing season as well as shift the geographic range of some tree species.

Geographically, Haor and Flash Flood Areas is located in between two major ecosystems of Bangladesh and Northeastern India (**Map 1.16**). One is Meghalaya-Assam-Tarap hill ranges in India and the other is Brahmaputra-Meghna river systems in Bangladesh. These hill ranges are covered with mixed evergreen forests from where Haors receive most of its freshwater through thousands of hill streams locally known as Charas. The Haors in the northeastern parts of Bangladesh are probably the most complex of seasonally inundated wetlands. They switch between a vast basin of water during the monsoon and a well-networked system of smaller wetlands including beels and canals in the summer.



Map 1.16: River System Map of Northeast Region

Source: CEGIS, 2015

The Sylhet Basin contains many large, semi-natural wetlands like haors, baors (Ox Bow lakes), and beels and waterfalls. This basin is close to Cherrapunji in India, which generates the highest rainfall in the world. The basin drains through an outlet at the south. The Sylhet Basin is tectonically active and subject to gradual subsidence. Subsidence is further exacerbated by the westward avulsion (movement) of the Brahmaputra, which, in turn, has decreased the sediment supply to the basin.

Farming and fisher folk households in the Haor Hotspot are dependent for their livelihoods on haors, beels and rivers in the northeast region, which provide a key source of livelihood for many rural poor in the country. The haors and beels (freshwater wetlands) provide key environmental services such as habitats for fish spawning, assimilation of wastes, flood attenuation, navigation and recharge to groundwater. These Haors and beels support major subsistence and commercial fisheries while the seasonally flooded lake shores support major rice-growing activities, and abundant aquatic vegetation provides ideal grazing for domestic livestock and a source of fuel and fertilizers for the local inhabitants.

The Haor basin is an internationally important wetland ecosystem providing habitats for various types of aquatic species of plants and animals. The Tanguar Haor, Aila Beel, Hakaluki Haor and Hail Haor are considered as Important Bird Areas (IBA). A large number of these birds use the aquatic vegetation for shelter, food and nesting. Every winter, the Haor and flash flood area is home to about 200 species of migratory waterfowls, including 100,000 to 150,000 ducks and other species. The largest Haor in the country is the Hakaluki Haor, which extends over 18,000 ha. During the rainy season, the haor consists of more than 80 inter-connected beels. The rich fish resources of Hakaluki support one of the largest inland fisheries in the country. Tanguar is an important "mother fisheries area", where many species breed during the rainy season. Haor swamps and marshes are particularly rich in aquatic plants with enormous diversity. Biomass productivity of these submerged plants is observed to be too high. Agriculture, fisheries and animal husbandry are three pillars of Haor economy.

Keeping in mind all these ecological benefits, the Tanguar Haor has been declared a Ramsar site as well as an Ecologically Critical Area (ECA). The Haor basin is the only region in Bangladesh where remnant patches of freshwater swamp and reed lands still exist. Hence, a wide variety of flora and fauna fall under the protection of international treaties and national legislation.

The Haor is also the habitat of fresh water swamp forest with flood-tolerant evergreen trees. A fully developed stand exhibits a closed canopy with mature trees standing ten to twelve meters tall. These trees mostly produce their seeds in the monsoon period and disperse them through water; seedlings grow in great quantities. In addition, woody shrubs and climbers are found. Swamp forest is adapted to monsoon flooding for three to four months, to depths of 0.5 to 2.5 m. Remnant swamp forest patches are now restricted to sloping areas, helping to protect homesteads from wave erosion, while some are recently replanted areas. These patches vary from a few plants to several hectares of more than a thousand trees. Depending on local conditions, particularly the extent of human disturbance, the luxuriance of the vegetation varies, from sparse low trees with undergrowth grasses to dense closed canopy with poor undergrowth. Freshwater swamp forest emerges due to flat low lying land becoming inundated due to rainfall runoff and inflow from surrounding river system. In swamp forest, the water table is typically very close to the surface.

Wetlands are extremely productive ecosystems, which provide crucial habitat and feeding and breeding grounds for many species of reptiles and amphibians. Many reptiles make their homes in the swampy wetlands. A study of National Conservation Strategy Implementation Plan claimed a total of 35 reptile species were recorded in Tanguar Haor area

Wetlands, both in terms of their extent (area and volume) and biodiversity are in serious decline. Out of Bangladesh's 260 freshwater fish species, more than 40% are now threatened with extinction. Land filling, encroachment, and land use change are the main reasons for shrinking of wetlands. Moreover, the Sylhet hilly tracts with small hillocks, locally known as "Tilla" having an average height of 40-60 m, with the highest peak around 170 m host tropical semi evergreen forest, particularly in the valleys. Bamboo is the most dominant vegetation type with at least seven different species. Diversity of other floral species is also very high.

It will be important to maintain forested areas in the Sylhet hilly tracts as well as the swamp forests. For the past several decades, forestlands have been under mounting pressure as more areas are converted to croplands and grasslands to meet the demand for food and raw materials. In addition, forestlands have been affected by increasing temperature, heat stress, and drought, with consequent loss of tree species and degradation of forests. The region's forests hold the key to the success of climate change mitigation efforts, and have great potential to sequester carbon through Reduced Emissions from Deforestation and Degradation (REDD), afforestation and reforestation, and forest management. In turn, deforestation releases CO_2 and reduces the potential for its sequestration.

The hilly forests assist in absorbing rainwater and reducing run-off and providing a cooling effect of temperatures. Both hilly and swamp forests can mitigate impacts of increasing number of dry days (dry periods) which are expected to be caused by increasing global temperatures or flash floods from intensive rainfall (extreme climate events) can be mitigated by hill and swamp forest areas through water retention, groundwater recharging, and slowing down rate of erosion (and mudslides) from hilly areas. It will be important to retain wetlands and forests in the Haor and Flash Flood Areas Hotspot to prepare for mitigating impacts of climate change projected over the century.

Long term challenges: Serious challenges in the Haor and Flash Flood Areas Hotspot are posed by: shrinking wetlands, reduced flushing of pollutants because of declining water throughput from the rivers, increasing subsidence of the Sylhet Basin due to decline in sediment deposits from rivers, and reduced flood holding areas, and receding groundwater table. There is a great concern for this swamp forest habitat due to over logging, and suspected seepage from upstream reservoirs resulting in significantly changed circumstances for many swamp forest species. Haors and beels are mostly inhabited by the poor and disadvantaged people who lack access to basic services including drinking water and sanitation. Due to absence of suitable water source and collection system, hoar people are affected by many water-borne diseases. Securing and maintaining freshwater wetlands as sources of vital ecosystem services, livelihoods and drinking water remain long term challenges.

Table 1.12: Key Vulnerabilities of the Haor and Flash Flood Areas Hotspot

Vulnerability from	Current State	Expected Change	Consequences under a BAU scenario
1. Precipitation	Highest rainfall in Sylhet Basin due to its proximity to Cherapungi, India, highest rainfall are in the world	Increase between 300mm in southeast to 800mm in northwest with increase in intensity	Increases in mean annual discharge rivers; may cause flash floods, extensive area under flooding, damage to infrastructure, destruction of crops
2. Subsidence and decreased sediment supply	Tectonically active and subject to gradual subsidence and westward avulsion of Brahmaputra (Assam earthquake 1950)	Further subsidence and river avulsion due to seismically active area (high magnitude earthquake probable)	Vital source for fisheries, irrigation water, ecosystem functioning and navigation may be disturbed affecting 1.9 million ha of the hotspot
3. Land filling, encroachment, land use change	Shrinkage in wetlands (area and volume); 40% out of 260 species of freshwater fish threatened with extinction (IUCN)	Continuing land filling, encroachment, land use change	Reduced flood holding areas; reduced re-charging of groundwater; loss of crucial habitat and breeding grounds, and livelihoods of poor

Source: BDP 2100 Technical Team Analysis, GED 2015

1.7.4 *River Systems and Estuaries Hotspot*

Major rivers, including the Ganges, the Brahmaputra-Jamuna, the Padma and the Meghna and their numerous tributaries and distributaries make Bangladesh a land of rivers, building the Bengal Delta, one of the largest of its kind. The catchment area of these rivers is about 1.72 million km^2 of which only 7% lies within the borders of Bangladesh. This catchment generates 120 million ha-m of runoff annually, of which only 10% is generated within Bangladesh. In addition to the vast quantities of water, these rivers carry about 1.1 billion tonnes of sediment every year. These rivers are dynamic in nature, as the land mass is composed of recent deltaic deposits and the major rivers originate in young mountains across the country's borders, such as the Himalayas, the Meghalaya and the Tripura Hills in India, China, Nepal and Bhutan. These young mountains yield huge quantities of sediment due to their active tectonic movements, wind and rain activities in the regions, and snow melting.

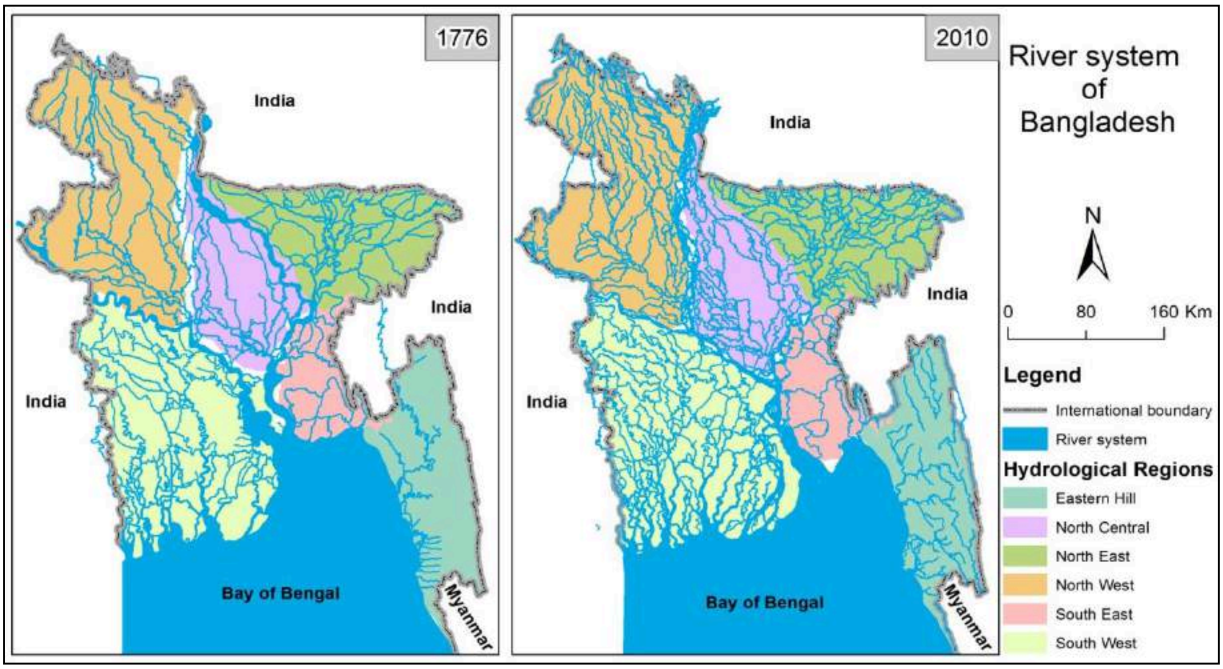
The Bengal Basin has been filled by sediments derived from erosion of the highland boundaries on all three landward sides. However, the main source of the sediment has been the Himalayas due to their alpine nature. Recently deposited, alluvial and deltaic sediments form about 90% of the land area of Bangladesh. The Ganges has, together with the Brahmaputra, delivered enormous quantities of sediment to the Bengal Basin. These sediments have formed the world's largest river delta with an area of about 100,000 km^2.

In line with the evolution of the river system, the rivers during the last 250 years have changed their respective courses several times (**Map 1.17**). The rivers abandoned their courses and subsequently, occupied several other new courses. In most of the cases, delta-building processes, together with tectonics and natural hazards, like earthquake played the main role for frequent avulsion and shifting processes of the rivers. Erosion and accretion dominate the morphological process in the Bengal Delta.

Table 1.13: Width, Length and Discharge of Major Rivers

Name	Average width (km)	Length (km)	Low discharge (cumec)	Peak discharge (cumec)	Type
Jamuna	12	230	3430	102535	Braided
Ganges	5	269	530	70868	Braided
Padma	10	121	3040	14200	Braided
Upper Meghna	3.4	156	2	19900	Anastomosing
Lower Meghna	1.1	65			Anastomosing

Source: Rivers of Bangladesh, 2010



Map 1.17: River System of Bangladesh in 1776 and 2010

Source: CEGIS, 2010

River bank erosion is a serious hazard that directly or indirectly causes the suffering of about one million people annually (**Table 1.14** and **Map 1.18**). While there is some accretion, on net river bank erosion dominates. A large number of people living in both rural and urban areas become the victims of flooding annually. These two hazards – flooding and river erosion – are major contributors to loss of life and property and damage to public goods and infrastructure. Sediments from river bank erosion combined with sediment deposits from the mountains create major difficulties for the navigability of the rivers.

Table 1.14: Erosion & Accretion in three Major Rivers of Bangladesh (1973-2018)

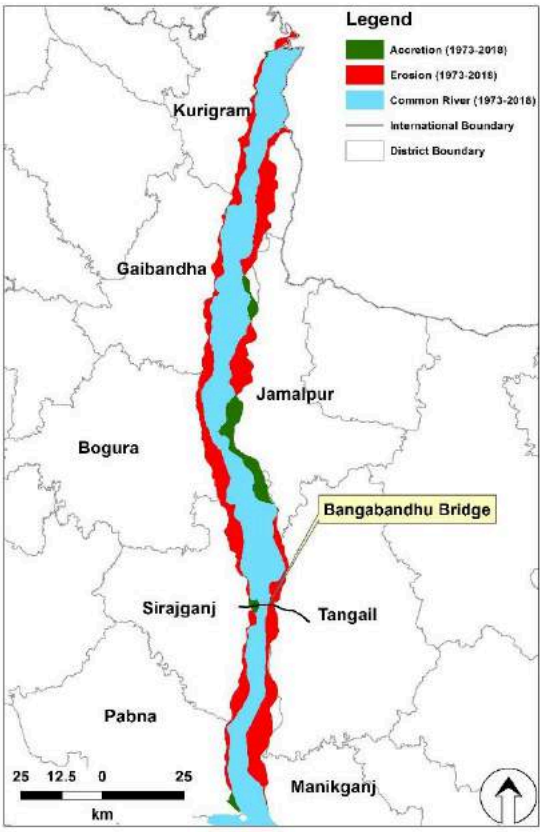
Name of River	Erosion (ha)	Accretion (ha)
Ganges	31,421	27,026
Jamuna	93,302	16,603
Padma	37,296	14,246
Total	**162,019**	**57,875**

Source: CEGIS, 2018

Map 1.18: Erosion Characteristics of Major Rivers

Source: CEGIS, 2016

Jamuna River Erosion and Accretion: The Jamuna river is particularly prone to river erosion with most land loses concentrated in Kurigram and Sirajganj (**Map 1.19**). Some limited land accretion happens in Jamalpur, Bogura and Sirajganj. Yet, net losses are substantial. The adverse impact on the river-erosion affected districts is enormous.



Map 1.19: Erosion-Accretion along the Jamuna during 1973-2018

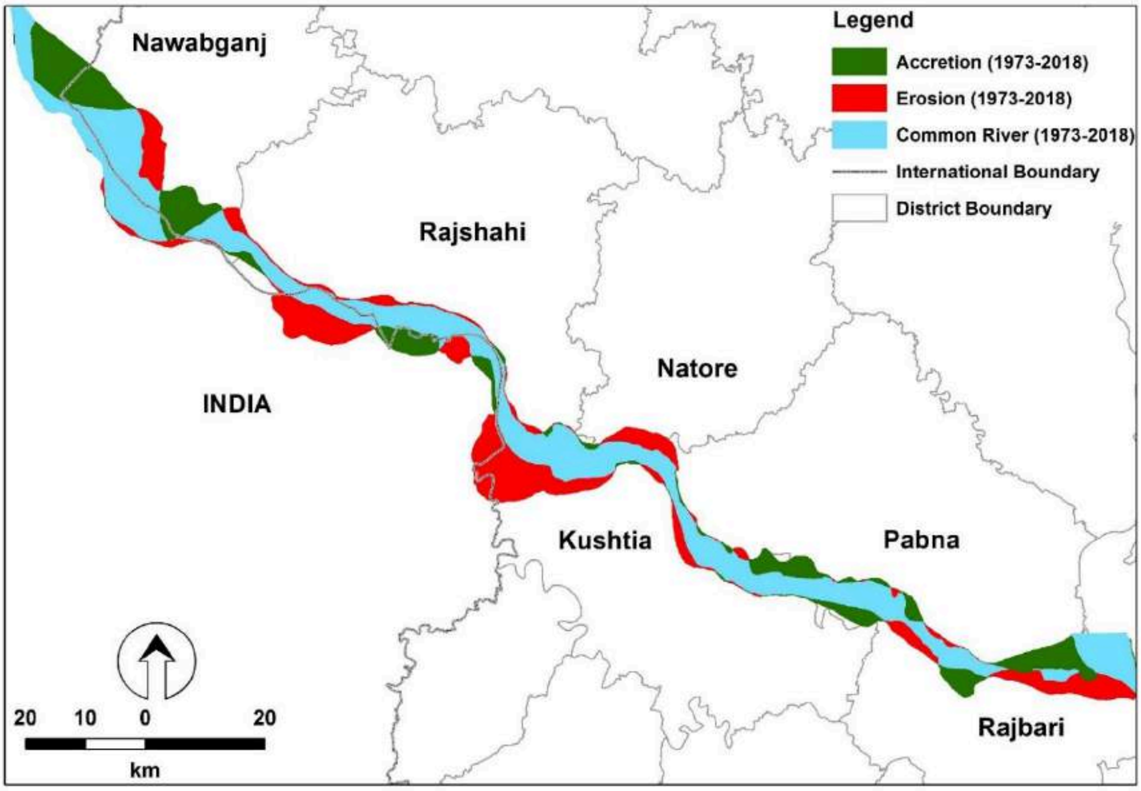
Source: CEGIS, 2014

Table 1.15: Bank Erosion and Accretion along the Jamuna River 1973- 2018

District	Eroded area (ha)	Accreted area (ha)
Bogra	11456	5094
Gaibandha	10215	1589
Jamalpur	10864	4993
Kurigram	19584	312
Manikganj	6568	34
Pabna	2738	14
Sirajganj	23697	4540
Tangail	8180	25
Grand Total	**93302**	**16603**

Source: CEGIS, 2018

The Ganges River: The total length of the Ganges is about 2,200 km but only the lower 220 km are in the territory of Bangladesh, meandering with alternating expansions and contractions. After the commencement of the Farakka Barrage in India, the drastic reduction of annual dry season flow and discharge in the mid-1970s have been observed mainly due to the flow diversion by the barrage. The sediment load of the river is about half a billion tonnes per year. Erosion-accretion pattern and amounts are shown in **Map 1.20** and **Table 1.16**. In the 1980s and 1990s, the annual rate of riverbank erosion was very high as the large meandering bends were in the development phase at that time. In the recent past, chute cut-off had occurred at these bends, which facilitated to intervene in the system without providing much effort. During the period of 1973-2014, the total erosion of the Ganges River was 31,421 ha and total accretion of land was 27,026 ha.



Map 1.20: Erosion-Accretion along the Ganges River 1973-2018

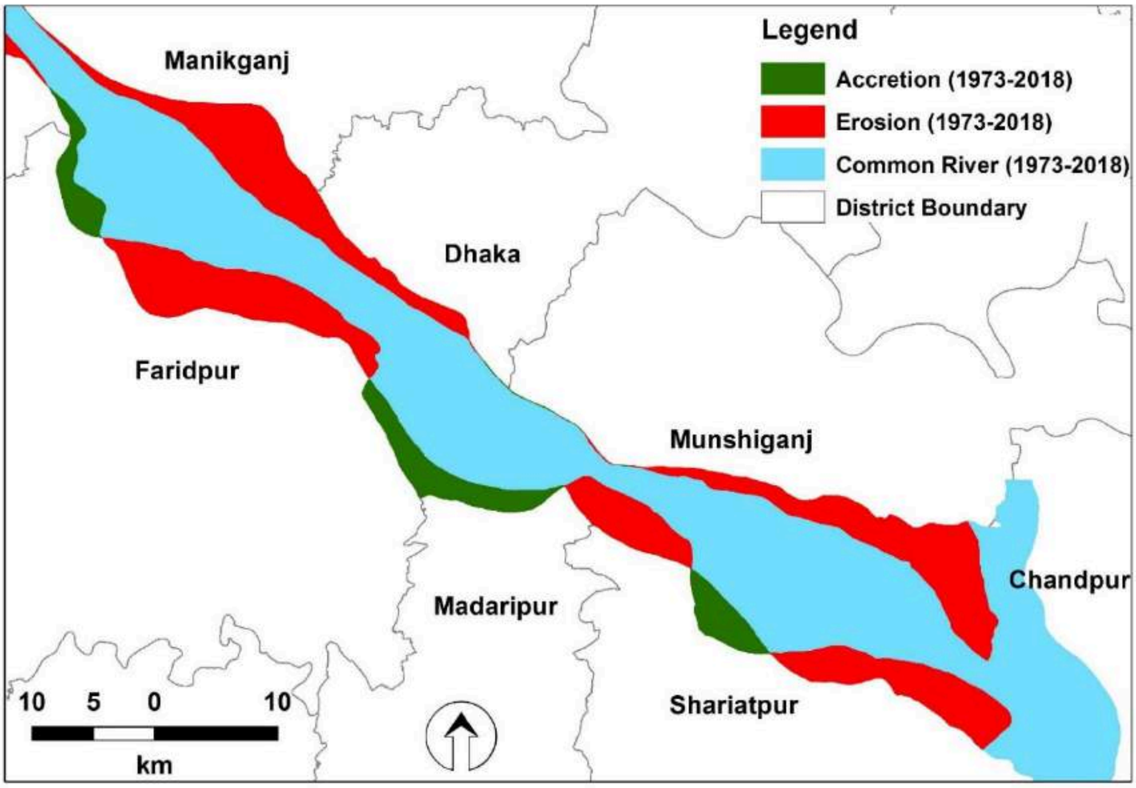
Source: CEGIS, 2018

Table 1.16: Bank Erosion and Accretion along the Ganges River 1973 - 2018

District	Eroded area (ha)	Accreted area (ha)
Kushtia	11834	1617
Natore	2047	148
Nawabganj	4997	10735
Pabna	8044	10001
Rajbari	7845	2698
Rajshahi	2160	1828
Grand Total	**31421**	**27026**

Source: CEGIS, 2018

The Padma River: The Padma River is the combined flow of the Jamuna and the Ganges rivers stretching from Aricha to its confluence with the Meghna River near Chandpur. Like the Jamuna and the Ganges, the Padma is also highly dynamic. The river shows braided and straight patterns through intermediate meandering state, both spatially and temporarily. During the last few decades, the Padma River has changed its plan form causing erosion and accretion (**Table 1.17** and **Map 1.21**). The annual maximum erosion rate may exceed 1,000 metre/ year in case of highly erodible bank materials, whereas the maximum erosion rate may be limited within a few meters per year in the case of less erodible bank materials. During the period of 1973-2014, the bank erosion and accretion was 37,296 ha and 14,246 ha respectively.



Map 1.21: Erosion-Accretion along the Padma River 1973-2018

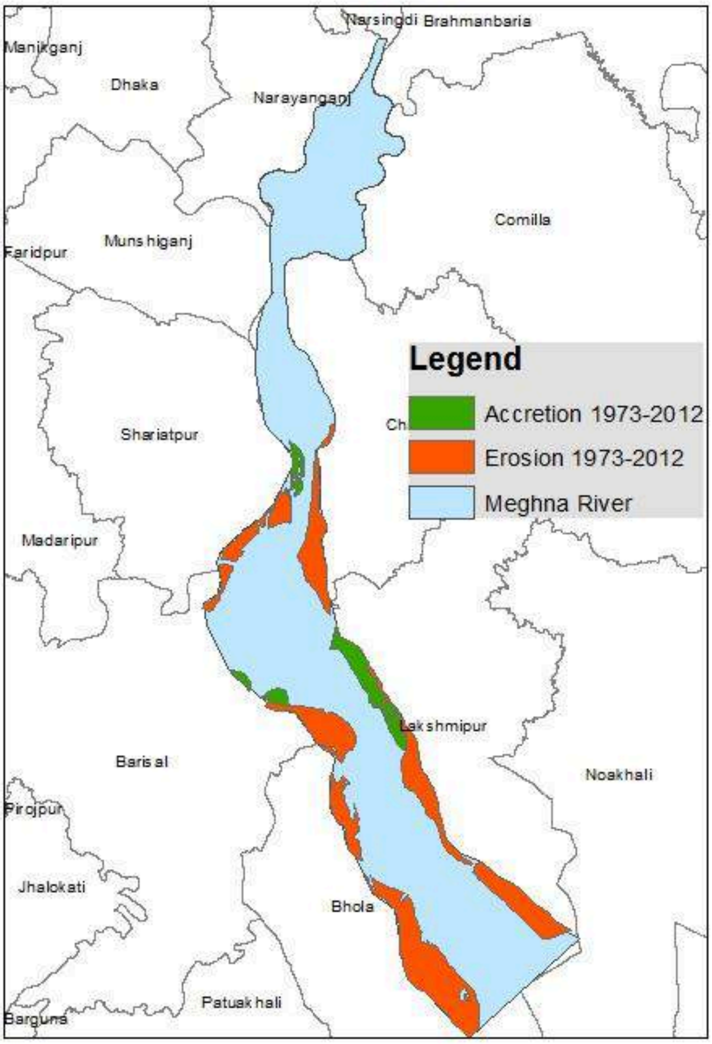
Source: CEGIS, 2014

Table 1.17: Bank Erosion and Accretion along the Padma River 1973 -2018

District	Eroded area (ha)	Accreted area (ha)
Dhaka	2564	15
Faridpur	8763	4525
Madaripur	2592	3107
Manikganj	7139	36
Munshiganj	5971	29
Rajbari	640	55
Shariatpur	9627	6478
Grand Total	**37296**	**14246**

Source: CEGIS, 2018

The Meghna River: Originating from Surma-Kushiyara river system, the Meghna River flows through the eastern part of Bangladesh and discharges into the Bay of Bengal. The part of the river up to the confluence with the Padma River is known as Upper Meghna whereas the remaining part is known as the Lower Meghna. The Upper Meghna is an important river of Bangladesh, being a drainage outlet for the North-Central, Northeast and the Southeast regions. It is one of the rivers, jointly building the Bengal Delta. Upper Meghna River can be better classified as an Anastomosing (multi-threaded low energy) river and its plan form is quite stable. The Upper Meghna River is flowing on the previous bed of the Old Brahmaputra, but with much smaller discharges. Unlike other major rivers, process of erosion and accretion in this river is slow. The Upper Meghna River is declining and this process will continue in future. Moreover, with sea level rise due to climate change, the bed level of the Meghna River will not rise due to less sediment supply from upstream.



Map 1.22: Erosion-Accretion along the Meghna River (1973-2012)

Source: CEGIS, 2014

Table 1.18: Bank Erosion and Accretion along the Lower Meghna River 1973-2012

District	Eroded area (ha)	Accreted area (ha)
Barishal	8,953	10,470
Bhola	4,112	1,234
Chandpur	7,608	4,463
Lakshmipur	3,595	3,702
Shariatpur	1,553	2,396
Total	**25,820**	**22,265**

Source: CEGIS, 2104

On the other hand, the Lower Meghna River is very dynamic. In terms of water flow volume, the lower Meghna River is ranked third in the world. Almost the total flow of the Ganges- the Brahmaputra- the Meghna basins runs through this river and carries a huge amount of sediment. Bank erosion and frequent char development are the main problems of this river (**Map 1.22** and **Table 1.18**). The river erodes its bank when any char develops and creates obstruction to the flow. Thus, riverine chars dominate the morphology of this river.

River Systems and the Economy: In the rural areas, people are mainly dependent on the agricultural land resources for livelihood and agricultural sector is dependent on river system for irrigation and drainage purposes. Bangladesh comprises of 30 agro-ecological zones which have developed based on physiography, soil properties, soil salinity, depth and duration of flooding which are relevant for land use and for the assessment of agricultural potential. A large number of rural people are dependent on rivers for their livelihood as fishermen, boatmen and by other business activities. Moreover, the river system also plays an important role in the urban areas as the water supply and the industrial sector are heavily dependent on the river resources. Navigation is a very important aspect of economic activities of the country.

The process of riverine erosion in the River Systems and Estuaries Hotspot is a major challenge that calls for long term strategic planning and response. Moreover, unplanned industrialization along the banks causes deterioration of water quality and ecosystem affecting the whole environment. In most of the countries, large rivers are well trained and countries are benefiting through using river resources. In Bangladesh this needs to be given careful thought and understanding the river systems is necessary to ensure proper river management.

In northwest region, the Barind Tract and the Atrai basin, a part of the Chalan Beel avulsion and westward shifting of the Brahmaputra River and construction of Teesta Barrage have caused significant changes in this region. Erosion, navigation during dry season, high extraction of groundwater, flood and water scarcity for irrigation are the major problems of this region. Controlling groundwater mining will be a challenging issue especially in the Barind Tract. Controlling the upstream intervention at international and local levels will be another challenge for this region.

In northcentral region, enormous sediment supply from upstream through Jamuna and its avulsion attributes to the off-take sedimentation of major rivers of this region. Maintaining navigation facilities is a major problem for this region as many rivers have become morphologically inactive. Discharged effluence and waste materials from industries have caused deterioration of water quality significantly. It would be challenging to maintain regulated flow, which can facilitate in improving water quality without making the banks of the rivers erosion prone.

The northeast region is a tectonically active basin the central part of which is subsiding. This increased subsidence rate is mainly caused by sediment starvation due to the avulsion of the Brahmaputra River. Moreover, the northern part of the region being most depressed, the rivers showed a tendency of shifting towards the north. Proper sediment management is for the necessity of this region to compensate the subsidence and other effects of climate change and at the same time to maintain the ecosystem. Maintaining proper sediment balance will be very challenging in northeast region as different sectors are related to it.

Table 1.19: Key vulnerabilities of the River Systems and Estuaries Hotspot

Vulnerability from	Current State	Expected Change	Consequences under a BAU scenario
1. Riverine erosion and accretion	By 2013, riverine erosion along the Ganges, the Jamuna, the Padma and theLower Meghna recorded at 179,258 ha while accretion only 75,263 ha	With 13% increase in precipitation projected and annual discharge of rivers over the the Ganges-the Brahmaputra- the Meghna floodplains, riverine erosion could increase	Loss of farmland, crops, homesteads and livelihoods affecting thousands of hectares along major rivers; damage to infrastructure
2. Drought / dry periods and reduced riverine flows	Upstream reduction of flows on transboundary rivers; difficulty of navigation during dry season, high abstraction of groundwater; water scarcity for irrigation	Aggravation of current problems	Loss of agricultural production, water scarcity, disturbed navigation in the Northwest Region, reduced groundwater recharge
3. River avulsion, sedimentation off-take, subsidence	Maintaining navigation facilities, rivers becoming morphologically inactive, banks become erosion prone in wet season	Increasing detrimental effects	Reduced / blocked navigation, deterioration of water quality from discharged effluence and waste materials from industries in the North-Central Region; maintaining sediment balance in the Northeast Region will be difficult
4. Tidal fluctuations and SLR	Lack of fresh water, salinity, groundwater arsenic and subsidence of polders	Loss of land from SLR, increase in salinity, loss of polders to storm surges, water logging, SLR	In the Southwest and South-Central increase in vulnerability and losses in agricultural production, possible negative health impacts from salinity, and out-migration due to loss of livelihoods
5. Flash floods in hill terrain and dry periods	Land degradation, deforestation, land use change, drying up of springs	Increasing soil erosion, sanding of rivers, bank erosion, flash floods, drainage problems	Increasing water scarcity in dry periods; flash floods, loss of life and crops, increased river sedimentation; river navigation increasingly difficult in the Eastern Hill Region

Source: BDP 2100 Technical Team Analysis, GED, 2015

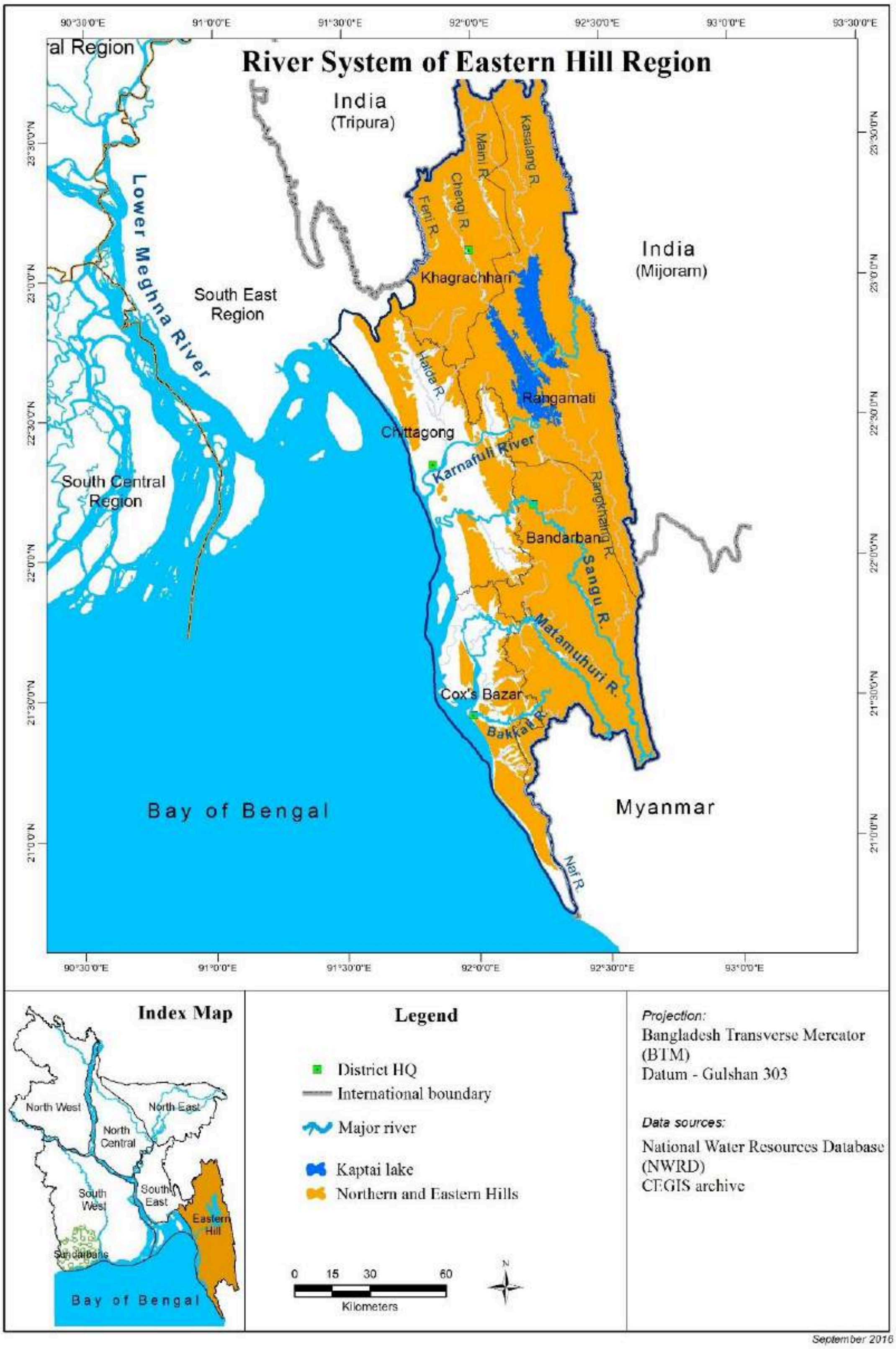
More than half of the southwest and southcentral regions are influenced by tide and salinity intrusions which are common features for several kilometers inland from the Bay of Bengal. This is a complex region of inter-linked ecosystems in the delta of the Ganges-the Brahmaputra Rivers. Delta progradation or delta building process is the most eminent feature of this region which is influenced by tectonic and seismic activities. This active delta building process has impact on accelerating the dynamics of rivers and Meghna Estuary of this region. This region is severely vulnerable in terms of climate change and SLR. Lack of fresh water, salinity, groundwater arsenic and subsidence of polders are the major problems of this region. Maintaining fresh water flow and sediment management in polder areas of the southwest have been identified to be the major challenges.

The topography of the Eastern Hill Region being different from the rest of the country, the rivers of the southeast region are different as well. These rivers did not change the same way as did rivers of the other regions. Rivers in the hilly region mainly follow the terrain of the hills. Most of the rivers of this region are flashy in nature and bank erosion occurs along the banks. Sedimentation due to deforestation and hilly cultivation practices causes navigation problem impeding commercial activities. The main challenge will be to deal with drainage congestion in the southeast region.

In summary, the vulnerabilities affecting the River Systems and Estuaries Hotspots are shown in **Table 1.19** below. To address these concerns, policy attention needs to focus on several areas: preparing a sustainable and adaptable long term plan; optimizing resources, maintaining connectivity of the river system, climate change and upstream intervention both within country and also beyond the international border. Integrated water management is needed to capture multiple benefits, including flood prevention and efficient use of water supply. Future projects involving water harvesting and storage structure with earth embankment spillways, outlet works, and canal facilities might have to be considered. The main challenge will be to link interventions adapting to climate change impacts with the country's strategy for higher growth with minimal impact on the environment.

1.7.5 Chattogram Hill Tracts Hotspot

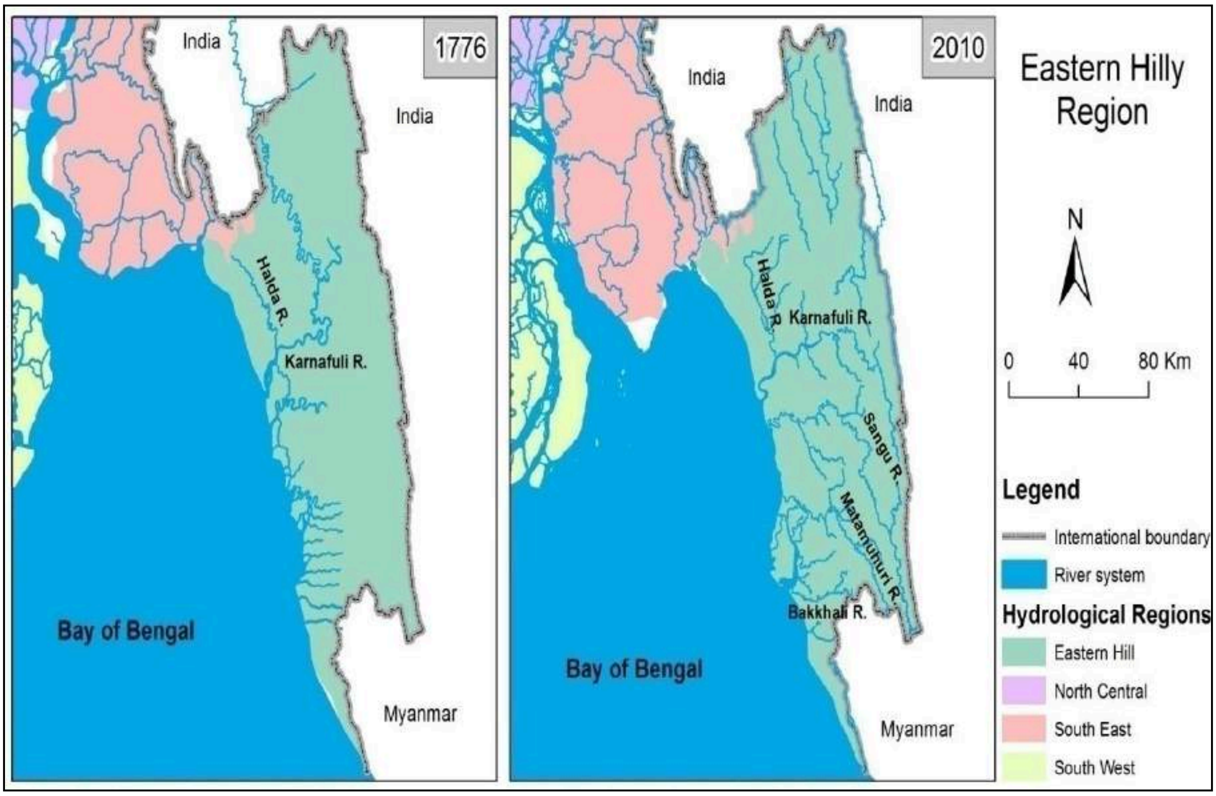
The Chattogram Hill Tracts (CHT) area, covering three districts Rangamati, Khagrachhari and Bandarban, is the only extensive hill area in Bangladesh bordering Myanmar on the southeast, the Indian state of Tripura on the north, Mizoram on the east, and Chattogram district on the west. The hills in the CHT rise steeply, thus looking far more impressive than their height would imply. Most of the ranges have scarps in the west, with cliffs and waterfalls. The CHT contains a man-made lake called Kaptai Lake, which has been created for the Karnafuli Hydro-Electric Project. Loss of forest and vegetation cover and unsustainable farming practices will intensify impacts of increased water runoff, soil erosion, landslides, and drying up of water springs and streams in this hotspot as a result of climate change.



Map 1.23: River Systems Map of Eastern Hill Region

Source: CEGIS, 2016

The region is characterized by a huge network of trellis and dendritic drainage consisting of some major rivers draining into the Bay of Bengal. The major rivers are the Karnafuli, the Sangu, the Matamuhuri and the Feni. The Karnafuli River has several important tributaries: Chengi, Kasalong and Rainkhiang. Presently, the region is separated from Myanmar by the Tuilanpui River. The topography of the region being different from the rest of the country, the rivers of the region do not change the same way as the rivers in the flood plains. Rivers in the hilly region mainly follow the terrain of the hills. The folds of the region's hills being north-south aligned the rivers also flow in north-south direction. The Kasalong, the Mainy and the Chengy rivers originating from the hill slopes, flow due south from the north and drain into the Kaptai Lake. The elevations of these river catchments are above 500 m. The three border-rivers, the Sangu, the Matamuhuri and the Naf, common with Myanmar, are situated in the southernmost extremity of the country.



Map 1.24: Historical Evolution of Rivers in CHT

Source: CEGIS, 2015

The main river of the region, the Karnafuli, originates from the Lushai hills in Mizoram (India). The river is flashy in nature and around 131 km long. Rainkhiang, Kasalong, Thega, Ichamati and Halda are its main tributaries and Saylok and Bakkhali are its major distributaries. Many streamlets are also connected with the rivers. The flow of the river is dependent on the rainfall at the upper hilly catchment areas. The river made the most significant change of its course from Kalurghat downwards. Normally, the river had a western and southwestern course. From the extreme corner of the Chattogram port it moves to the southwest to fall into the Bay of Bengal. The main problem of the river is bank erosion around Rangunia in Chattogram Coastal Plains. The river is now facing increasing sedimentation due to deforestation and hill cultivation practices. The upper reaches of the river are shallow and not navigable round the year.

The transboundary, perennial river Sangu (length 294 km) originates from the Arakan mountain of Myanmar (BDP 2100 Water Resources Baseline Study). The river enters Bangladesh from the Bandarbans district and outfalls into the Bay of Bengal. The river has tidal effect at the downstream and its average width is 120 m at Dohazari. The upstream reaches flow through a hilly region and it has less freedom to change its plan form. It is a flashy and meandering river and some erosion-accretion occurs in this river. The Bakkhali River (length 70 km) originates from the hilly area of the Naikhanchhari Upazilla of Bandarban district, flowing through Ramu and Cox's Bazaar Upazillas and finally outfalls into the Moheshkhali Channel (BDP 2100 Water Resources Baseline Study). In the downstream reach, its average width is 130 m. The Bakkhali, being a flashy river in nature, shows some common features such as flash floods and floodplain inundations. Erosion and accretion occurs in this river on a very small scale. Recently, the rate of erosion was seen to be decreasing, which could be the effect of dams on this river. The Matamuhuri River (length 146 km) is a transboundary river originating from the Lushai hills on the boundary of Bangladesh and Myanmar at Alikadam Upazilla of the Bandarban District (BDP 2100 Water Resources Baseline Study). The river has an average width of 154 m, bifurcates into two channels, which have tidal effects, and falls into the Maheshkhali Channel. Tributaries of the Matamuhuri River are Bamu Khal, Lama Chara and Popa Chara. A number of rubber dams have been constructed on this river which may have affected the river morphology. The Matamuhri also has flash floods and floodplain inundations, and steep slopes from the hilly regions. In general, most of the rivers of this region are flashy in nature, and erosion occurs along the banks. Sedimentation due to deforestation and hill cultivation practices causes navigation problems.

Wet evergreen and semi-evergreen forests occur in hilly areas of Bangladesh. Hilly forest extends from Teknaf peninsula, north along the Myanmar border to Chattogram Hills and CHT, and low hills in the district of Habiganj, Moulvibazar and Sylhet. The wet evergreen forests of the CHT are magnificent dense forests that support a diversified and rich biodiversity. The trees in the top canopy attain a height of about 45-60 m (BDP 2100 Ecological Settings Baseline Study). A few semi-evergreen species may occur but they do not affect the evergreen nature of the forests. The floral diversity is rich with epiphytes, orchids, and woody and non-woody climbers, ferns, mosses, aroids and palms particularly in shady moist places. Herbs and grasses are abundant and the undergrowth is a tangle mass of shrubs, bamboo and rattans. About 700 species of flowering plants grow in this forest type (Pasha 2005). Bamboo is abundant throughout the hilly areas and 18 bamboo species have been recorded from Bangladesh. The Semi-evergreen forests in the CHT in more exposed dry areas; trees in the top canopy reach a height of about 25-55 m with evergreen species predominating but having many deciduous species. In winter the semi-evergreen forests are distinguishable from evergreen forests. Over 800 species of flowering plants have been recorded in this forest type (BDP 2100 Ecological Settings Baseline Study).

Jhum cultivation (shifting cultivation) is the most common form of farming practiced by the Ethnic Groups' (11 ethnic groups) people for growing food in the hilly areas (BDP 2100 Socio-Economic Characteristics of Chattogram Hill Tracts Baseline Study). As the fallow period is getting shorter due to population pressure, Jhum is causing denudation of vegetation, loss of top soil and a degraded environment as a whole. However, proponents of Jhum claim that burning of the shrubs during the process of jhum cultivation increases minerals in the top soil. Also, the burning drives away harmful insects and makes the ground warm, thus accelerating the emergence of naturally fallen seeds of forest plants. Notwithstanding the pros and cons, jhum cultivation will remain to meet food security of the hilly areas. In such a situation, modified hill farming systems applying agro forestry are needed to minimize soil disturbance.

Unsustainable farming practices by settled farmers from the lowlands and deforestation has added to the degradation. Erratic rainfall due to climate change and deforestation has made the search for water increasingly difficult for the Ethnic Group population of the CHT, especially for women. As the water bodies diminish, the search for water takes ever longer, and as women and children are assigned the task, they suffer most.

Landslides are becoming a growing hazard, which occur following intense and protracted periods of rain along with removal of top soil and vegetation. Sometimes, landslides are triggered by light rainfall, because people have cut away mud from steep slopes, increasing the likelihood of landslides. Though the rainfall is the main trigger, development and deforestation in the hills also contribute to the growing number of landslides. Nearly half a million people live in areas at high risk of landslides in the hilly region of Bangladesh (BDP 2100 Disaster Management Baseline Study). With a tropical monsoon climate, 90% of rain falls between June and October, often triggering landslides. A landslide early warning system in hilly areas of Bangladesh has potentially saved hundreds of lives in a region where weather stations monitor rainfall and send text messages to warn people of impending landslides hours before the disaster takes place. The text messages are sent to the mobile phones of 10 officials in different government agencies, who can take immediate action and evacuate people from danger areas. The stations also send local rainfall data at regular intervals to an online database so patterns can be analyzed to improve the warning system and flood forecasting.

Table 1.20: Key Vulnerabilities of the Chattogram Hill Tracts Hotspot

Vulnerability from	Current State	Expected Change	Consequences under a BAU scenario
1. Loss of forest and vegetation cover	Increased water runoff, soil erosion, and drying up of water springs and streams as a result of climate change	Increasing sedimentation of Karnaphuli river	Loss of fertile soils, farmland, crops, homesteads and livelihoods; longer treks in search of water (especially for women and children)
2. Flash floods in hilly terrain	Land degradation, deforestation, land use change.	Increasing soil erosion, sanding of rivers, bank erosion in coastal plains, flash floods, drainage problems	Flash floods, loss of life and crops, increased river sedimentation; river navigation increasingly difficult in the Eastern Hill Region

Source: BDP 2100 Technical Team Analysis, GED, 2015

Long term challenge: The major long term challenges are: maintaining forest cover to reduce run off, increase water retention capacity of the soil and vegetation, maintain water sources, springs and waterfalls in the hills, and increase fallow periods in areas of jhum cultivation or alternatively achieve high rates of adoption of agro forestry and environment friendly agricultural practices. Economic development programs have to be specifically focused on the needs of hill peoples and the ethnic groups; governance and administrative structures need to strictly implement land management practices conducive to forest and landscape conservation with mitigation steps (e.g. REDD) positively impacting climate change as well as benefiting local people and stewards of the forests.

1.7.6 Urban Areas Hotspot

The urban population base has expanded rapidly from 9% to nearly 28% between 1974 and 2011, which makes Bangladesh a 'rapidly urbanizing country'. With a population of 42 million in 2011 and increasing on a daily basis due to in-migration from rural areas, the urban area is the most densely populated area in Bangladesh averaging about 1590 people per km^2. Population concentration in urban areas together with climate change induced negative impacts such as increasing SLR, salinity, water logging, prolonged dry periods, intensive rainfall, increased river discharges, receding groundwater table, and contamination of surface waters will compound matters and increase strains and stress on service providers and disaster risk managers in urban centres.

Table 1.21: Urbanization Overview

Census year	Total national population (million)	Growth rate of national population (%)	Total urban population (million)	Level of Urbanization (%)	Decadal increase in urban population (%)	Annual exponential growth rate of urban population (%)
1951	44.17	0.5	1.82	4.33	18.38	1.69
1961	55.22	2.26	2.64	5.19	45.11	3.72
1974	76.37	2.48	6.27	8.87	137.57	6.66
1981	89.91	2.32	13.23	15.18	110.68	10.66
1991	111.45	2.17	20.87	19.63	57.79	4.56
2001	123.1	1.47	28.61	23.1	37.05	3.15
2011	150.4	1.37	42.11	28.4	47.19	4.12

Source: Bangladesh Bureau of Statistics (BBS), 2012

The most significant urban population growth in Bangladesh occurred during the 1961-74 inter-census period; over 6 million people were living in urban areas constituting roughly 8.8% of the total population. Thus the percentage increase of the urban population during these 13 years was striking. That accelerated growth is to a great extent the result of the very recent influx from rural villages. The growth rate of the urban population was 5.4% during 1981-1991. By 2001 the total urban population stood at 28.6 million.[2] In 1974 people living in urban areas accounted for only 8.8% of the population whereas in 2011 this urban population was 28% of total population.

The annual exponential growth rate of urban population is approximately 4% and the level of urbanization is estimated at 28% with a decadal increase in urban population at 47%. As a result of this rapid urban growth, Bangladesh's urban areas have the fastest growing number of people living in slums. For example, the annual growth rate of slums in Dhaka is approximately 7%.

[2] BBS, Household Income and Expenditure Survey 2010; World Bank WDI, 2015

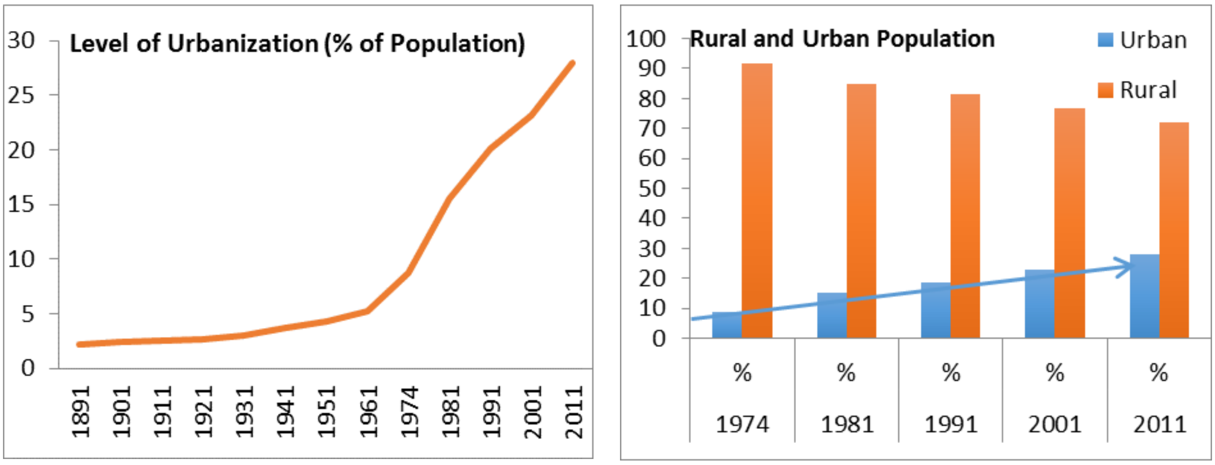


Figure 1.3: Level of Urbanization and Rural - Urban Population Trends

Source: **BBS, 2012**

The push factors driving people from rural to urban areas are the socio-economic, demographic and cultural issues, which include unemployment, poverty, cyclones, floods, sea level rise, droughts, river erosion, social discrimination and disputes at the district level, the pattern of migration also shows a net outmigration from several districts to the urban centers of several prosperous districts, especially Dhaka. Thus, evidence shows that the population of Barishal, Jhalokathi, Pirojpur, Khulna and Bagerhat districts have actually declined between 2001 and 2011 due to out-migration. In an environment of a fairly robustly growing population of Bangladesh (1.3% per year between 2001 and 2011), the combined population of the 9 lower Delta region districts has actually declined.

This may be attributed to loss of livelihoods from cyclonic damage, salinity and sea level rise pushing people into out-migration to escape the miseries and uncertainties of climate change and natural disasters. 29% of Barishal division's arable land was classified as "salt-affected" in 2010, up from 20% in 1973. Rising sea levels have contributed to the trend, aggravating the effects of intensive agriculture. Furthermore, cyclones Sidr (2007) and Aila (2009) destroyed embankments and left coastal zone submerged under saltwater for months.

The pull factors attracting people to urban areas include the concentration of resources, employment opportunities, better living and educational facilities, etc. in the urban areas. For example, according to World Bank assessment, approximately 80% of the garments industry in Bangladesh, accounting for the overwhelming majority of the country's exports, is located in Dhaka city. Between 2040 and 2050, the country's population is projected to become predominantly urban. The rural-urban migration is putting stress on urban resources; overcrowding in urban areas –particularly in city slums – and the absence of sanitation and sewerage systems cause waterborne and airborne diseases to become prevalent. High population density in urban centres is, hence, a key issue that requires urgent attention. Urban sprawl, settlements and development in challenging and hazardous areas is increasing such as in high flood risk areas, riverbeds, coastal flood plains, cyclone and storm surge risk areas, and eroding areas along the rivers and coasts. Informal growth causes cities and settlements to grow in a haphazard way. Its magnitude brings problems in supplying basic services, employment, transport and waste disposal, especially for slum dwellers and the urban poor. Especially, Dhaka has been growing at an enormous rate. From 1991-2001 the population increased by 2 million and from 2001-2011 by 9 million. These have resulted in rapid urban growth. The area of the city expanded from 510 km^2 in 1981 to 1,528 km^2 in 2011. The city is growing denser at a rapid pace and low-lying wetlands are converted into urbanized settlement. Thus, agriculture, wetlands and flood zones have disappeared. Growing pace of urbanization as well as increased population is putting pressure on the already stressed water supply and sanitation systems. Due to further lowering of groundwater (GW) levels and seasonal variation, the shallow tube wells cannot yield water especially in dry season, causing a serious threat. Adjacent rivers are heavily polluted from municipal and industrial sources, and may further deteriorate and clean ups are required.

There is inadequate infrastructure and institutions for dealing with faecal sludge from households and commercial institutions. Sustainable groundwater abstraction, allocation of scarce water resources, restoration of water quality, wastewater management, treatment of effluents – all these issues present an enormous challenge to make urban areas safe and livable. The effluent discharges from the washing, dyeing, finishing (WDF) factories, in particular, are heavily polluted with high levels of dissolved solids and chemicals. Estimates of the number of factories with Effluent Treatment Plants (ETPs) vary from 40 to 80% although it is widely acknowledged that many of the installed plants are poorly designed or not operated in an appropriate and responsible manner. Water demand for most of the textile manufacturing processing and dying industries is extensive. The high demand can put pressure on domestic consumption of water supply by DWASA. The private deep tube wells (DTW) abstraction in Dhaka (both by industries, communities and households) represents a substantial percentage of the total groundwater abstraction.

Apart from textile industries, the leather industry is of significance to the urban water cycle; there are reportedly around 155 tanneries operating in Bangladesh. Over 90% of the tanneries were located in the Hazaribagh area in Dhaka in a highly congested area of less than 30 ha of land. Now all of them have been shifted to Savar, Dhaka. It is estimated that approximately 40 m^3 of water are required to process a tonne of wet salted hides. For comparison, modern processes utilized in Europe are able to reduce the water use to 20 m^3 or less. In addition to the water use, more than 450 kg of chemicals are used in the process. As only a fraction of the chemicals are retained in and on the leather, the majority is discharged to the environment in various forms including wastewater discharges. The total volume of effluent discharged from tanneries is estimated at 20,000 m^3 per day, which is in line with the capacity of the new Centralized Effluent Treatment Plant (CETP) currently being constructed in Savar. The industry yet contributes significantly to poor river water quality and the associated environmental and health impacts.

Domestic, industrial and agricultural pollution put surface water under increasing strain for maintaining drinking water quality. Especially in the direct vicinity of Dhaka and Chattogram rivers suffer from deteriorating qualities. Overall, surface water quality in Bangladesh's rivers is deteriorating. Untreated sewage and sullage water often ends up in the storm water drainage system. Due to polluting industries, poor sewers and waste collection systems and the rapid (informal growth), environmental pollution is increasing. Not only groundwater and streets get polluted; there is also air and noise pollution. Due to lack of wastewater treatment and poor drainage system there is water logging as black water is not always collected in a closed system but ends up directly and untreated in the surface water.

Table 1.22: Pollution Overview in Hotspots

Pollution Type	Hotspots
Air Pollution	Major cities such as Dhaka, Chattogram, Khulna, Sylhet, Rajshahi, Barishal, Gazipur and Narayanganj
Water Pollution	Major rivers such as Padma, Ganga, Jamuna and Meghna; also rivers around the major cities Rivers around Dhaka and Narayanganj – Buriganga, Shitalakhya, Turag, Balu Rivers near Chattogram city – Karnafuli, Halda Rivers besides Barishal city – Kirtonnekhola River besides Sylhet city – Surma Rivers besides Khulna city – Moyuri , Rupsa, Bhoirab Rivers across the Sundarbans and Mongla Port – Rupsa and Passur
Soil Pollution	Ship breaking waste contaminated area – Chattogram coast Industrial polluted area – Dhaka, Gazipur, Narsinghdi, Narayangonj
Waste Management	Major cities: Dhaka, Chattogram, Khulna, Barishal, Sylhet, Gazipur, Narayanganj
Noise	Major cities

Source: BDP 2100 Technical Team Analysis, GED, 2015

Rapid and uncontrolled urbanization has caused the development of formal urban extensions and informal urban fringe development within naturally vulnerable locations such as floodplains, wetlands and other low-lying areas. Additionally, erosion from areas under development produces sedimentation, which obstructs (natural) drainage capacities and development in floodplains limits natural floodwater storage. Under a 1-meter sea level rise scenario, the inundated area (808 km^2 or 0.58%) would be greatest in Khulna while the temporarily inundated area (20,089 km^2 or 14%) would be greatest in Dhaka. Dhaka's population would face the highest risks.

Long term challenges for urban area hotspot from climate change are: sea level rise causing rivers backing up and blocking receding waters from inundated areas in the dry season which creates risk of water logging; land reclamation by filling up natural wetlands and water bodies thus reducing water absorption, storage and flood water holding basins in and around urban areas; sinking groundwater table because of intensive groundwater abstraction leading to insufficient supply of freshwater for growing population in urban areas in dry periods; increasing precipitation with intense and extreme rainfall/storm events and river discharge creating flash floods in urban areas; increasing effluents and pollution of land and water bodies leading to contamination of ground and surface water and sources of urban areas; and increasing strain and stress of city services and disaster risk management institutions, which will be unable to cope with ever growing in-migration of rural population into urban areas, increasing water borne diseases, flash flood disasters, and a breakdown of infrastructure and communications. Addressing these complex challenges in urban areas require concerted and well planned investments in infrastructure and administrative reforms to tackle urban planning, settlements and a long term plan to cope with in-migration into urban areas from rural villages. The urban water supply issues are discussed in depth in **Chapter 10**.

In summary, the vulnerabilities affecting urban areas hotspots are:

Table 1.23: Key vulnerabilities of the Urban Areas Hotspot

Vulnerability from	Current State	Expected Change	Consequences under a BAU scenario
1. Urban sprawl, unplanned settlements and development	Settlements in hazardous areas such as high flood risk areas, riverbeds, coastal flood plains, cyclone and storm surge risk areas, and eroding areas along the rivers and coasts; slum growth in Dhaka City at 7% per annum	increasing risk of floods in inner city areas; breakdown of basic services – water supply, sanitation, waste disposal; increase in water borne diseases; contamination of surface waters; reduced re-charging of groundwater sources	Loss of life and property; rescue and relief efforts increasingly hampered and difficult; vulnerable and poor in slums will suffer most
2. Lowering of groundwater levels	Less freshwater available for industrial and domestic consumption; drying up of shallow tubewells in dry season	Increasing water shortages	Decline of industrial output; social unrest due to water shortages; water borne diseases due to use of contaminated water for drinking
3. Untreated sullage / faecal sludge and industrial effluents	Surface / groundwater contamination from dissolved solids and chemicals	Increasing pollution of surface water and groundwater sources	Environmental and health hazards for all sections of the urban population; agricultural output / horticultural products grown close to urban areas irrigated with contaminated surface and groundwater
4. Air and noise pollution	Increasing traffic and traffic jams; increasing emissions and noise pollution	Further increase in traffic, noise and emissions	Increase in respiratory illnesses; loss of time sitting in log jams; decline in economic productivity and increasing health costs
5. Sea level rise and increasing precipitation	Higher tides and blocking of receding monsoonal rains (e.g. Chattogram)	Risk of permanent inundation; increasing flood risks; breakdown of disaster-risk management structures	Loss of life and property; reduction in economic output and loss of GDP

Source: BDP 2100 Technical Team Analysis, 2015

1.8 Economic Impacts of Climate Change

1.8.1 Aggregative Economic Costs

Climate change and its ramifications are central to the vision of sustained development of the Bangladesh Delta. It raises critical issues for long term planning in addressing resource constraints and gaps across regions and across time. According to Nicholas Stern (Stern Review, 2007), climate change presents a unique challenge for economics: it is the greatest and widest-ranging market failure ever seen.[3] The science of climate change means that it is a very different form of externality from the types commonly analyzed in economics. Climate change has special features that, together, pose particular challenges for the standard theory of externalities owing to the following: (a) climate change is an externality that is global in both its causes and consequences;

[3] Stern, N. 2006. Stern Review: The Economics of Climate Change. Government of UK. London

(b) the impacts of climate change are persistent and develop over time; once in the atmosphere, some GHGs stay there for hundreds of years; (c) the uncertainties are considerable, about size, type, and timing of impacts; so the framework of analyses used must be able to handle risk and uncertainty; and (d) the impacts are likely to have a significant effect on the global economy if action is not taken to address climate change.

Economists describe human-induced (anthropogenic) climate change as an "externality", with largely negative implications for economies and societies. Economic losses from climate change have to be posited against costs of adaptation or mitigation. The Stern Review finds convincingly that the costs of adaptation and mitigation are way below the estimated GDP losses and other human costs associated with climate change. At this point there may not be a clear idea of what it would cost to do a proactive adaptation and mitigation programme. A rough estimate of the kind of costs involved in adaptation and mitigation can be gathered from a South Asian study (ADB, 2014). Also, the Bangladesh Climate Change Strategy and Action Plan (BCCSAP, 2009) provides a list of programmes that need to be undertaken. **Table 1.24** presents annual average cost between 2010 and 2050 and the range of estimates within the 90% confidence interval, both in terms of absolute monetary values and as a percentage of GDP.

Table 1.24: Annual Average Climate Change Adaptation Cost for South Asia (2010 - 2050)

Policy Scenario	Adaptation Target	$ Billion		GDP (%)	
		Annual Average Cost	Range	Annual Average Cost	Range
BAU_1	2100 worst case (6.9°C, 1.1 m SLR)	110.9	51.2-198.0	1.32	0.64-2.29
BAU_2	2100 (4.5°C, 0.70 m SLR)	72.6	33.1-127.8	0.86	0.42-1.46
BAU_3	2050 (2.5°C, 0.30 m) SLR)	40.2	18.3-71.5	0.48	0.23-0.81
$C\text{-}C_1$	2100 (2.5°C, 0.55 m SLR)	40.0	18.8-71.4	0.48	0.24-0.82
$C\text{-}C_2$	2050 (1.9°C, 0.30 m SLR)	31.0	14.2-54.5	0.36	0.18-0.62

BAU= business as usual, C-C=Copenhagen-Canoun, GDP=gross domestic product, SLR=sea level rise

Source: ADB: Assessing the Costs of Climate Change and Adaptation in South Asia, 2014

To summarize, climate change impacts are aggravatingly increasing year-on-year; under BAU-1 scenario, which refers to a 6.9°C temperature rise and a 1.1 meter sea level rise by 2100 (worst case scenario), the cost of damage from sea level rise, drought and dry periods, increasing night temperatures, and extreme events such as intensive precipitation, extremely high wind speeds during cyclones, and storm surges could rise upto 2.0% of GDP per annum taking in account climate uncertainties. To avoid BAU, at the COP21 meeting in Paris in December 2015, the global community committed to strong actions to reduce greenhouse gas emissions and cap global warming to 2°C. Adapting to a lower temperature under the Copenhagen-Cancun (and now Paris) scenario (C-C-2) by 2050 could bring the cost of adaptation down to US$ 31 billion per annum.

In Bangladesh case, annual GDP loss could range from 1.1% for moderate climate change to 2% of GDP for extreme climate change. Bangladesh, a signatory to the COP21 declaration, is also committed to do its share in restraining GHG emissions and adopting strategies for spread of green energy. With good policies the costs of action to mitigate environmental impacts of climate change need not be prohibitive and would be much smaller, which provides the logical inference for Bangladesh that the benefits of strong, early action on climate change outweigh the costs.

1.8.2 Sectoral Effects

Agriculture: A rise of 1°C–2°C in combination with lower solar radiation causes sterility in the rice spikelet. High temperature reduces yields of high-yielding varieties of aus, aman, and boro rice. Climate change, especially in temperature, humidity, and radiation, increases the incidence of insect pests, diseases, and microorganisms. Simulation studies predict about 17% decline in overall rice production and as high as 61% decline in wheat production compared with the baseline situation. The highest impact would be on wheat followed by rice (aus variety). By 2050, this could lead to a reduction in 4.5 million tonnes of rice output at the 2002 level of production. Of the three varieties of rice grown in Bangladesh, aus rice seems to be the most vulnerable. Simulations using a Canadian climate model, projecting existing cropping patterns into the future, a temperature increase of 4°C would cause significant decrease in production: some 28% for rice and 68% for wheat. An apparent fertilization effect due to doubling of atmospheric concentration of CO_2 may result in an overall 20% increase in rice production; however, a 60% moisture stress on top of other effects might cause a decline in boro yield as high as 32%. It is feared that moisture stress would be more intense during the dry season, which might force farmers to reduce the area under boro cultivation. The associated shortfall in food grain production would severely threaten food security.

Under a moderate climate change scenario the crop loss due to salinity intrusion could be about 0.2 million tonnes. The loss of production due to such effects may be higher than that under floods. Bangladesh is projected to be vulnerable to increasing temperature and CO_2 level, which could result in a decline in rice yield of as much as 23% by 2080. Simulations show that under the BAU scenario, due to the reduction in yield, paddy production would fall by 1.60% in 2050 and 5.05% in 2100. The decline in paddy yield due to climate change will bring a negative impact on real GDP of Bangladesh by 0.67% in 2050 and 0.93% in 2100 under the BAU scenario. Given the high prevalence of poverty, food security in the country is closely linked to “rice security”. A fall in rice production would increase its price, which would then place upward pressure on the overall consumer price index (CPI) of the economy (i.e. resulting in a decrease in household real consumption). This would put additional pressure on the government in ensuring the country’s long term food security.

Health: In Bangladesh, additional morbidity per year from dengue due to climate change by 2090 under the B1 scenario could reach 23,876 persons and dengue fatalities 314, and higher under the other two scenarios. The number of cases would be slightly higher during the monsoon months than in winter. The annual morbidity from malaria by 2090 could increase to 440,000 persons and fatalities could reach 2,525 with the A2 scenario though less under the other scenarios. Water-borne diseases, such as diarrhea and dysentery, and vector-borne diseases, such as malaria and dengue, are climate sensitive. Climatic factors like temperature and precipitation are considered to be the key determinants of the distribution of many disease-carrying vectors.

Sea level rise and permanent inundation: At 1m SLR a significant part of dryland in Bangladesh will be permanently inundated; the fall in production in all sectors in the economy due to the land quantity shock would lead to a fall in real GDP.

Impact on infrastructure: Climate change and the resultant floods and cyclones will have a significant impact on infrastructure in Bangladesh. In the absence of any exact estimates of the projected loss on infrastructure, it is assumed in the CGE model used in the projections underlying the macroeconomic framework in Chapter 5that due to the impact of climate change, the capital stock in the construction sector would be depleted by 0.05% annually until 2100. Simulation shows that the infrastructure shock would have a negative impact on all sectors in the economy. In general, larger impacts would be observed in the industrial and services sectors and the magnitude of these negative effects would intensify beyond the end of the century. A negative shock on infrastructure as a result of climate change would have serious negative impacts on the overall economy of Bangladesh. The sectors closely linked to the construction sector, such as forestry, cement, metals, and mining, would experience large falls in production. Real GDP would continue to fall in 2030 and in 2100. Currently, the poor status of infrastructural development is already a serious binding constraint to realizing growth targets.

Energy: Every 1% of GDP growth is estimated to lead to a growth of 1.4% in electricity demand in a typical developing country (Ahmad and Suphachalasai 2014). For a 5%–6% typical annual economic growth rate, this would imply a need for close to 7%–8% growth in electricity supply. Per capita power generation is about 433 kilowatt hours (kWh) (as of 2015). Close to 40% of the population do not have access to gas and electricity (BDP 2100 Socio-Economic and Demographic Condition Baseline Study). Projected climate change can affect both energy generation (especially hydropower and thermal) and energy demand during hot summer seasons (especially during peak hours). Further, regular cyclones and floods cause power supply failures and infrastructure damages. Energy demand for rural irrigation is an important component in Bangladesh. An increase in drought conditions can have severe impacts on energy demand, as pumping load rises with falling water tables. Currently, the energy demand–supply gap worsens during irrigation periods, when the system is already suffering from "load shedding". This can produce a negative feedback loop where poor farmers, who are economically hit hard due to both the reduced harvest and energy supply shortages. Climate-induced energy demand for space heating or cooling depends mostly on already existing air- conditioning or heating infrastructure. With 70% of the population rurally based, the quantifiable impact on energy demand may be less than in other countries. However, this means that living conditions of poor people may worsen, as they may have to tolerate excessive heat or cold due to climate change as supply will lag behind.

Forest and other ecosystems: Forests provide materials like timber, pulp, pole, fuel wood, food, and medicine; habitat for wildlife; and a primary base for biodiversity. They also provide oxygen, control or reduce the intensity of the cyclones and tidal surges in the coastal zone of Bangladesh, and influence rainfall and water yield in the river systems. Of the total area of Bangladesh, agricultural land makes up 65% of its geographic surface, forest lands (2.52 million ha) account for almost 17%, and urban areas are 8% (BDP 2010 Forest and Biodiversity Baseline Study). Water and other land uses account for the remaining 10%. Many of the anticipated adverse effects of climate change, such as SLR, higher temperatures, and an increase in cyclone intensity, will damage the forest resources of the country, put pressure on many climate-sensitive species, and cause increased erosion and deterioration of soil quality in many upland forested areas. The world's largest mangrove forest, the Sundarbans, is extremely vulnerable to climate change. SLR will increase saltwater intrusion and negatively affect the forest. Loucks et al. (2010) predict a 96% decline in tiger habitat in Bangladesh's Sundarbans mangroves with a 28 cm sea level rise if sedimentation does not increase surface elevations. Considering that the salinity regime inside the forest will significantly change as a consequence of climate change, it has been argued that increased salinity would have discernible adverse impacts on forest regeneration and succession (Khan et al. 2008).

1.9 Concluding Remarks

A summary of the sectoral impacts is provided in **Table 1.25**. The evidence on aggregative and sectoral losses makes clear that Bangladesh faces serious climate change challenges that have serious welfare implications if unaddressed. These implications partly related to the quality of life by degrading the environment and damaging the ecological balance. But they also concern reduction of welfare from adverse consequences for loss of production, assets and livelihoods. The nature and origins of the possible adverse consequences have been discussed in this Chapter. The quantitative effects of climate change for long term socio-economic outcomes measured in terms of GDP growth, employment and poverty are discussed in detail in **Chapter 5** in the context of the various Delta scenarios and policy options. A more detailed description of the socio-economic characteristics of the Delta is provided in the next chapter.

Table 1.25: Possible Sectoral Impacts of Climate Change

Sector / Asset	Climate Change	Impact	Possible Consequences under BAU scenario
1. Agriculture	Rise in temperature of 1°C–2°C in combination with lower solar radiation	sterility in the rice spikelet; reduces yields of high-yielding varieties of aus, aman, and boro rice; incidence of insect pests, diseases, and microorganisms	about 17% decline in overall rice production and as high as 61% decline in wheat production compared with the baseline; By 2050, a reduction in 4.5 million tonnes of rice output at the 2002 level of production.
	Temperature increase of 4°C	apparent fertilization effect due to doubling of atmospheric concentration of CO_2 may result in an overall 20% increase in rice production; however, a 60% moisture stress on top of other effects might cause a decline in boro yield as high as 32%.	decrease in production by some 28% for rice and 68% for wheat; decline in paddy production by 1.60% in 2050 and 5.05% in 2100; negative impact on real GDP by 0.67% in 2050 and 0.93% in 2100
	Salinity intrusion under moderate SLR	Crop loss	about 0.2 million tonnes or more
2. Health	Temperature and precipitation increase	Increasing dengue and malaria risk; water-borne diseases like diarrhea and dysentery; congestion in urban areas; increase in emissions	By 2090 increase in Dengue cases by 24,000 with fatalities 314; malaria cases by 440,000 and fatalities could reach over 2,500; respiratory illnesses; and increasing health costs
3. Land	1 m sea level rise; Increased precipitation	Inundation permanent and seasonal	17-21% area loss (up to 30,000 km^2 inundated; additional 16% land

Sector / Asset	Climate Change	Impact	Possible Consequences under BAU scenario
			inundated due to increased rainfall (5,500 km^2)
4. Infrastructure	Floods; cyclones; sea level rise	Permanent and reparable damage	capital stock depletion in the construction sector by 0.05% annually until 2100; sectors closely related to construction would experience larger falls in real GDP
5. Energy	Cyclones, floods, dry periods	Affecting hydropower and thermal generation; energy infrastructure damage; loss of energy in irrigation sub-sector	Increased load shedding; increase in energy demand-supply gap; fall of production; GDP losses in agriculture and industry
6. Forest and other ecosystems	Sea level rise; increase in temperatures; salt water intrusion	Impact on species composition and extinction	40% mangrove loss; 96% decline in tiger habitat
7. GDP	N/A	Deacrease in GDP	By 2050, annual GDP losses are projected to be 2.0% per annum

Source: BDP 2100 Technical Team Analysis, GED, 2015

Chapter 2
Socio-economic Characteristics of the Bangladesh Delta

Chapter 2: Socio-economic Characteristics of the Bangladesh Delta

2.1 Background

As noted in Chapter 1, despite considerable development progress, Bangladesh faces substantial risks and vulnerabilities that are intimately linked with the geography of the country. While the Delta widely encompasses much of Bangladesh and the risks to natural disasters extend to most of the country, the magnitude of the risks and associated vulnerabilities vary significantly by regions. The hotspot classification also showed that the nature of these risks and vulnerabilities are multiple and affect different districts differently. There are variations even within districts at the sub-district (Upazilla) level. In order to understand how nature and human beings interact and how livelihood and welfare are impacted by geography and climate change, it is important look at the socio-economic characteristics of the different delta areas. This analysis has provided useful background for developing the BDP 2100.

The guiding principle of the strategy would be to develop a baseline of socio-economic characteristics of the Delta using the available information, understand the specifics of the downside risks and vulnerabilities posed by geography and climate change in relation to the baseline, and develop strategies, policies, programmes and institutions that provide necessary support to minimizing these risks and vulnerabilities. With limited financial and administrative capacities, interventions that make the best contribution in terms of improving the welfare of the population and safeguarding the population from the downside risks of the Delta will need to be given priority. So, a good understanding of the population's welfare based on observed socio-economic characteristics is an essential pre-requisite to developing sound delta strategies.

This Chapter provides in detail the major socio-economic characteristics of the Delta region. Section 2 provides a description of the data and methodology used for the analysis. Summary features at the aggregate hotspot level are discussed in section 3. Against the main results of this aggregative analysis, section 4 provides a deeper district level and sub-district level analysis of specific risks and vulnerabilities and how they impact on human welfare measured in terms of poverty and income. The section develops a simple analytical framework for classifying districts by the intensity of climate change and natural hazard risks and discusses how these are correlated to poverty and income. Section 5 deepens this analysis further by picking up specific experiences of districts that have adapted to the various natural hazards to secure better poverty and income outcomes.

2.2 Data and Methodology

Data: Proper understanding of the risks and vulnerabilities requires zeroing in to as much specificity as possible based on available data. Fortunately, the Bangladesh Bureau of Statistics (BBS) conducts detailed periodic reviews of different socio-economic aspects of Bangladesh. These data are based on special-purpose surveys and provide a wealth of information about how people are faring in terms of different socioeconomic indicators. These include population, household size, literacy, education, income, employment and poverty. The surveys are at the household level and cover all the upazillas of Bangladesh. Although the definition of the administrative divisions including the number of upazillas have changed over time and the measurement of income is fraught with estimation problems, the data nevertheless provide major insights on the welfare of the Bangladeshi population over time and spatially. The population and poverty data are particularly telling and constitute important indicators about how the country is adjusting to various opportunities and risks related to geography and climate change.

The analysis of the Chapter is based on the unit record data of four major sample surveys conducted by BBS. They include: Household Income and Expenditure Survey (HIES) 2000 and 2010; and Labour Force Surveys (LFS) 2000 and 2013. The choice of years of the surveys depended on two considerations- (i) to track at least the decadal trends beginning in 2000 and (ii) use the most recent information where available. In additional to these surveys, information of Population Census 2001 and 2011 are also used. Brief descriptions of the four sample surveys are provided below.

Box 2.1: Description of Sample Surveys

Household Income and Expenditure Survey (HIES) is one of the core activities of the BBS. It contains a broad collection of socio-economic information at the household level. The HIES is composed of 9 sections. This survey provides valuable data on household income, expenditure, consumption, savings, housing condition, education, employment, health and sanitation, water supply and electricity, etc. The survey data can also be used for compilation of national accounts of the household sectors, analysis of poverty circumstances and other information on household related characteristics. It also provides the weights for computation of consumer price index (CPI). It has become an important data source for the preparation of Five Year Plans (FYP). It is also used for monitoring the progress of poverty reduction and the Millennium Development Goals (MDGs) indicators. HIES has been conducted at five year intervals. The most recent HIES in Bangladesh are HIES 2000, HIES 2005 and HIES 2010.

Labour Force Survey (LFS) is a comprehensive data based on current activity status of the population aged 15 years and over. It has been conducted to: estimate the size of the labour force (economically active population) by age, gender, education and locality; estimate the number of employed persons by occupation, industry and status of employment; assess the demographic and socio-economic characteristics of current labour force; assess the average hours worked, earnings, etc. of employed persons; assess the extent of unemployment/underemployment; and estimate the number of educated unemployed by age, gender and locality. LFS has been conducted on a regular basis with more or less three years interval since 1980. The most recent LFS's in Bangladesh are LFS 2002-03, LFS 2005-06, LFS 2010 and LFS 2013.

Methodology: One of the objectives of the Chapter is to derive the socio-economic characteristics of the six Delta Hotspots using the available survey information. Data contained in the surveys are associated with the highest administrative unit (Divisions) to the third administrative unit (Upazillas/Thanas). Assigning data to the six Delta Hotspots involves extensive mapping exercises using the administrative units of the surveys and definitions/maps of the six Delta Hotspots. Specifically, the steps include:

a) Identifying the lowest administrative units with description and code (i.e. as defined in the respective surveys).
b) Assigning codes to the six Hotspots. These are:
    - The Haor and Flash Flood Areas (Code 06)
    - The Coastal Zone (Code 03)
    - The River Systems and Estuaries (Code 02)
    - The Barind and Drought Prone Areas (Code 04)

- The Urban Areas (Code 01)
- The Chattogram Hill Tracts (Code 05)

c) Recoding all lowest survey administrative units to the six Delta Hotspots codes. The lowest administrative units which are not mapped to the six Delta Hotspots have default code 00 and named as "Relatively Less Hazard Prone Area (RLHP)". STATA software has been used for recoding and socio-economic information generation.

d) The distribution of lowest administrative units according to the six Delta Hotspots for HIES 2010 is provided in **Figure 2.1** as an example.

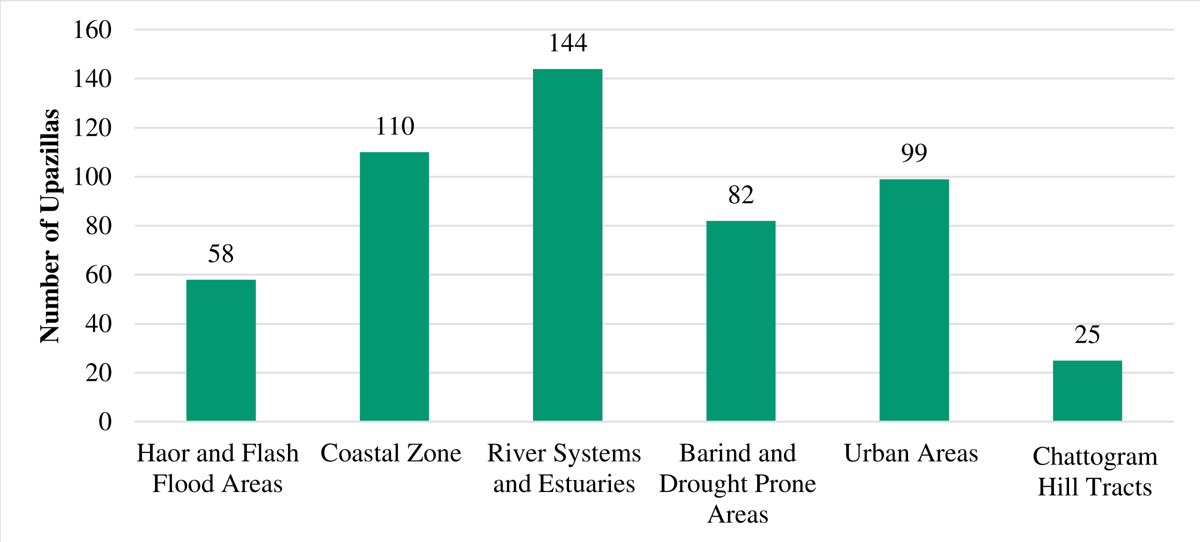


Figure 2.1: Distribution of Upazillas by Hotspots

Source: BDP 2100 Estimates, GED, 2015

Note: In the case of urban areas, the lowest administrative unit considered is Thana.

2.3 Basic Hotspot Indicators

Population distribution: Basic indicators related to area and population are provided in **Table 2.1**. The River Systems and Estuaries constitute the majority share of Bangladesh's population, followed by urban areas. The urban areas have the highest population density. Barind and Drought Prone Areas and River Systems and Estuaries also have high population density with more than 1,000 person per km^2. The Chattogram Hill Tracts (CHT) area has a small share of the country's population and has low population density.

Table 2.1: Basic Indicators - Population and Area

Hotspots	Area (km²)	Share (%)	Population (million) 2001	Share (%)	Density (Per km²) 2001	Population (million) 2011	Share (%)	Density (per km²) 2011
Haor and Flash Flood Areas	16,574	11.2	12.9	9.9	779	15	10	906
Coastal Zone	27,738	18.8	20.4	15.6	735	22.4	15	807
Chattogram Hill Tracts	13,295	9	1.4	1.1	105	1.7	1.1	128
Urban Areas	19,823	13.4	26.2	20.1	1,320	31.5	21	1,588
Barind and Drought Prone Areas	22,848	15.5	20.4	15.6	894	22.8	15.2	999
River Systems & Estuaries	35,204	23.8	37	28.4	1,052	41.4	27.6	1,177
RLHP Areas	12,089	8.2	12.3	9.4	1,016	15	10	1,238
Total	***147,570***	***100***	***130.5***	***100***	***884***	***149.8***	***100***	***1,015***

Source: BDP 2100 Estimates (GED 2015) based on Bangladesh Population Census 2001 and 2011.

An interesting population dynamic is the variable growth of population by hotspots (**Figure 2.2**). Not surprisingly, the urban population has grown the fastest between 2001 and 2011. It grew 70% faster than the national population. Interestingly, the population growth rate in the coastal zone has been almost 50% lower than the national average. Similarly, population in river systems and estuaries and in the Barind and drought prone areas have grown slower than the national average. The areas not mapped to Delta hotspots, because locationally they are relatively less vulnerable to natural disasters than the hotspot regions, has also grown faster than the national average. These population movements suggest that there have been a net out-migration from the relatively more disaster-prone region to the relatively less disaster prone region. This has been an important coping mechanism of the disaster affected population. This result will be explored in greater detail later in the chapter.

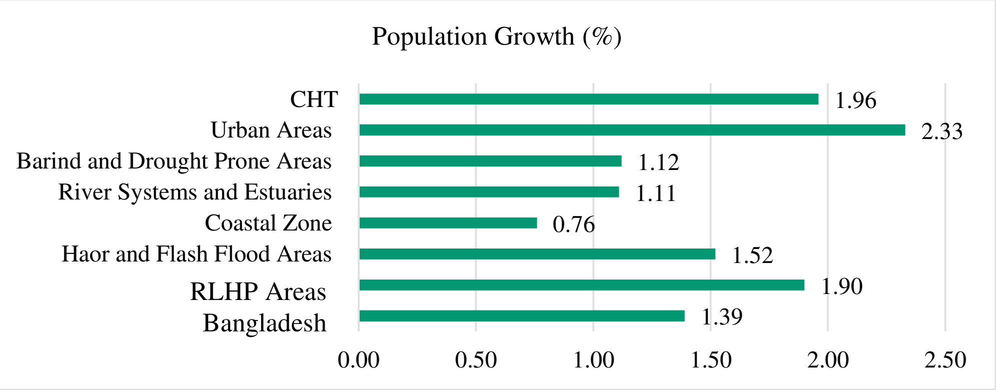


Figure 2.2: Population Growth by Hotspot (2001-2011)

Source: BDP 2100 Estimates (GED 2015) based on Bangladesh Population Census 2001 and 2011.

Literacy: Significant variations are observed for literacy rate – a basic education indicator (see **Figure 2.3**). Urban areas have the highest literacy rates both in 2001 and 2011 compared to all other hotspots. The coastal zone also out-performs other hotspots on literacy rates. Surprisingly, the lowest literacy rate has been found for Haor and Flash Flood Areas in both periods. Even CHT districts outperform the Haor districts in literacy on average.

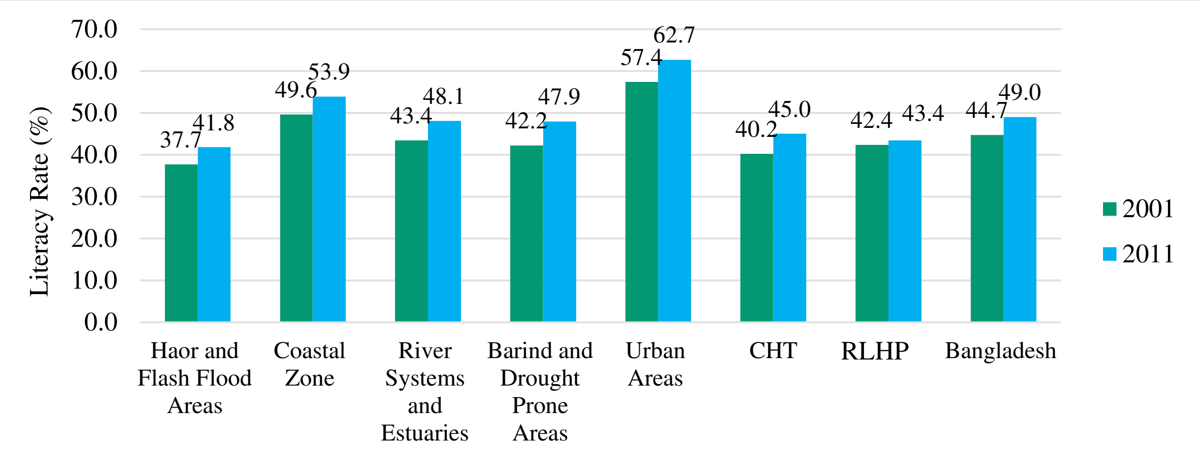


Figure 2.3: Literacy Rates across Hotspots

Source: BDP 2100 Estimates (GED 2015) based on Bangladesh Population Census 2001 and 2011

Housing Condition: Housing condition is an important non-income welfare measure. Two well accepted criteria for assessing the housing condition are the roof and wall materials, which have been summarized across various hotspots of Bangladesh in **Table 2.2** and Error! Reference source not found.. Roof and walls of houses built with brick/cement represents most superior quality followed by houses constructed with corrugated iron sheet (CIS)/brick/wood materials. The lowest quality houses are made of materials such as straw/hay/ bamboo/others.

Housing conditions have improved substantially in Bangladesh between 2000 and 2010. In 2000, only 5.4% roofs of the houses in Bangladesh were made of brick/cement. In 2010, this percentage increased to about 10.4%. Roof of houses constructed with CIS/brick/wood materials ranged between 75% in 2000 and 84% in 2010. However, most significant improvement has been reported for the third or lowest category of roof materials. House roofs built with straw/ hay/ bamboo/ others materials (i.e. lowest quality) have reduced from 19.4% in 2000 to only about 5.8% in 2010.

Table 2.2: Housing Structure - Roof Materials (% of Households)

Sl	Hotspots	2000			2010		
		Brick/ Cement	CIS/Brick/ Wood	Straw/Hay/ Bamboo/Others	Brick/ Cement	CIS/Brick/ Wood	Straw/Hay/ Bamboo/Others
1	Haor and Flash Flood Areas	3.29	74.21	22.5	4.13	88.29	7.59
2	Coastal Zone	4.29	71.45	24.26	7.01	82.02	10.97
3	Chattogram Hill Tracts	5.37	63.4	31.23	1.14	64.45	34.42
4	Urban Areas	13.23	68.56	18.21	29.37	67.69	2.94
5	Barind and Drought Prone Areas	3.12	70.41	26.47	7.18	88.82	4.00
6	River Systems and Estuaries	4.09	86.63	9.28	6.64	91.52	1.84
7	RLHP Areas	9.13	63.72	27.15	8.07	87.27	4.66
8	Bangladesh	5.36	75.27	19.37	10.37	83.88	5.75

Source: BDP 2100 Estimates (GED 2015) based on HIES 2000 and 2010

The changes in roofing condition, however, vary across the Hotspots. Percent of roofs built with brick/cement reduced in 2010 compared to 2000 in only CHT. In all other Hotspots the houses with roofs built with brick/cement have increased in 2010 compared to 2000. Except for the urban areas, percentage roof constructed with CIS/brick/wood materials increased between 2000 and 2010 across other Hotspots. Percentages roof made of the lowest quality materials such as straw/hay/bamboo/others have reduced across all Hotspot.

In 2000, around 14.2% walls of the houses in Bangladesh were made of brick/cement. In 2010, this percentage increased to more than 25%. Percentage of house walls constructed with CIS/ brick/ wood materials increased from 44.3% in 2000 to about 55.2% in 2010. However, most significant improvement has been reported for the third or lowest category of wall materials. House walls built with straw/hay/bamboo/others materials (i.e. lowest quality) have reduced from 41.5% in 2000 to about 19.7% in 2010.

However, similar to the roofing condition, the changes in wall condition vary across the hotspots. Only CHT reported reduction in walls built with brick/cement in 2010 compared to 2000. In all other hotspot the percentages have increased in 2010 compared to 2000. Except for the urban areas and Barind and Drought prone areas, percentage of walls constructed with CIS/brick/wood materials increased between 2000 and 2010 in all other hotspots. Percentages of wall made of the lowest quality materials such as straw/hay/bamboo/others have reduced across all hotspots.

Table 2.3: Housing Structure- Wall Materials (% of Households)

Sl	Hotspots	2000			2010		
		Brick/ Cement	CIS/Brick/ Wood	Straw/Hay/ Bamboo/Others	Brick/ Cement	CIS/Brick/ Wood	Straw/Hay/ Bamboo/Others
1	Haor and Flash Flood Areas	9.88	39.02	51.1	14.78	60.51	24.71
2	Coastal Zone	14.42	48.69	36.89	20.59	61.45	17.96
3	Chattogram Hill Tracts	10.56	21.23	68.21	9.47	31.70	58.82
4	Urban Areas	26.89	35.01	38.1	49.98	33.57	16.45
5	Barind and Drought Prone Areas	13.34	56.86	29.81	24.34	53.04	22.62
6	River Systems and Estuaries	11.42	43.28	45.31	17.31	66.34	16.34
7	RLHP Areas	16.85	37.63	45.52	25.85	57.22	16.93
8	Bangladesh	14.23	44.33	41.45	25.12	55.18	19.70

Source: BDP 2100 Estimates (GED 2015) based on HIES 2000 and 2010

Trends in housing conditions as typified by materials used for roofs and walls during the decade of 2000 suggest improvements for most hotspots in Bangladesh. This finding is in line with the perception that rising income levels in Bangladesh led to the improved housing condition. However, the reductions in the percentage of superior quality houses in hotspots such as CHT are cause of concern and perhaps suggest lack of willingness to invest in quality houses under deteriorating environment.

Water and Sanitation: Access to clean drinking water and sanitation facilities are also important non-income measures of a household's wellbeing. Three types of drinking water sources are reported in the HIES: piped water; tube well and others. Quality of sanitation is also categorized by three types: sanitary/pucca; kutcha and open/others. Household's access to sources of drinking water across various hotspots of Bangladesh is shown in **Table 2.4**, while **Table 2.5** reports sanitation conditions across hotspots.

Dominant source of drinking water in Bangladesh in 2000 was tube well with more than 92% of households using this source. Only 4.3% households had access to piped water and 3.4% households had to use other sources. For the Urban areas, despite the access to pipe water, tube well was their main source of drinking water with more than 75% of the household using this source. Some 17% had access to pipe water.

Although tube well has remained the main source of the drinking water in Bangladesh, the percentage of household with tube well dropped to 85.4% in 2010. Percentage of households with piped water increased to 10.6% in 2010. The others category shows slight increase to 4%. The other categories emerged as important sources for CHT as coverage of tube well reduced. The other category also increased for coastal zone. This may be due to increased salinity in the case of Coastal Zone and lowering of surface water level in the case of CHT (as discussed in **Chapter 1**).

Table 2.4: Sources of Drinking Water (% of Households)

Sl	Hotspots	2000			2010		
		Piped Supply	Tubewells	Others	Piped Supply	Tube well	Others
1	Haor and Flash Flood Areas	2.29	93.65	4.06	3.09	94.36	2.55
2	Coastal Zone	2.53	92.35	5.12	3.68	88.93	7.40
3	Chattogram Hill Tracts	10.74	84.44	4.81	9.96	55.80	34.24
4	Urban Areas	17.42	75.68	6.9	38.12	61.27	0.61
5	Barind and Drought Prone Areas	0.41	97.47	2.12	3.06	96.24	0.71
6	River Systems and Estuaries	2.48	96.29	1.23	4.13	90.95	4.92
7	RLHP Areas	7.61	88.1	4.29	12.24	87.58	0.18
8	Bangladesh	4.26	92.4	3.34	10.62	85.37	4.01

Source: BDP 2100 Estimates (GED 2015) based on HIES 2000 and 2010

Significant improvements happened with respect to sanitation facilities in Bangladesh between 2000 and 2010. Percent of households with sanitary or pucca facilities almost doubled between 2000 and 2010. In 2000, percent of Bangladesh households with sanitary, kutcha and open toilets were 29.3%, 51.3% and 19.4% respectively. The corresponding percentages for 2010 respectively were 51.1%, 44.5% and 4.4% suggesting significant improvement over the decade.

There are important differences in sanitation facilities by hotspots and some of the differences widened between 2000 and 2010. Thus, for example, the sanitation facility deteriorated for Haor and Flash Flood Areas where households with sanitary/pucca toilets dropped to 27.1% in 2010 from 38.3% in 2000. At the same time Haor households with kutcha toilets increased from 48.7% in 2000 to over 64% in 2010. Increase in the percent of households with open toilets in CHT (i.e. from 0% in 2000 to 8.4% in 2010) is a cause of concern. Sanitation facilities in all other hotspots experienced marked improvement in 2010 compared to 2000.

Table 2.5: Use of Different Kinds of Sanitation Facilities (% of Households)

Sl	Hotspots	2000			2010		
		Sanitary/ Pucca	Kutcha	Open/ Others	Sanitary/ Pucca	Kutcha	Open/Others
1	Haor and Flash Flood Areas	38.27	48.66	13.07	27.09	64.28	8.63
2	Coastal Zone	33.43	61.66	4.91	66.02	32.53	1.45
3	Chattogram Hill Tracts	22.35	77.65	0.0	22.36	69.25	8.38
4	Urban Areas	37.28	50.74	11.98	63.80	34.46	1.74
5	Barind and Drought Prone Areas	13.42	41.39	45.19	35.73	56.52	7.76
6	River Systems and Estuaries	30.76	52.71	16.53	56.87	38.24	4.89
7	RLHP Areas	25.53	45.7	28.77	44.27	52.78	2.94
8	Bangladesh	29.27	51.34	19.39	51.06	44.54	4.40

Source: BDP 2100 Estimates (GED 2015) based on HIES 2000 and 2010

Power and Communication: Electricity situation has improved significantly between 2000 and 2010 (**Table 2.6**). Percent of household with electricity connections, which was 30.1% in 2000, increased to over 55% in 2010. More than 80% of urban households had electricity connections in 2010. However, electricity connection is still low for CHT hotspot with 37% coverage, followed by the Haor and Flash Flood Areas with 45% coverage.

Bangladesh has experienced a tremendous expansion in mobile phone coverage between 2000 and 2010. Nationwide, households with cell phone, which was only 1.3% in 2000, jumped to 63.7% in 2010. As expected, the increase in coverage was highest for the urban households (i.e. from 3% in 2000 to 81% in 2010). Households with mobile phone in all other hotspots are also impressive with more than 50% of household coverage.

Table 2.6: Electricity, Internet and Mobile Phone Connections (% of Households)

Sl	Hotspots	2000			2010		
		Electricity	Internet	Mobile Phone	Electricity	Internet	Mobile Phone
1	Haor and Flash Flood Areas	31.11	NA	0.79	45.44	0.42	55.36
2	Coastal Zone	24.46	NA	1.26	49.38	1.02	63.91
3	Chattogram Hill Tracts	49.88	NA	1.79	37.04	0.48	49.42
4	Urban Areas	49.69	NA	2.98	81.36	5.82	81.02
5	Barind and Drought Prone Areas	19.71	NA	0.49	47.22	0.43	55.27
6	River Systems and Estuaries	32.10	NA	1.24	54.97	0.34	64.60
7	RHLP Areas	28.57	NA	1.95	50.94	0.29	59.10
8	Bangladesh	30.10	NA	1.33	55.25	1.38	63.73

Source: BDP 2100 Estimates (GED 2015) based on HIES 2000 and 2010

Occupation: In order to assess the pattern of occupation structure, two types of activities have been considered- agriculture and non-agriculture. Although wider classifications are desirable, it could not be implemented due to problems in definition and coverage between the surveys. **Table 2.7** shows the changing patterns in occupation across hotspots in Bangladesh.

Table 2.7: Structure of Main Occupation (% of Households)

Sl	Hotspots	2000		2010		Period Growth Rate (%)	
		Agriculture	Non-Agriculture	Agriculture	Non-Agriculture	Agriculture	Non-Agriculture
1	Haor and Flash Flood Areas	43.5	56.5	40.7	59.3	-0.63	0.49
2	Coastal Zone	41.1	58.9	32.7	67.3	-2.04	1.43
3	Chattogram Hill Tracts	14.9	85.1	47.9	52.1	22.20	-3.88
4	Urban Areas	28.4	71.6	25.7	74.3	-0.94	0.37
5	Barind and Drought Prone Areas	54.0	46.0	44.6	55.4	-1.74	2.04
6	River Systems and Estuaries	43.7	56.3	36.6	63.4	-1.61	1.25
7	RLHP Areas	49.4	50.6	36.5	63.5	-2.61	2.54
8	Bangladesh	43.5	56.5	36.2	63.8	-1.67	1.28

Source: BDP 2100 Estimates (GED 2015) based on HIES 2000 and 2010

In 2000, more than 43% of households reported agriculture as their main occupation while 57% were engaged in non-agricultural activities. In 2010, 63.8% household reported non-agriculture as their main occupation and only 36.2% of households were engaged in agricultural activity. This trend suggests 16% drop in agriculture as main occupation and 12% increase in non-agricultural occupation. The greater diversification of sources of income has been a major contributor to poverty reduction in Bangladesh.

There are some important differences in occupation sources by hotspots. The urban areas have the most diversified occupation sources with low reliance on agriculture. This is also true for CHT. But there are two major differences. First, urban areas have substantial manufacturing activities, especially the dynamic ready-made garments (RMG) sector. In contrast, the CHT hardly has any organized manufacturing. So, the bulk of non-agricultural activities in CHT are informal services. Secondly, while the dependence of urban areas on agriculture has fallen, it has increased in CHT. Unlike in other parts of Bangladesh, in CHT there has been a reversal in the pattern of occupation with people moving away from informal services to agriculture.

Similarly to urban areas, the occupational reliance on agriculture has fallen in other hotspots as well. The progress has been stronger in the coastal belt compared to other hotspot areas. However, much of the large scale manufacturing and organized services that offer the best paid jobs and self-employment prospects are concentrated in urban areas,

Income: Trends in per capita income are shown in **Table 2.8**. According to HIES data, per capita income has increased by 2.7 times between 2000 and 2010 due to expansion of economic activities and reduced population growth rate, which amounts to an annual average growth of 10.5% in nominal terms. Allowing for the annual inflation rate of 7.5% per year, average per capita real incomes grew by 3% per year in Bangladesh. This is a major factor for the reduction in poverty levels over this period. Except for the CHT and the Haor and Flash Flood Areas, average real income grew substantially in all Delta hotspots and also in the RHF areas. Importantly, the Barind and Drought

Prone Areas hotspot experienced the fastest growth in average real per capita incomes, which explains the fastest reduction in poverty in this hotspot.

Table 2.8: Per Capita Income Pattern (BDT current prices)

Sl	Hotspots	2000 (HIES)	2010 (HIES)	Average Income growth (HIES) (%)	FY2011 (National Accounts)
1	Haor and Flash Flood Areas	12,971.5	22,946.0	5.9	23,148
2	Coastal Zone	11,601.6	30,186.2	11.0	27,238
3	Chattogram Hill Tracts	20,801.9	28,754.3	3.3	30,305
4	Urban Areas	16,579.9	53,822.3	11.3	54,714
5	Barind and Drought Prone Areas	8,026.4	31,305.1	14.6	20,453
6	River Systems and Estuaries	12,400.4	38,383.8	12.0	22,582
7	RLHP Areas	9,297.8	42,481.6	16.4	31,787
8	Bangladesh	13,097.1	35,411.3	10.5	37,859

Source: BDP 2100 Estimates (GED 2015) based on HIES 2000 and 2010; FY2011 District Level GDP

Under-reporting of income by the upper income group is well known. There are other problems of coverage as well. An indication of this mis-reporting problem is provided by the district-level per capita GDP estimates derived from national accounts for FY2011. The HIES income includes transfer payments from foreign remittances that are about 7-8% of GDP. Even so, HIES per capita income inclusive of remittances falls short of per capita income measured in terms of GDP. The distribution by hotspots is also quite different.

Labour Force Participation and Employment: Creating decent employment opportunities for the new entrants into the labour market is a major challenge in Bangladesh. 6^{th} FYP and 7^{th} FYP have further elaborated this challenge by categorizing them into their quantitative and qualitative dimensions. First challenge is to create sufficient employment opportunities for rapidly increasing growing labour force (3% per annum or 1.8 million new jobs per year). Second challenge is to create more jobs in the manufacturing and organized service sectors relative to agriculture and informal economy since research shows that labor productivity and real wages are higher in manufacturing and organized services sectors.

Labour force participation rate has been increasing in Bangladesh – primarily due to two factors – (i) rising share of the working population in total population; (ii) growing participation of female in the labour market (see **Table 2.9**). Total participation has increased from 54.9% in 2000 to over 57% in 2013. The picture is however mixed across the hotspot regions. More specifically, participation rate has increased for Urban areas, Haor and Flash Flood areas, Barind and Drought Prone areas and the RHF areas. However, participation rate has fallen in Coastal Zone, River Systems and Estuaries and CHT. The above trend perhaps captures the migration of working age population due to both push and pull factors.

Female labour force participation experienced an increase of around 10 percentage points over the 13 year period. During the same period, male participation rate experienced slight decline of about 2 percentage points. Female labour force participation increased for all hotspots although the participation rate is more pronounced for the urban areas compared to other hotspots.

Table 2.9: Labour Force Participation Rate (%)

Hotspots	2000			2013		
	Male	Female	Total	Male	Female	Total
Haor and Flash Flood Areas	77.5	19.2	48.4	82.7	31.4	56.5
Coastal Zone	85.1	27.1	56.1	79.7	30.3	54.1
Chattogram Hill Tracts (CHT)	85.2	52.3	68.8	83.9	53.2	68.5
Urban Areas	85.0	16.1	50.5	82.3	42.7	62.3
Barind and Drought Prone Areas	83.7	30.6	57.1	81.8	32.9	57.3
River Systems and Estuaries	85.8	26.8	56.3	80.9	29.6	54.5
RLHP Areas	86.7	25.3	56.0	84.2	34.7	58.9
Bangladesh	84.1	23.9	54.9	81.7	33.7	57.2

Source: BDP 2100 Estimates (GED 2015) based on LFS 2000 and 2013

Trends in employment, unemployment and underemployment have been captured in **Table 2.10**. On the whole, employment has increased substantially economy wide. Open unemployment is low and steady. Importantly, underemployment (less than 35 hours of work per week) has fallen substantially economy wide and across all hotspot areas. Consistent with the observed pattern of population growth rate, the employment rate has fallen in the coastal zone, barind and drought prone area and the river systems and estuaries but increased in urban and other three areas. As expected, the employment rate has expanded most in urban areas.

Table 2.10: Employment and Unemployment Rate (%)

Hotspots	2000			2013		
	Employed	Unemployed	Underemployed	Employed	Unemployed	Underemployed
Haor and Flash Flood Areas	47.3	1.5	19.2	53.9	2.5	5.1
Coastal Zone	58.8	1.3	20.4	51.4	2.8	4.4
Chattogram Hill Tracts (CHT)	50.4	0.9	23.1	65.8	2.6	10.7
Urban Areas	45.8	2.3	11.9	59.2	3.0	2.4
Barind and Drought Prone Areas	63.2	1.2	16.4	55.6	1.6	1.9
River Systems and Estuaries	55.5	1.7	17.5	52.2	2.2	3.7
RLHP Areas	53.9	2.9	17.9	55.7	3.1	4.3
Bangladesh	51.1	2.3	16.7	54.6	2.5	4.2

Source: BDP 2100 Estimates (GED 2015) based on LFS 2000 and 2013

Distribution of employed population by broad activities such as agriculture, industry and services is shown in **Table 2.11**. The results suggest a clear pattern of falling agricultural employment in favour of industry. For the entire Bangladesh, employment in agricultural activity reduced by about 6 percentage points between 2000 (i.e. 51.3%) and 2010 (i.e. 45.7%). During the same period, employment in services activity also experienced a reduction of 1.5 percentage points. The trends across the regions are however mixed, with four regions that experienced a reduction in services employment while the remaining three reported increase in services employment. The above trend of rising industry employment at the expense of agriculture clearly suggests the growth of higher income employment.

Table 2.11: Distribution of Employed Persons (%)

Hotspots	2000			2013		
	Agriculture	Industry	Services	Agriculture	Industry	Services
Haor and Flash Flood Areas	70.1	5.2	24.7	52.3	15.2	32.5
Coastal Zone	58.2	8.3	33.5	49.7	17.6	32.8
Chattogram Hill Tracts (CHT)	60.3	3.7	36.0	65.2	7.7	27.1
Urban Areas	30.9	20.5	48.6	22.0	31.8	46.1
Barind and Drought Prone Areas	65.1	14.0	20.9	58.5	15.2	26.2
River Systems and Estuaries	56.2	12.0	31.8	46.7	18.8	34.5
RLHP Areas	60.0	7.6	32.3	44.6	26.6	28.8
Bangladesh	51.3	13.1	35.6	45.1	20.8	34.1

Source: BDP 2100 Estimates (GED 2015) based on LFS 2000 and 2013

The distribution of employment by major sectors throws important light on the diversification of economic opportunities by hotspots. The urban areas are most diversified in terms of a growing industrial sector employment. The share of industrial employment grew substantially from 21% in 2000 to 32% in 2013. Except for CHT, the economies of other hotspots have also changed significantly. Yet, compared with the urban areas, the employment share of manufacturing is between 8-19%. In particular, all other Delta hotspots continue to rely between 47-65% of employment in agriculture. This continued heavy reliance on agriculture for livelihood makes the work force more vulnerable to climate change and natural hazards.

2.3.1 *Poverty and Inequality*

Bangladesh has made impressive progress in reducing poverty. Nevertheless, further poverty alleviation remains a major policy challenge. For example according to the projections of 7th FYP, almost a quarter of the population was poor as measured by the upper poverty line. Given the pervasive nature of poverty in Bangladesh, the reduction of poverty and extreme poverty is considered as the most important indicator of development. In this sub-section, an assessment of poverty, inequality and vulnerability is provided using well accepted measures such as FGT[4] and Gini coefficients[5].

Table 2.12 below shows the trends in head count poverty along with poverty gap, poverty severity and inequality across all hotspots. Between 2000 and 2010, annualized percentage point reduction in head count poverty as measured by the upper poverty line[6] has been 1.7 for Bangladesh as a

[4] This is composed of three measures: (i) the simplest measure of the prevalence of poverty, headcount ratio, is the proportion of population with a per capita income below the poverty line. (ii) The depth of poverty is measured by the poverty gap index (PGI). The poverty gap measures the average short fall in consumption relative to the poverty line and thus overcome the first limitation of the head count ratio. (iii) The average of the squared poverty gap for each poor person is the SPGI. This is a dispersion measure of the severity of poverty. Severity measure is sensitive to the consumption distribution among the poor. That is, it weights the deficit in consumption relative to the poverty line more heavily the poorer the person is.

[5] The Gini index on the other hand is more sensitive to consumption differences in the middle of the distribution. The values of all three indices lie between zero and one with higher value implying greater inequality.

[6] Bangladesh uses a cost of basic needs (CBN) methodology to calculate two national poverty lines – the lower poverty line and the upper poverty line – which estimate the incidence of extreme poverty and total poverty rates, respectively.

whole. There is substantial variation in poverty rate among the hotspots. In 2010, the lowest poverty rate happened in the urban hotspot (20.7 %). On the other hand the River Systems and Estuaries Hotspot shows the highest poverty incidence of 38.3%, which is 22% higher than the national average and 85% higher than the average poverty rate for the urban areas. The coastal belt also exhibits higher than national average poverty rate.

Two hotspot regions reported higher rates of poverty reduction than the national average. These are Barind and Drought Prone Areas (2.6 percentage points); and Haor and Flash Flood Areas (2.0 percentage points). Poverty reduction rate of the RHF region has been found similar to the national average of 1.7 percentage point. Lowest reduction rate happened for CHT (1.37 percentage points) followed surprisingly by Urban areas (1.42 percentage points) and River and Estuary (1.54 percentage points).

Table 2.12: Poverty and Inequality (%)

Sl	Hotspots	2000				2010				Percentage Change (Head count poverty)	
		Head count	Gap	Severity	Gini Coefficient	Head count	Gap	Severity	Gini Coefficient	Decade	Annualized
1	Haor and Flash Flood Areas	48.45	13.7	4.9	0.30	28.8	6.4	1.9	0.30	19.7	2.0
2	Coastal Zone	48.51	14.6	5.4	0.32	32.1	6.9	2.3	0.33	16.4	1.6
3	Chattogram Hill Tracts	42.31	3.2	0.8	0.36	28.6	3.9	1.1	0.24	13.7	1.4
4	Urban Areas	34.85	9.4	3.2	0.38	20.67	2.7	0.7	0.35	14.2	1.4
5	Barind and Drought Prone Areas	52.80	23.0	9.8	0.29	27.25	6.6	2.1	0.33	25.6	2.6
6	River Systems and Estuaries	53.72	16.1	6.4	0.33	38.32	8.4	2.6	0.31	15.4	1.5
7	RLHP Areas	54.08	19.6	8.0	0.33	36.82	7.2	2.1	0.38	17.3	1.7
8	Bangladesh	48.9	12.9	4.5	0.33	31.5	6.5	1.8	0.32	17.4	1.8

Source: BDP 2100 Estimates (GED 2015) based on HIES 2000 and 2010

Above variations in poverty reduction rates requires one qualification. The lower poverty reduction rate for Urban areas is to a large extent due to the migration of people (especially poor people) from the environmentally vulnerable regions of coastal belt and river and estuary regions. Regarding the RLHP areas, the continued high average poverty rate despite being relatively safe from natural hazards is owing to the dominance of Mymensingh District in this group. Mymensingh and also Sherpur Upazillas, although relatively less prone to natural hazards, have large share of low-income agriculture, substantial landless labor and low rates of literacy. These suggest that the

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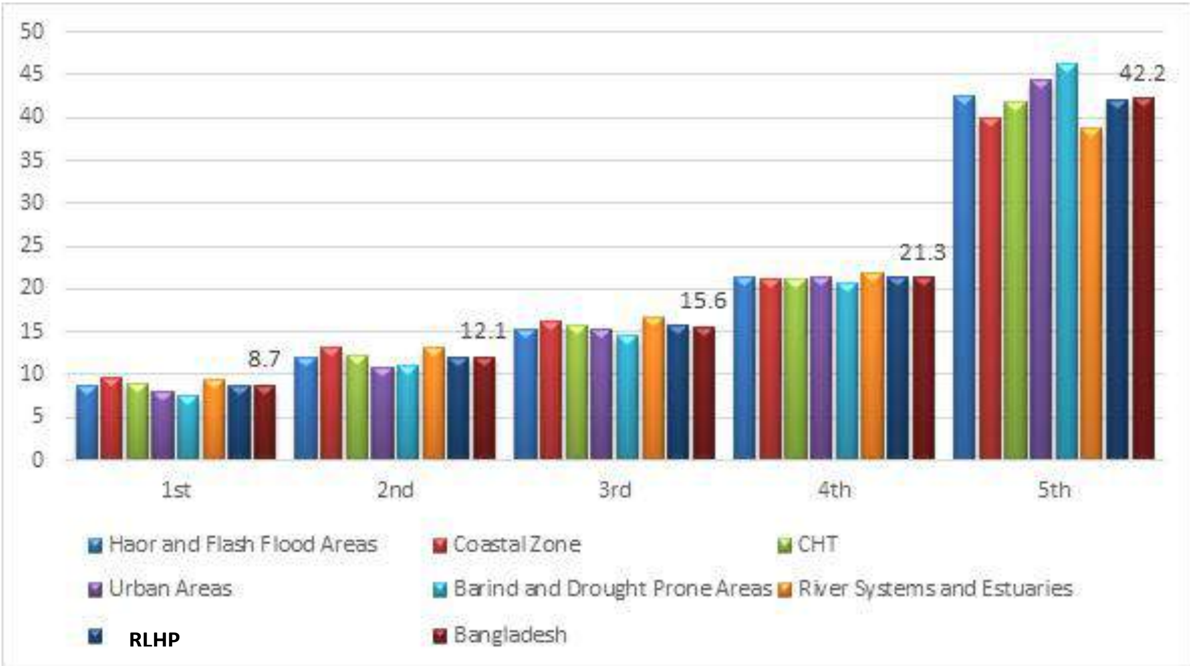
Upper and lower poverty lines are calculated for 16 areas (including adjustments made for urban and rural areas) to take account of regional variation in prices. Both poverty lines take both food and non-food expenditures into account. Upper poverty lines vary from 1,311 BDT per month in rural Sylhet to 2,038 BDT in Dhaka and between 1,192 BDT in rural Khulna to 1,495 BDT in urban Chattogram (BBS, *HIES 2010 Survey Report*, Dhaka, BBS, 2010).

exposure to natural hazards is an important risk for poverty, but there are other socio-economic factors that also affect poverty.

Regarding consumption inequality, estimated Gini coefficient has remained more or less stable at around 0.3. No significant variations in Gini values have been found across the hotspots between 2000 and 2010. A part of the reason for stable consumption inequality is the growing role of remittances that have helped smooth consumption for the poor. Similarly, the availability of micro-credit and safety net spending of the government has helped protect consumption.

In order to get further insights into the distribution patterns, income distribution by quintile has also been estimated for all hotspots for 2000 and 2010. The results are summarised in Figure 2.4. The results suggest a mixed trend in income distribution between 2000 and 2010. For instance, the income shares of bottom quintile and top quintile were 8.7% and 42.2% respectively in 2000, while the corresponding shares for 2010 were 9.1% and 41.6% suggesting an improvement at the national level. Similarly improvements in income distribution have been found in CHT (share of bottom and top quintiles - 8.1% and 44.4% respectively in 2000; the corresponding shares for 2010 were 11.1% and 35.7%); Urban areas (shares of bottom and top quintiles - 7.5% and 46.2% in 2000; the corresponding shares for 2010 were 8.2% and 43.2%) and River and Estuary (share of bottom and top quintiles - 8.6% and 42.1% in 2000; the corresponding shares for 2010 were 9.2% and 40.5%). On the other hand, income distribution deteriorated for the other four hotspots.

Panel A. Distribution of Income for 2000



Panel B: Distribution of Income for 2010

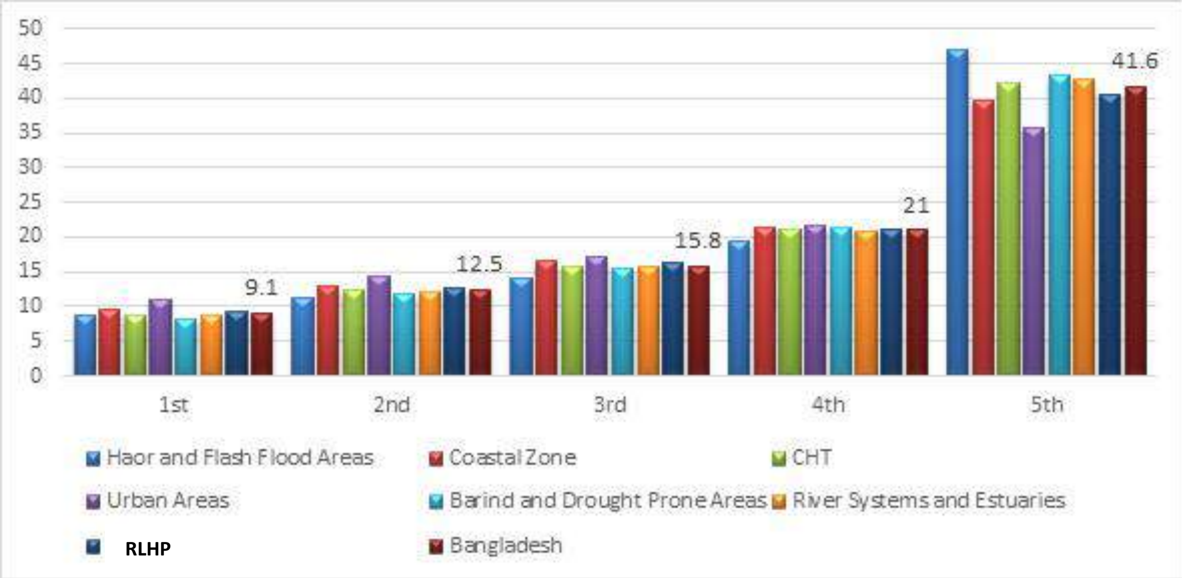


Figure 2.4: Income Distribution Pattern by Quintiles

Source: BDP 2100 Estimates (GED 2015) based on HIES 2000 and 2010

To test for the vulnerability of the poor to shocks, the Upper Poverty Line (UPL) was increased by 25% (i.e. UPL x 1.25). Although there is no accepted threshold for the near poor or the vulnerable population, an individual whose per capita consumption is less than the UPL x 1.25 is considered vulnerable. The results are shown in **Table 2.13**. Accordingly, in 2000 almost 60% of the population may be considered vulnerable to various shocks (i.e. environment and covariates). This proportion dropped by about 22 percentage points in 2010; some 38% of the population was vulnerable in 2010 under the UPL x 1.25 criteria. Between 2000 and 2010, annualized percentage point reduction in head count vulnerability as measured by the near poor poverty line (UPL x 1.25) has been 2.2. However, similar to trends observed for the moderate poverty, noticeable variations in poverty reduction rate across hotspots have been found in the case of vulnerability. In particular, the Coastal Zone and the River Systems and Estuaries Hotspots are most vulnerable to natural hazard shocks. Not surprisingly, the Urban Areas are much more resilient.

Table 2.13: Poverty Vulnerability (%)

Sl	Hotspots	2000			2010			Percentage Point Change (Head count poverty)	
		Head count	Gap	Severity	Head count	Gap	Severity	Decade	Annualized
1	Haor and Flash Flood Areas	60.6	23.1	9.9	36.0	13.6	4.9	24.6	2.5
2	Coastal Zone	60.6	24.0	10.5	40.1	14.0	5.3	20.5	2.1
3	Chattogram Hill Tracts	52.9	9.3	2.8	35.6	10.2	3.2	17.1	1.7
4	Urban Areas	43.6	17.3	6.9	25.8	7.2	2.2	17.7	1.8
5	Barind and Drought Prone Areas	66.0	33.6	16.6	34.1	13.2	4.9	31.9	3.2
6	River Systems and Estuaries	67.2	25.3	11.6	47.9	16.6	6.2	19.2	1.9
7	RLHP Area	67.6	29.1	14.0	46.0	14.9	5.3	21.6	2.7
8	Bangladesh	59.8	23.1	10.3	38.0	12.8	4.6	21.8	2.2

Source: BDP 2100 Estimates (GED 2015) based on HIES 2000 and 2010

2.3.2 *Socio-economic Analysis of Hotspots*

The socio-economic analysis at the hotspot level provides some important messages. They also provide indications about where deeper probing is needed to paint an adequate picture of the socio-economic vulnerability of the Bangladesh Delta population to geography and climate change. This analysis is needed to develop an appropriate response mechanism. The deeper analysis will also provide useful insights about the effectiveness of past and ongoing policies, programmes and institutions in the context of fighting the natural vulnerabilities and improving the welfare of the citizens.

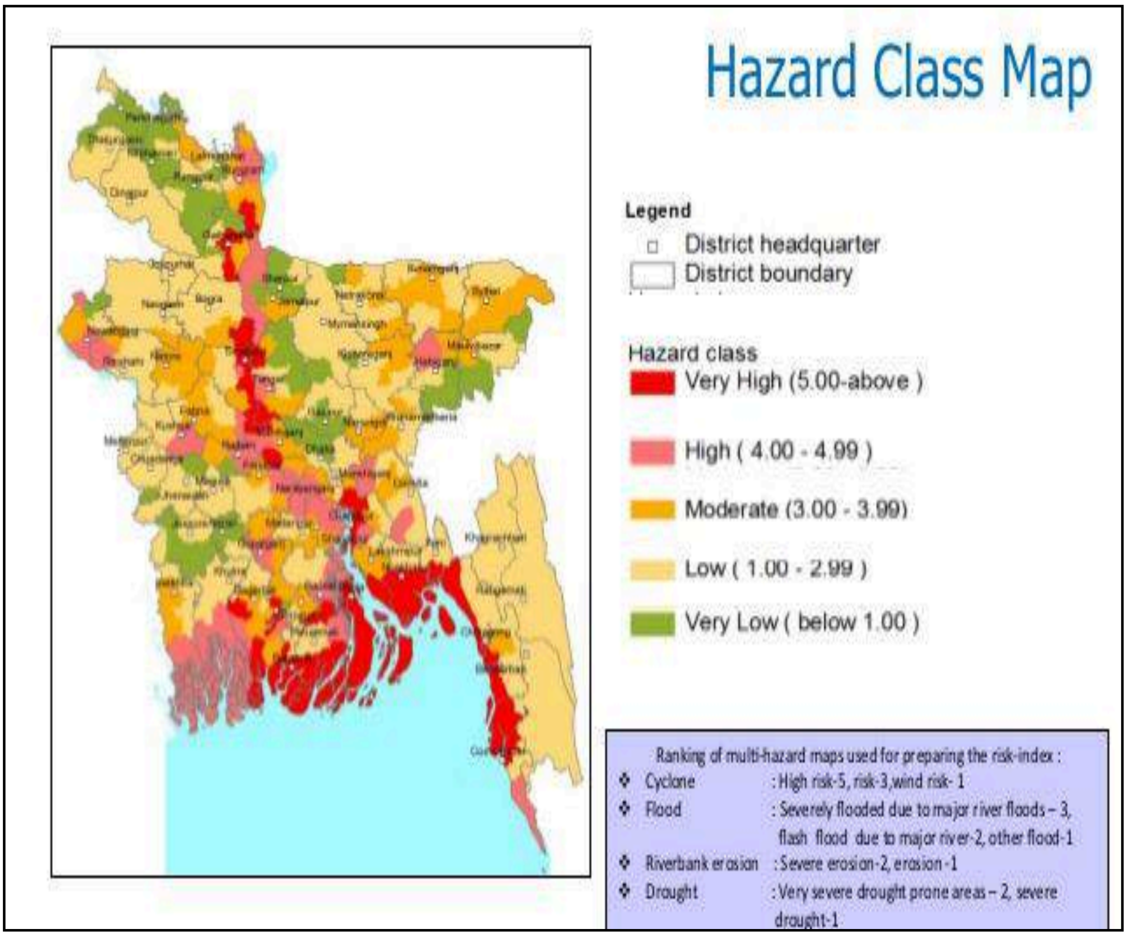
- Since independence Bangladesh has made substantial progress in increasing incomes, creating jobs, diversifying the economic activity base of the population, reducing poverty, increasing education and literacy levels and improving the quality of life as reflected in various non-income measures of welfare such as housing, safe water supply, sanitation and access to electricity and mobile phones. This progress has been particularly impressive after 2000.
- The progress with citizen welfare has been fairly broad-based when measured against the various delta hotspot zones. All areas have been benefited.
- Nevertheless, some hotspot areas have done better than others. In general, the urban areas have out-performed other delta hotspots. Among these other hotspots, the River Systems and Estuaries and the Coastal Zone have made relatively lower progress in terms of poverty reduction. The Haor and Flash Flood Areas and the CHT are lagging behind in terms of non-income welfare indicators.
- Population dynamics show that there has been net out-migration from the Coastal Zone and from the River Systems and Estuaries primarily to the Urban Areas.
- An important policy question is what explains the differential socio-economic performance across the Delta regions? In particular, to what extent is higher poverty incidence and its severity in the coastal belt, River Systems and and Estuaries and Haor and Flash Flood Areas are linked to natural vulnerabilities?
- The Barind and Drought Prone Areas have made the most impressive progress in reducing the incidence of poverty between 2000 and 2010. What explains this progress, especially in light of the risks presented by vulnerability to droughts?
- What explains the observed pattern of outmigration from the Coastal Zone and River Systems and Estuaries to the Urban Areas? Is this pattern linked to the incidence of natural vulnerabilities?

The CHT area has low poverty incidence. However, it has experienced relatively low progress with non-income indicators of welfare. Also, it has the lowest income per capita and it has experienced an increase in the dependence on agriculture for livelihood. How does geography and climate change impact on the income prospects and welfare of CHT? These are important policy questions. Aggregation at the hotspot level does not allow a fuller analysis of these issues because poverty and income vary considerably within each hotspot. Also, natural disasters affect areas differently within each hotspot. A more disaggregated analysis of poverty and natural disasters at the district and sub-district (Upazilla) levels are necessary to address these questions more convincingly.

2.4 Vulnerability to Natural Disasters

2.4.1 *District Level Vulnerability*

Although almost all of Bangladesh Delta is vulnerable to some kind of natural disaster, the nature and magnitude of these vulnerabilities vary substantially by districts. In some instances, the vulnerabilities also vary by sub-districts. One useful way of visualizing these vulnerabilities is to look at the hazard map of Bangladesh (**Map 2.1**). As is clear, most of the coastal belt and parts of river and estuary districts fall under the highest disaster risk. Both regions face multiple risks, although arguably the Coastal Zone faces more risks on average than any other hotspot. For example, Coastal Zone districts face as many as five types of natural disasters including flooding, salinity, cyclone, river erosion and water-logging. Additional risk is posed by land loss to sea owing to sea level rise. The risk is long term but could be devastating. In the River Systems and Estuaries, the main risks are those of flooding and river erosion. In some districts, flooding may be overwhelming causing serious economic damages on a regular cycle.



Map 2.1: Hazard Map of Bangladesh by District

Source: BDP 2100 Disaster Management Baseline Study, GED 2015

Table 2.14 provides a summary of districts that face serious natural hazard risks. Within these hazard-prone districts the intensity and spread of hazard cover varies. To identify the intensity of hazards, a risk ranking of the districts is also provided in **Table 2.14**. The ranking is based on a simple methodology whereby districts facing the most number of hazard risks are ranked as most hazard-prone. More specifically, districts that face 4 or more types of hazards are rated as the most hazard-prone districts and are given a rating of 1. Districts that face 3 types of hazards are rated as next most hazard-prone and given a rating of 2. Some districts that face 2 types of hazard but the intensity and potential economic damage is large[7] are also rated as 2. Finally, districts that face 2 hazards but the intensity is relatively lower than those included under category 2 are rated as 3. The methodology does not seek precision but is intended as indicative to enable an assessment of the relationship with welfare indicators, especially poverty and income.

Table 2.14: District Level Natural Hazard Ranking

District	Hazard Ranking	Sea Level Rise	Flood	Cyclone	Salinity	Drought	River Erosion	Water Logging
Bagerhat	1	x	x	x	x			X
Barishal	2		x	x			x	
Barguna	1	x	x	x	x		x	
Bhola	1	x	x	x	x		x	
Chandpur	1		x				x	
Bogura	2		x			x	x	
Cox's Bazar	1	x	x	x	x			
Faridpur	2		x				x	
Feni	1	x		x	x		x	
Gaibandha	1		x				x	
Jamalpur	1		x				x	x
Jashore	2				x	x		x
Jhalokati	2		x		x			
Lalmonirhat	2		x			x	x	
Khulna	1		x	x	x			x
Kurigram	1		x			x	x	
Lakshmipur	1	x	x	x	x		x	x
Magura	3		x			x		
Manikganj	3		x				x	
Munshiganj	2		x				x	x
Natore	2		x			x		
Nawabganj	2					x	x	
Nilphamari	3		x				x	
Noakhali	1	x		x	x		x	x
Pabna	2		x				x	
Patuakhali	1	x	x	x	x		x	
Pirojpur	1		x	x	x		x	
Rajbari	2		x				x	
Rajshahi	2					x	x	
Rangpur	2		x			x	x	
Satkhira	1	x	x		x	x		x
Shariatpur	2		x				x	
Sirajganj	1		x				x	
Sylhet	3		x				x	
Sunamganj	3		x				x	
Tangail	2		x				x	

Source: BDP 2100 Technical Team Analysis, GED, 2015

[7] This mainly involves the floodplain districts and the potential intensity is assessed on the basis of historical record of damage from floods.

The hazard ratings show that 16 districts are most hazard prone in the Bangladesh Delta. These are: Bagerhat, Barguna, Bhola, Chandpur, Cox's Bazar, Feni, Gaibandha, Jamalpur, Khulna, Kurigram, Lakshmipur, Noakhali, Patuakhali, Pirojpur, Sirajganj and Satkhira. Most of these are a part of the Bangladesh coastal belt. The common challenges they face include seal-level rise, coastal flooding, cyclones and salinity. Some also face problems from river erosion and water-logging. Additionally, this highest vulnerability group includes five districts belonging to the rivers and estuary category (Chandpur, Gaibandha, Jamalpur, Kurigram and Sirajganj). These districts face severe river flooding and river erosion challenges on a fairly recurring cycle causing considerable economic losses and hardships to the population.

Next in hazard vulnerability ranking are some 15 districts comprising of: Barishal, Bogura, Faridpur, Jashore, Jhalokati, Lalmonirhat, Munshiganj, Nawabganj, Natore, Pabna, Rajbari, Rajshahi, Rangpur, Shariatpur and Tangail. These mostly belong to River Systems and Estuaries group or the inner part of the coastal belt. Some are also a part of the Barind and Drought Prone Areas Hotspot. Flood risk and river erosion are the main types of hazards, although districts in the Barind and Drought Prone Areas Hotspot face drought problems in addition to river flooding and river erosion.

In the category 3 there are 5 districts: Magura, Manikganj, Nilphamari, Sylhet and Sunamganj. They face a mixture of flooding and drought related hazards. The intensity of flooding is relatively lower than found in districts under category 2.

Recently, two hazards, namely lighting-thunderstorms and landslides have become intensified but information on their ranking according to districts are yet to be available.

Table 2.15: Correlation between District Level Natural Hazards and Welfare

District	Hazard Ranking	Per capita income FY2010/11 (BDT)	UPL2010 (%)	LPL2010 (%)	UPL2000 (%)
Bagerhat	1	48,696	42.2	24.0	32.8
Satkhira	1	37,083	46.3	29.7	59.7
Noakhali	1	29,565	9.6	3.4	49.5
Bhola	1	37,023	33.2	20.4	68.5
Cox's Bazar	1	35,225	32.7	16.2	40.6
Patuakhali	1	38,582	25.8	14.7	39.9
Pirojpur	1	33,453	44.1	30.9	51.1
Chandpur	1	31,998	51.0	30.3	52.2
Barguna	1	40,225	19.0	9.8	54.2
Feni	1	26,225	25.9	14.6	44.8
Khulna	1	58,346	38.8	21.2	37.9
Lakshmipur	1	30,862	31.2	18.1	57.8
Jamalpur	1	32,922	51.1	34.2	56.5
Gaibandha	1	29090	48.0	30.3	70.5
Sirajganj	1	29,088	38.7	22.7	59.7
Kurigram	1	35,107	63.7	44.3	57.8
Munshiganj	2	29,713	28.7	15.6	49.4
Pabna	2	38,938	31.5	16.7	49.5
Jashore	2	39,242	39.0	18.0	32.4
Rangpur	2	32,232	46.2	30.1	69.0
Tangail	2	30,957	49.7	18.0	65.6

District	Hazard Ranking	Per capita income FY2010/11 (BDT)	UPL2010 (%)	LPL2010 (%)	UPL2000 (%)
Faridpur	2	30,405	36.3	19.8	65.5
Shariatpur	2	30,277	52.6	34.4	73.3
Rajbari	2	32,615	43.4	25.7	63.4
Barishal	2	37,934	54.8	39.9	55.1
Natore	2	37,940	35.1	21.3	42.8
Rajshahi	2	40,008	31.4	16.5	49.6
Bogura	2	34,396	16.6	6.7	45.7
Jhalokati	2	30,407	40.5	26.7	33.8
Lalmonirhat	2	32,528	34.5	16.7	55.3
Nawabganj	2	28,442	25.3	12.1	47.4
Magura	3	35,171	45.4	25.9	60.2
Manikganj	3	35,347	18.5	8.0	57.0
Nilphamari	3	27870	34.8	18.8	65.5
Sunamganj	3	25872	26.0	20.6	57.7
Sylhet	3	31,966	24.1	19.5	38.2
Bangladesh Average		37,859	31.5	17.6	49.8

Source: Poverty data from HIES 2010 and 2000; Per capita income from BBS

An important analytical question is how the hazard profile of districts is correlated with economic outcomes. **Table 2.15** shows the results in terms of per capita income and poverty profile. **Table 2.15** is a powerful summary of some very interesting economic results:

- Consistent with the expected impact of natural hazards on welfare, there is a strong positive correlation between incidence of poverty and the intensity of natural hazards. Some 70% of the 16 districts ranked as most exposed to natural disasters (intense risk category with ranking of 1) also show poverty rates that are higher than the national average using the upper poverty line for 2010. The important exceptions are Noakhali, Barguna, Bogura, Feni and Patuakhali. Interestingly, except Bogura, these are all coastal belt districts. A deeper analysis of how these 5 districts have succeeded in securing better welfare outcomes for the residents despite facing intense natural hazard pressure will have important insights for developing the Delta Plan.
- There is a similar highly positive correlation between high-risk districts (risk ranking of 2) and poverty. Some 67% of these districts have poverty rates that are higher than the national average and 13% have poverty rates same as the national average.
- At the national level, of the 15 most poverty-stricken districts, almost 90% of the districts belong to natural hazard risk categories 1 or 2 (**Figure 2.5**). The 2 exceptions are Mymensingh and Sherpur that are relatively less hazard prone.
- When it comes to per capita income, some 80% of the most-intense hazard-prone districts (risk ratings of 1) had per capita income below the national average. The corresponding percentages were: 67% for districts in risk category 2 and 100% for risk category 3. In risk category 1, the exceptions are Khulna, Bagerhat, Barguna and Patuakhali. Khulna and Bagerhat in particular have done very well in securing substantially better than average per capita income (54% higher than the national average for Khulna and 29% higher in Bagerhat). However, Patuakhali is close to the national average while Barguna is 6.2% higher. In the case of risk category 2, although there are 5 districts that have average per capita income higher than the national average, only one district (Rajshahi) has significantly higher than national average per capita income (5.7%

higher). Others are bordering around the national average. The positive experiences of Khulna, Bagerhat and Barguna to secure significantly larger-than-national average per capita income despite the large risks posed by the intense natural disasters in these districts deserves closer look to understand how these districts have countered the adverse effects of natural disasters.

- The link between exposure to natural hazards and per capita income is complicated by the fact that the two industrial-commercial urbanized districts of Dhaka and Chattogram alone account for at least a quarter of total national GDP. The income share of agriculture, which is the most vulnerable economic activity in terms of exposure to natural hazards, is small in these two districts. A more meaningful link between natural disaster and income requires district level data on income share of agriculture, which unfortunately is not available. Yet, as noted, the experiences of Khulna, Bagerhat and Barguna will throw useful insights about how they have succeeded in fighting against the exposure of their per capita income to natural disasters.

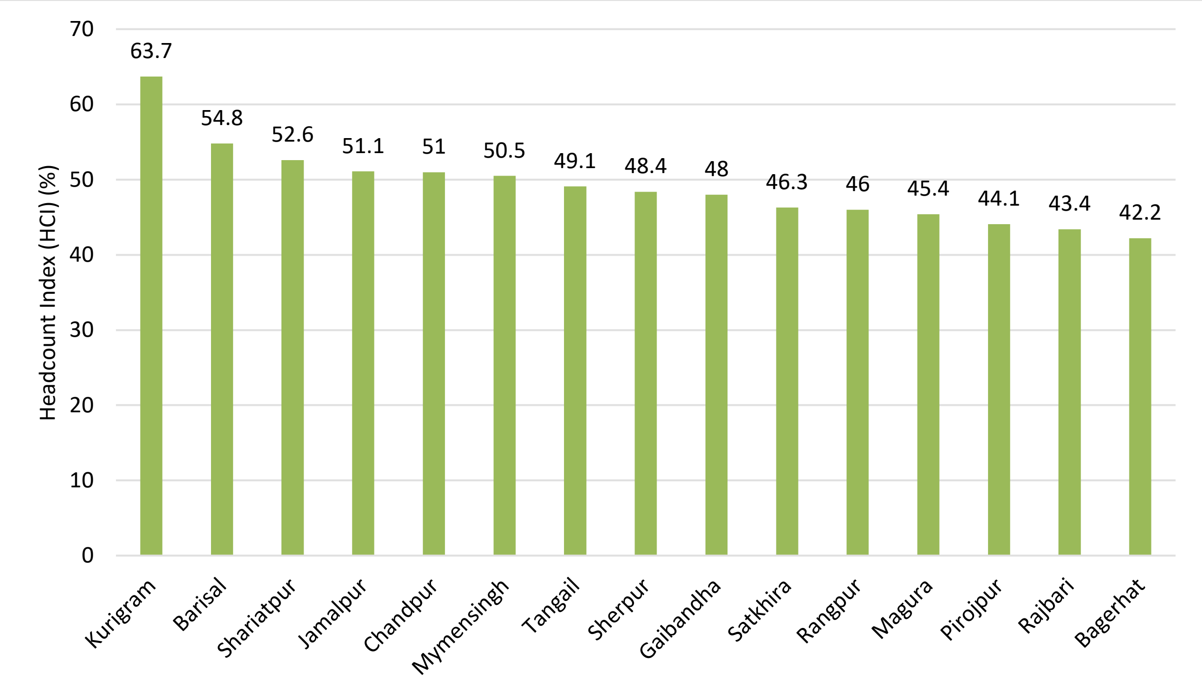


Figure 2.5: Most Poverty Stricken Districts, UPL 2010 (%)

Source: HIES, 2010

2.4.2 *Insights from Sub-district Poverty Profile*

Further insights on the relationship between poverty and vulnerability to natural hazards can be gauged by looking at the poverty level at the sub-district level. Detailed analysis of poverty profile shows that the incidence of extreme poverty is much higher in the rural areas, which are heavily dominated by traditional agriculture as the main means of livelihood. **Figure 2.6** shows the poverty incidence for the extreme poor (lower poverty line) for the 15-poorest of the poor sub-districts (upazilla). The results are very striking. Some 90% of these upazillas belong to risk-category 1. More specifically, these are: Bhurangumari, Char Rajibpur, Chilmari, Nageshwari, Phulbari, Rajarhat, and Ulipur (Kurigram district with risk rating of 1); Bakerganj, Hizla, Mehndiganj and Muladi (Barishal district with a risk rating of 1); Haim Char (Chandpur district with a risk rating of 1); Dewanganj (Jamalpur district with a risk rating of 1). One poorest of the poor upazilla (Gowainghat) belongs to the district of Sylhet (risk rating of 3). Only one upazilla (Nandail) is in the low-risk district of Mymensingh.

The situation in Kurigram is most telling. Located on the mouth of the mighty river Brahmaputra's entrance in Bangladesh, all upazillas of this district are very poor, to a large part due to heavy exposure to natural disasters caused by a combination of substantial flooding and river erosion. The population is heavily dependent on traditional agriculture for livelihood. A large part of the population lives on the char areas that frequently get inundated due to river flooding causing immense hardships to the population. Even the urban area, Kurigram sadar Upazilla, suffers from high incidence of poverty (extreme poverty rate of 40.5% in 2010). There is very little manufacturing base and private sector activities are primarily informal in nature concentrated in trading and transport. Significant economic diversification is yet to happen. The access to international migration is also very limited.

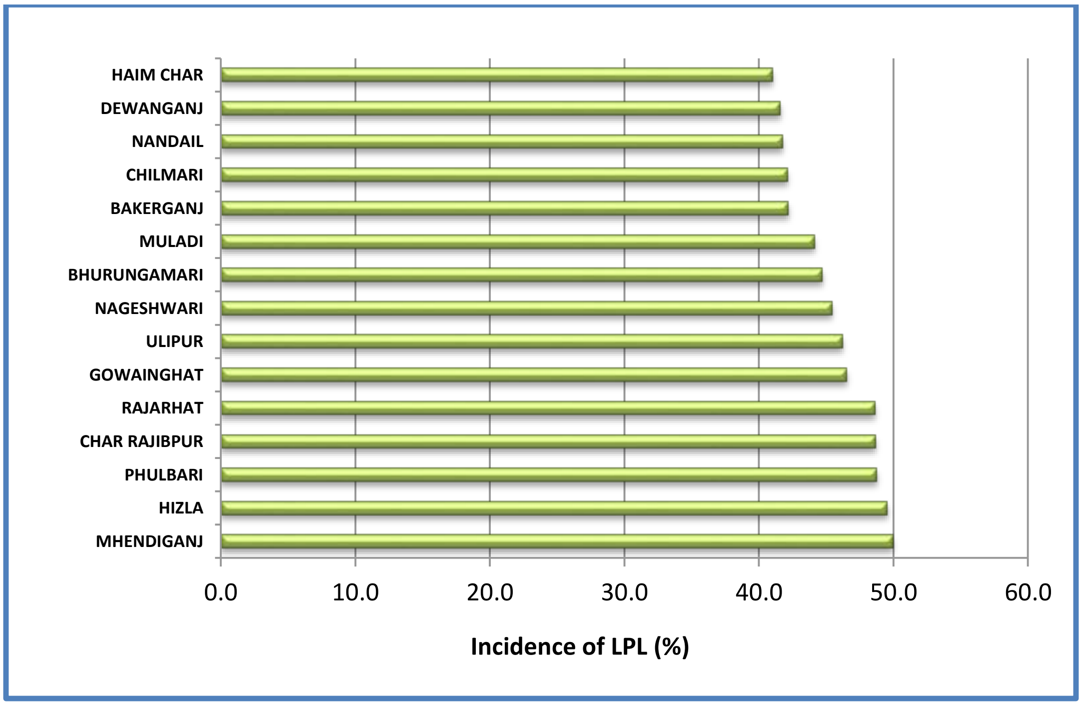


Figure 2.6: Poorest of the Poor Upazillas

Source: HIES, 2010

2.5 Understanding the Positive Adaptive Experiences

As noted, there are several positive experiences where districts facing severe natural hazards have nevertheless succeeded in either overcoming poverty or securing notable income outcomes. These examples are: Barguna, Bagerhat, Bogura, Feni, Khulna, Noakhali and Patuakhali. Except Bogura, these are all coastal districts with signifcant exposure to all kinds of natural disasters. Bogura, although not a coastal district, nevertheless faces several sources of natural hazards including flooding, river erosion and droughts. Although detailed district level data on income and employment sources are not available, a reasonable storyline can be developed by piecing together the available information. To assist this analysis, the available information is put together in **Table 2.16.** Within the group there are three types of experiences: Barguna, Bogura and Patuakhali that have experienced positive growth in income and reducing poverty; Noakhali and

Feni that have experienced substantial reduction in poverty but average per capita income is considerably below the national average; and the third group comprising of Khulna and Bagerhat that have experienced very good progress with increase in income but have not done well with poverty reduction in comparison with the national averages. Each of these experiences has important policy implications.

Table 2.16: Profile of Districts with Positive Adaptation

District	Density (population/km²)	Population growth rate (%) (2001-2011)	Per capita GDP in Tk. (2011)	Poverty (UPL 2010)	Poverty (LPL 2010)	Agriculture (% of HH income)	Remittance (% of HH income)	Foreign remittance (% of HH income)
Bagerhat	387	-0.97	48,696	42.2	24.0	42.8	7.4	1.3
Barguna	507	0.90	40, 225	19.0	9.8	25.0	4.9	2.5
Bogura	1212	1.62	34,396	16.6	6.7	23.5	9.1	5.5
Feni	1612	1.89	26,225	25.9	14.6	7.4	44.5	40.1
Khulna	548	1.21	58,346	38.8	21.2	30.1	3.4	1.6
Noakhali	897	2.29	29,565	9.6	3.4	24.0	17.7	14.0
Patuakhali	496	0.89	38,582	25.8	14.7	12.3	4.3	0.2
National average	1016	1.88	37, 859	31.5	17.6	20.0	9.3	7.5

Source: HIES, 2010 and National Accounts, BBS

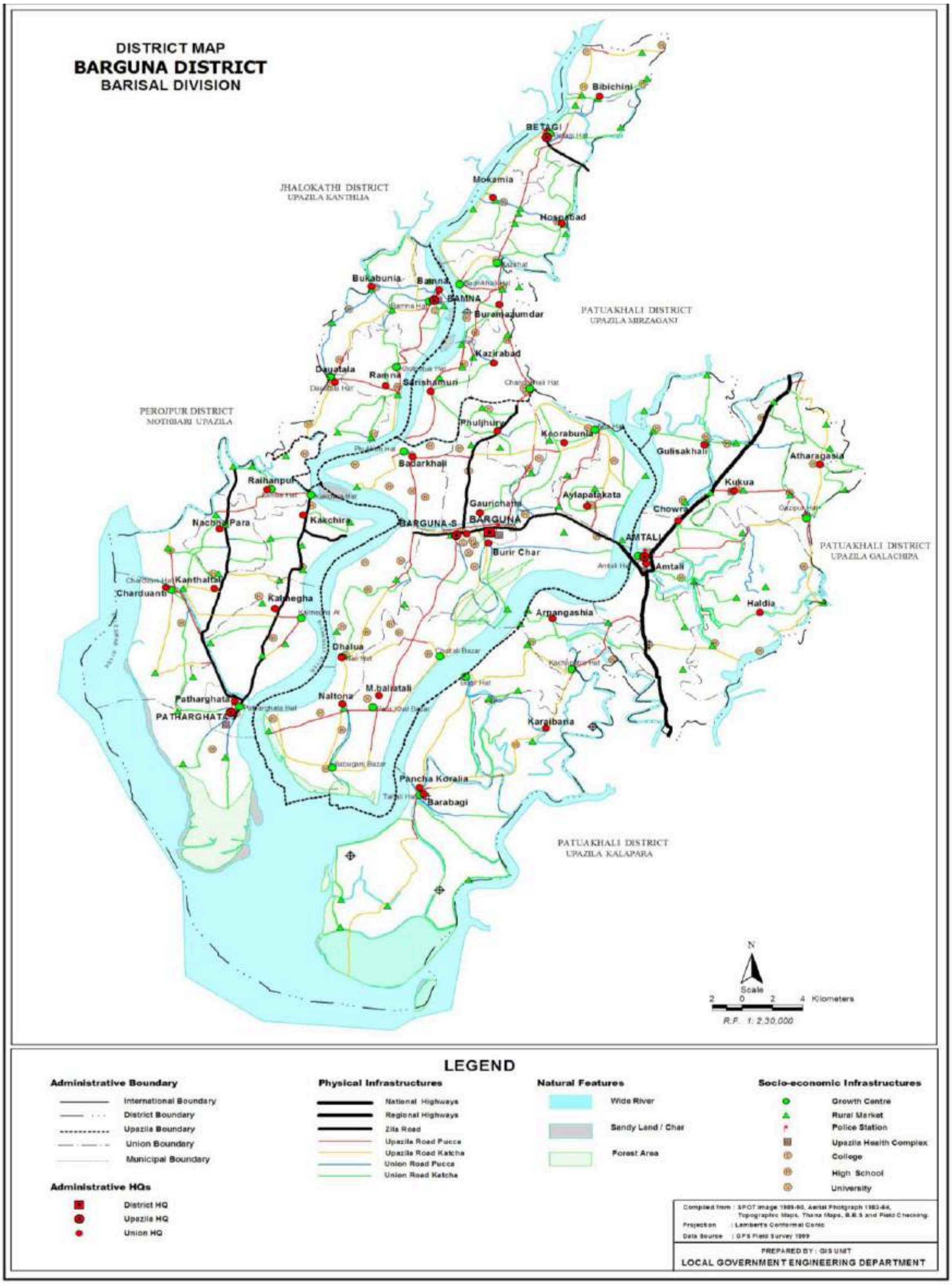
2.5.1 Barguna District

Barguna Experience: Barguna is located of the southern coastal belt, right on the edge of the Bay of Bengal (**Map 2.2**). Geographically, it is exposed to all the hazards of the Coastal Zone hotspot. Yet it has achieved considerable progress with poverty reduction unlike many other coastal belt districts. It also enjoys per capita income that is higher than the national average. Looking at the sub-district profile, all the upazillas have performed well in terms of both upper and lower poverty levels **(Table 2.17)**.

Table 2.17: Poverty Level by Upazilla in Barguna District

Upazilla	UPL 2010	LPL 2010
Amtali	22.8	12.0
Bamna	17.1	8.9
Barguna sadar	19.2	9.9
Betagi	19.6	10.3
Patharghata	12.9	6.1

Source: HIES, 2010 and 2000



Map 2.2: Barguna District Map

Source: LGED, Local Government Division, Ministry of Local Government, Rural Development & Cooperatives

Both Amtali and Patharghata are openly exposed to the sea. While Amtali has the highest poverty rate within Barguna, Patharghata has the lowest poverty rate in the district. Barguna has a fairly diversified economy with agriculture accounting for about a third of its income. It has also succeeded in diversifying agriculture with an export-oriented fishing component that has contributed to its income growth. A major favorable factor for Barguna is its population density. At 507 per km^2, its density is 50% lower than the national average. Population growth rate is also nearly half the national rate owing to net out-migration. This has reduced the population pressure. Rice productivity is very low owing to salinity and other hazards. But agricultural diversification and low population pressure have all helped real agricultural wages grow, which has been an important contributor to reducing poverty. The Patharghata Upazilla has benefitted particularly from higher incomes from the thriving fishing industry. In contrast, the Amtali Upazilla's agriculture is primarily crop dependent. This major differential in income sources explains the weaker poverty performance of Amtali relative to Patharghata.

Barguna made substantial progress in reducing poverty between 2000 and 2010, cutting the poverty rate by more than 50%. The headcount poverty rate fell from 47% in 2000 to below 20% in 2010. This progress has been broad-based with all Upazillas benefitting. Income growth based on agricultural diversification and a range of non-agricultural services has contributed to this progress with poverty reduction. A part of the adjustment has happened through the out-migration of population to other parts of Bangladesh. Barguna did not benefit much from international migration.

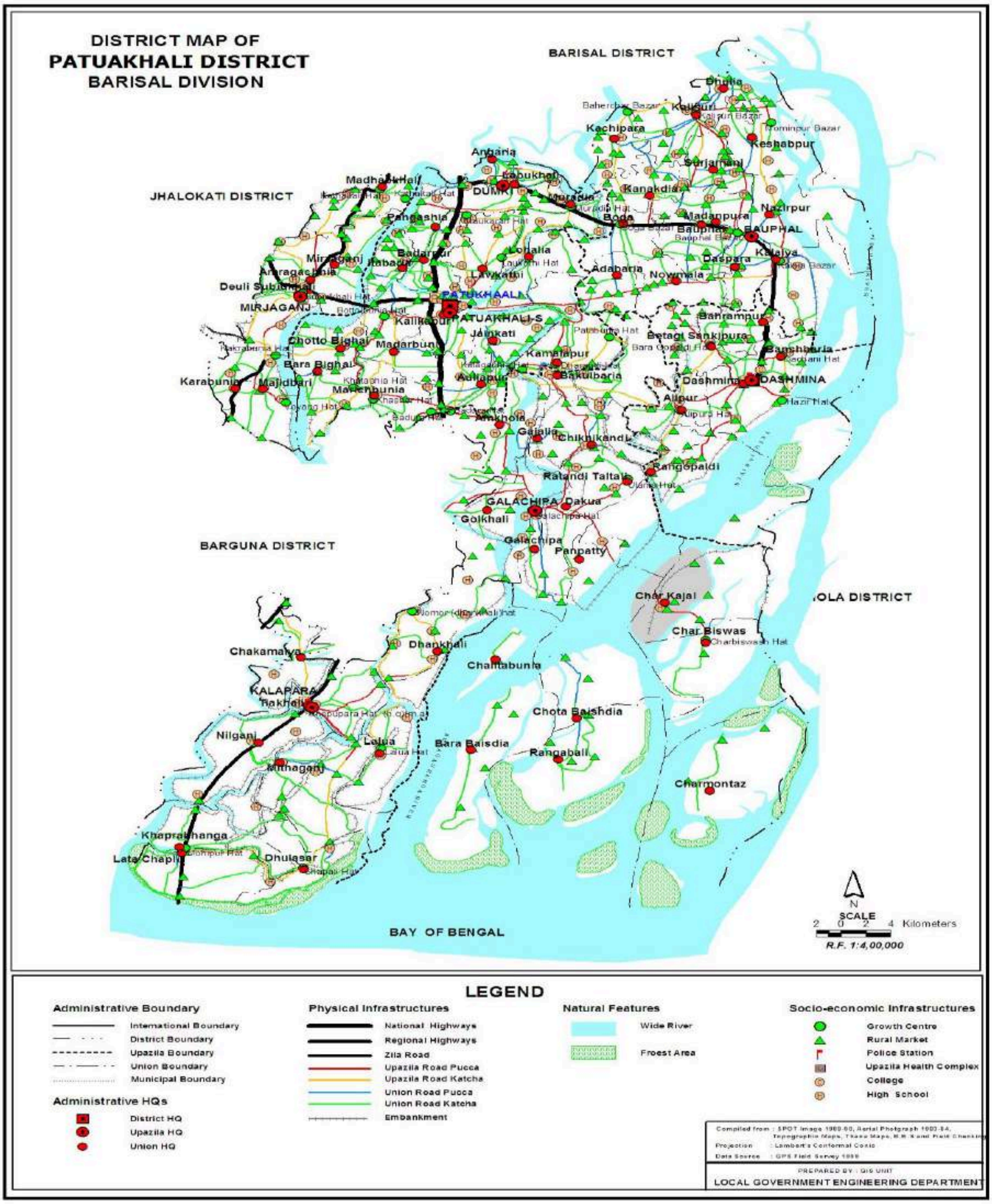
2.5.2 *Patuakhali District*

Patuakhali Experience: Like Barguna, Patuakhali is a coastal district with open access to the Bay of Bengal. It is exposed to all the coastal hazards. Additionally, it faces severe river flooding and erosion problems. Notwithstanding these risks, Patuakhali has achieved per capita income that exceeds the national average and poverty levels are below the national average. Poverty level has also fallen substantially between 2000 and 2010, from 39.9% to 25.8%. Poverty performance by Upazilla level shows that the performance is fairly broad-based except for the urban area of Patuakhali Sadar. An interesting result is that the Upazilla of Kalapara, which is exposed to the open sea, has relatively lower rate of poverty than the District average and substantially lower than the district town.

Table 2.18: Poverty Distribution by Upazilla in Patuakhali District

Upazilla	UPL (%) 2010	LPL (%) 2010
Bauphal	24.0	13.9
Dashmina	21.8	11.3
Dumki	22.0	13.1
Galachipa	26.0	14.4
Kalapara	20.3	9.7
Mirzaganj	17.8	9.6
Patuakhali Sadar	36.9	23.3

Source: HIES 2010 and 2000.



Map 2.3: Patuakhali District Map

Source: LGED, Local Government Division, Ministry of Local Government, Rural Development & Cooperatives

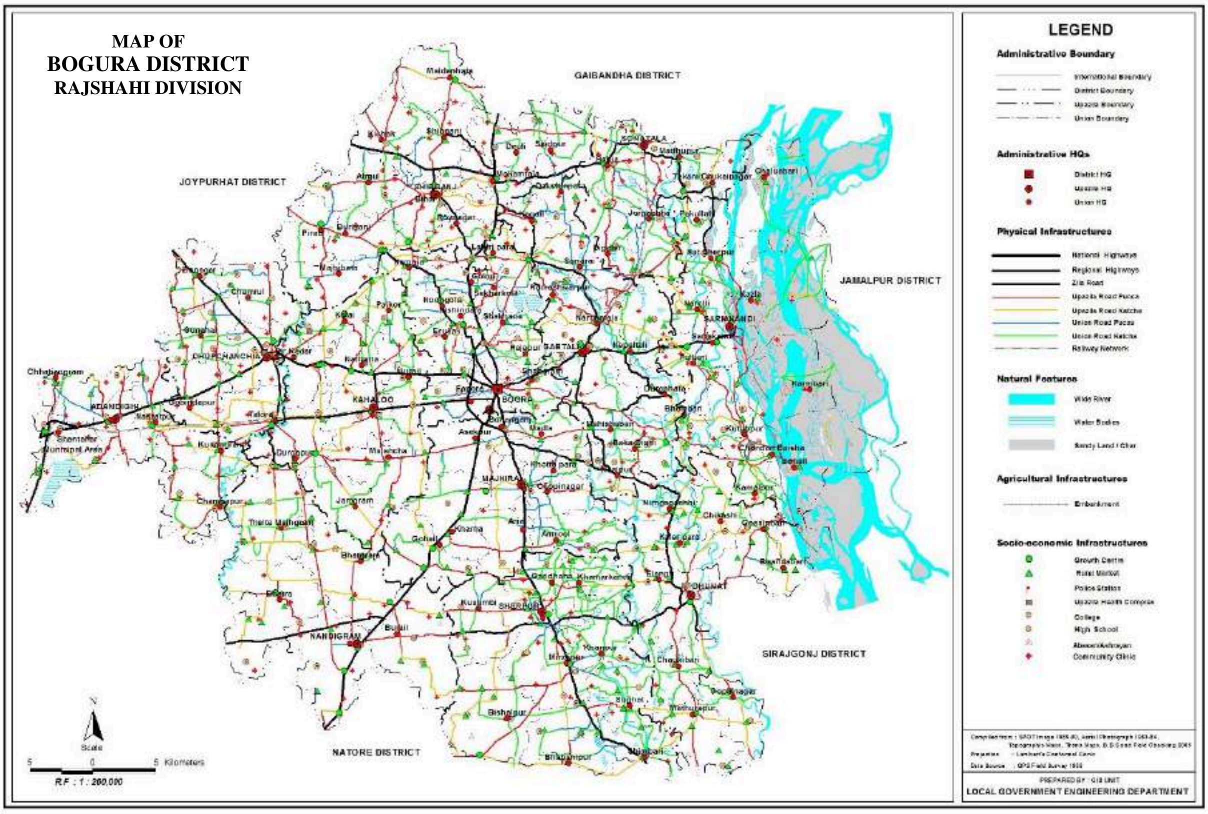
In terms of income source, Patuakhali has substantially diversified the economy with agriculture accounting for only 13% of income. There is a thriving sea-based fishing industry that has helped diversify incomes. Tourism is growing based on the famous Kuakata beach area. Patuakhali city is also diversifying into a center of trade and commerce. The development of the Payra port will further help diversify the Patuakhali economy. On the natural front, low population density and net out-migration has reduced the population pressure on agriculture and employment. Patuakhali is also opening up to converting its coastal location to its advantage through the Payra port and the Kuakata beach resort developments.

While these positive factors have contributed to Patuakhali's efforts to adapting to the high incidence of natural disasters, its ability to improve crop productivity is still lagging behind owing to the continued adverse effects of the high incidence of flooding and salinity. At only 0.72 tonnes per acre, average rice productivity is the lowest in Bangladesh (41% lower than the national average and 55% lower than the best performer Naogaon). Importantly, the incidence of poverty is highest in the Patuakhali urban area of Patuakhali sadar. This is very telling. The three Upazillas that are most exposed to natural disasters are Kalapara, Galachipa and Dashmina. Kalapara is exposed to the sea while Galachipa and Dashmina suffer from river erosion and flooding. Galachipa also has several large char areas that frequently get inundated. Yet, the poverty rates in these three upazillas are lower than the relative upland Upazilla Patuakhali Sadar, the District headquarter.

Kalapara has converted its sea exposure into a resource base through the Kuakata tourism resort, through commercial deep sea fishing and now through the establishment of the ongoing Payra port. Both Galachipa and Dashmina are dominated by agricultural activities. However, they are relatively sparsely populated and have diversified into fisheries and trading that has helped fight the heavy exposure to natural disasters. Net out-migration has also helped lower the pressure in the labor market. Agricultural productivity is low but income from fishing and trading has helped protect rural incomes. In contrast, the Patuakhali Sadar has a substantially higher population density and growing population pressure from in-migration from the disaster prone areas. The growing labor force has not found adequate employment because of a weakly diversifying urban economy. Trading and informal services dominate urban economic activity. Employment in manufacturing and formal services is small.

2.5.3 Bogura District

Bogura Experience: The Bogura District is an upland location relative to the sea level but parts of the District are heavily exposed to river flooding and erosion from the Jamuna river (**Map 2.4**). Parts of Bogura also are drought prone. Notwithstanding these risks, in recent years Bogura is slowly transforming into a dynamic economy. Its per capita income in 2010 was 6% lower than the national average but substantially higher than other Northern rice belt area. In addition to the significant role of a strong agriculture that contributes to 24% to household income, Bogura has a sizeable manufacturing sector. Organized trade and commerce is also gaining significance owing to the Jamuna Bridge that has facilitated trade and commerce with the capital city of Dhaka. This growing and transforming District economy has contributed substantially to the rapid reduction in poverty, with the incidence of extreme poverty falling to single digit. Despite per capita GDP that is nearly half that of the capital city Dhaka, Bogura boasts of a substantially lower poverty incidence than Dhaka notwithstanding much higher incidence of natural disasters. Its economic strength has allowed it to retain its population.



Map 2.4: Bogura District Map

Source: LGED, Local Government Division, Ministry of Local Government, Rural Development & Cooperatives

The poverty progress is broad-based and shared by all Upazillas (**Table 2.19**). Nevertheless, there are some important variations. The Upazillas of Saraikandi and Sonatola that are most exposed to river flooding and erosion also have relatively higher poverty levels.

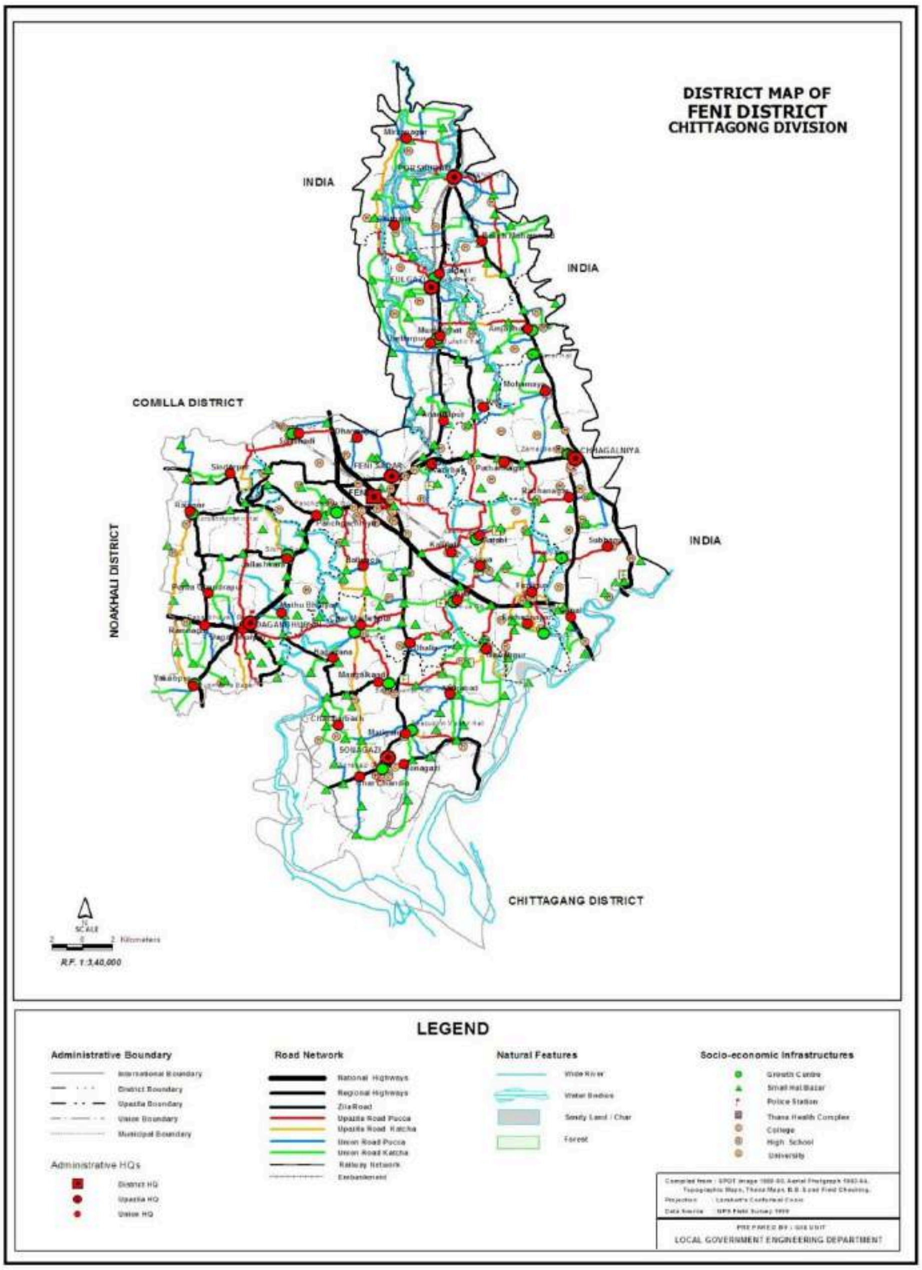
Table 2.19: Upazilla Level Poverty in Bogura District

Subdivisions (Upazillas)	UPL 2010 (%)	LPL 2010 (%)
Adamdighi	13.1	5.1
Bogura Sadar	17.6	9.1
Dhunat	19.8	7.3
Dhupchanchia	13.2	5.1
Gabtali	15.6	5.7
Kahaloo	11.7	4.0
Nandigram	16.1	6.3
Sariakandi	21.6	8.7
Shajahanpur	12.5	5.0
Sherpur	15.7	5.6
Shibganj	16.9	6.3
Sonatola	23.7	10.3

Source: HIES, 2010

2.5.4 *Feni District*

Feni Experience: Owing to geography, the district of Feni faces all the hazards of a coastal District (**Map 2.5**). It is densely populated, with the population density that is 40% higher than the national average. Population growth rate is also high unlike other coastal Districts. Its per capita income is low, almost 40% lower than the national average in 2010. Yet, remarkably, its poverty level in 2010 was below the national poverty level.



Map 2.5: Feni District Map

Source: LGED, Local Government Division, Ministry of Local Government, Rural Development & Cooperatives

What explains this poverty reduction performance despite low per capita income and large vulnerability to natural disasters? The most important factor is the heavy inflow of foreign remittances. Feni is a large contributor to the Bangladeshi migrant work force that sends in significant amount of money to their families. According to HIES 2010 data, as much as 44% of household income in the Feni District came from remittances and 90% of which came from foreign remittances. The remittances in turn finance a considerable amount of non-agricultural activities, primarily services including construction, trade, education and transport. Accordingly, much of the Feni population's household income and consumption is protected from the adverse effects of natural disasters. Feni also has an important locational advantage; it is close to the vibrant economy of the port city of Chattogram, which is the main trade and commerce hub for Bangladesh.

Nevertheless, there are visible differences in terms of welfare among the 4 Upazillas of Feni (**Table 2.20**). The most populous Upazilla, Sonagazi, located on the sea front and most exposed to the risks of natural disasters, especially sea-level rise, salinity and inundation, has substantially higher poverty than the other three upazillas. The poverty rates in Sonagazi (both upper and lower poverty rates) exceed the national average.

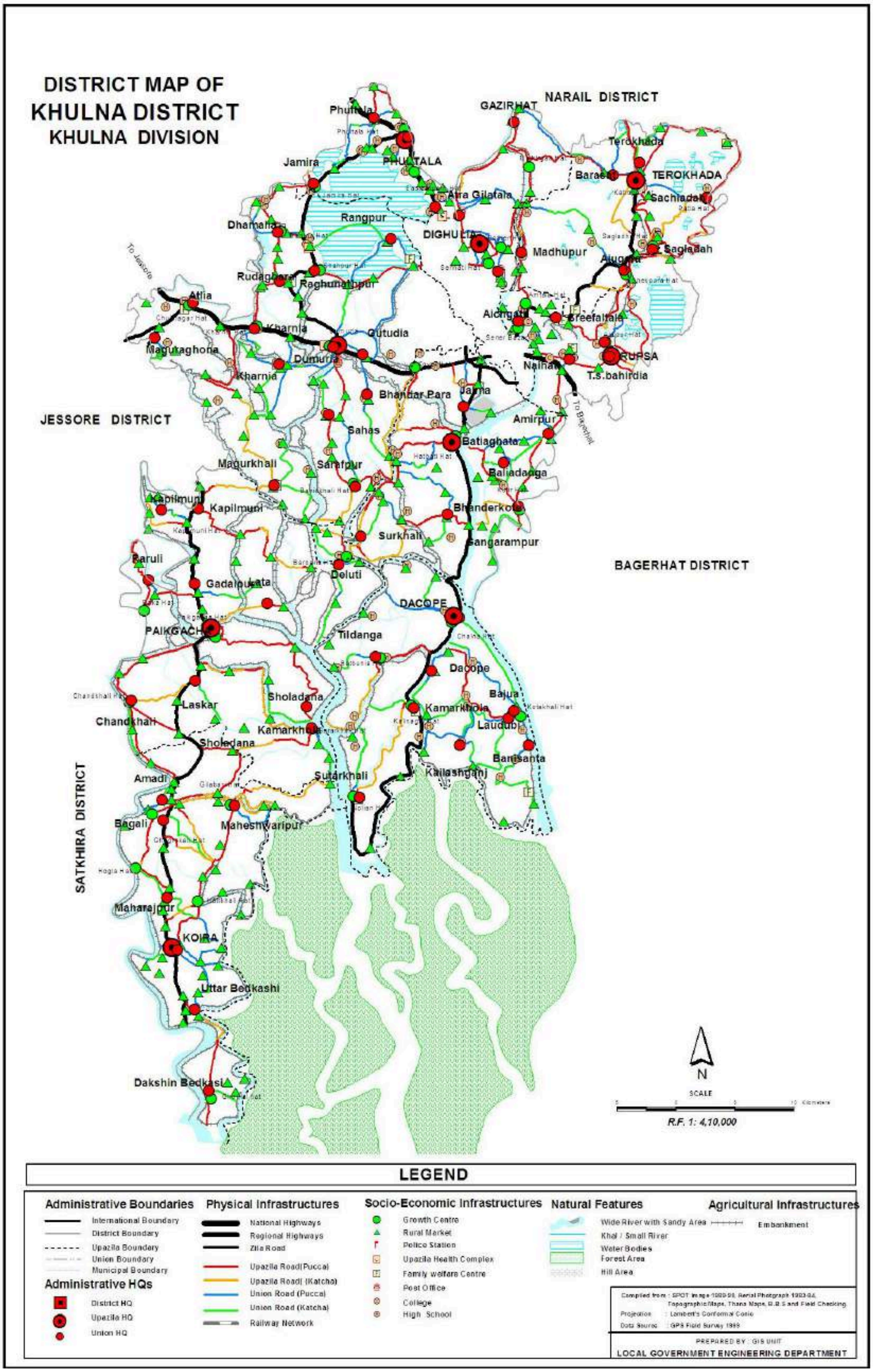
Table 2.20: Feni Upazilla Level Poverty

Upazilla	UPL 2010	LPL 2010
Chhagalnaiya	25.9	14.4
Daganbhuiyan	16.3	7.5
Feni sadar	18.6	9.4
Fulgazi	31.8	17.8
Parshuram	30.6	18.6
Sonagazi	44.5	28.5

Source: HIES, 2010

2.5.5 Khulna District

Experience of Khulna: The District of Khulna is the Divisional headquarters of the Khulna Division. It is an important industrial belt and is also in close proximity to the second port of Bangladesh, Mongla Port. Located on the extreme southwest of the Bangladesh coast, Khulna shares a considerbale part of Bangladesh's largest mangrove forest cover the Sundarbans (**Map 2.6**). The Sundarbans provide a substantial natural protection to the district against the impacts of sea level rise and ravages of cyclone, but salinity has emerged as a serious problem and constraint on crop agriculture owing to sea water encroachment through the river systems. The problem is exacerbated by the drying up of upstream fresh water flows in the rivers.



Map 2.6: Khulna District Map

Source: LGED, Local Government Division, Ministry of Local Government, Rural Development & Cooperatives

Despite being a divisional head quarter and a hub for many industrial and commercial activities owing to its strategic location close to the second sea port of Bangladesh, Khulna District exhibits high levels of poverty. This poverty problem is pervasive including in the 4 of the 5 thanas under the Khulna city metropolitan areas. The only exception is Sonadanga metropolitan thana (**Table 2.21**). Like other districts Khulna also experienced a significant reduction in poverty between 2005 and 2010 (by nearly 35%). Yet, the poverty rate remains substantially higher than the national average[8] suggesting that there are serious income distribution problems. Indeed the lopsided poverty differential between the affluent Sonadanga metropolitan town and the rest of the District is indicative of this income inequality. One important qualifier is that while by income measure the Khulna District shows high rates of poverty, non-income measures of welfare show much better soio-economic outcomes.

Table 2.21: Upazilla Level Poverty Distribution in Khulna District

Upazillas/ Metropolitan thana	UPL 2010 (%)	LPL 2010 (%)
Batiaghata	40.5	22.7
Dacope	44.5	24.9
Daulatpur	34.5	17.4
Dumuria	37.2	19.6
Dighalia	39.3	21.9
Khalishpur	41.1	23.5
Khan Jahan Ali	31.9	16.8
Khulna Sadar	35.5	18.8
Koyra	49.1	29.1
Paikgachha	42.4	23.3
Phultala	33.7	17.0
Rupsa	36.9	20.2
Sonadanga	19.3	7.3
Terokhada	49.6	30.0

Source: HIES 2010

While income poverty progress has not been as positive as in the neighboring Barguna district, Khulna has done remarkably well in increasing per capita income. In FY2011, the per capita District income of Khulna was estimated as the second largest (Tk. 58, 396) after the capital city of Dhaka and some 54% higher than the national average. This is remarkable given the serious nature of natural disasters facing the District. This also indicates the potential for better welfare results in terms of income poverty reduction based on a resolution of the distribution challenges. Several factors explain the strong per capita income performance. First, Khulna has substantial manufacturing and organized commercial activities. The Mongla port is in close proximity making it an important trading destination from nearby cities. Average income from these sources tend to be much higher than informal trading, small scale manufacturing and crop agriculture that characterizes most other high-risk coastal districts. Second, Khulna has converted the salinity problem facing crop agriculture to an opportunity by investing heavily in commercial shrimp

[8] For Khulna the comparison is made with 2005 as the 2000 district poverty estimate is considered less reliable.

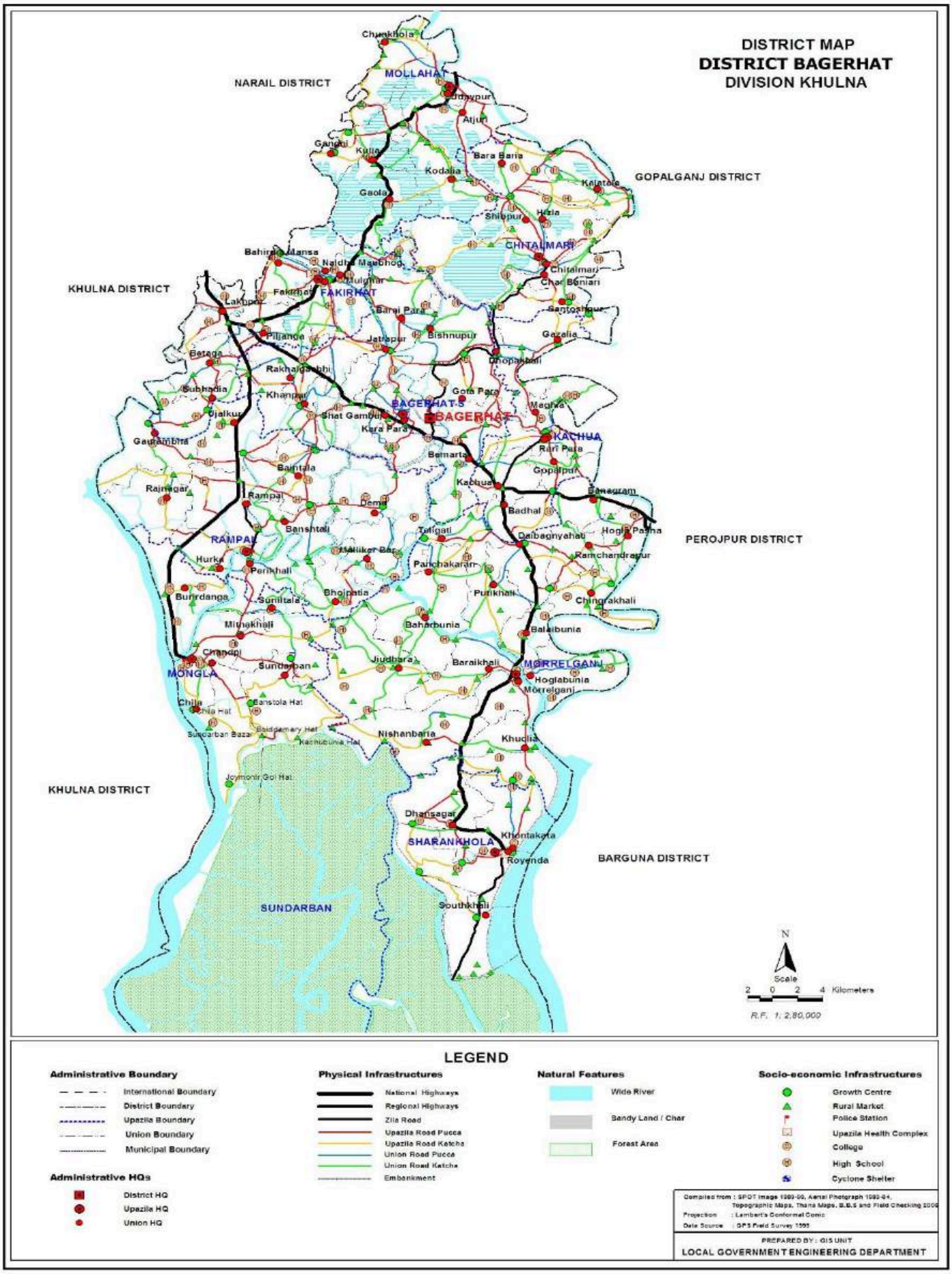
cultivation for exports. It is the third largest producer of shrimp in Bangladesh accounting for 19% of total shrimp production in FY2014. Third, it has been able to protect rice productivity relatively better than other coastal districts owing to the natural protection against sea level flooding provided by the Sunderbans as well as from investments in polderization.

An important policy question is why poverty incidence is so high, despite having the second highest per capita income? This is related to large income inequality. Upazillas like Koyra and Dacope are the most poor because they are located around the Sundarban forest with very limited economic options and are engaged in very low income activities. Other primarily rural Upazillas are heavily dependent upon crop agriculture. Shrimp farming is done though large scale commercial operations and have not percolated to the farmers except through wage employment. Income in the urban areas generally tends to be unequally divided. Much of the income is concentrated in the top 5-10% of the population. The urban areas are densely populated. The slump in the jute industry hurt Khulna employment prospects (Uddin et al 2014). There is considerable informal low income employment in the metropolitan areas. Limited good income opportunities for the working class and high population density explain much of the high concentration of urban poverty in Khulna.

2.5.6 *Bagerhat District*

Experience of Bagerhat: The district of Bagerhat is a coastal district located in the Khulna Division. Parts of the Sundarbans forest are located in Bagerhat. The second largest sea port of Bangladesh, the Mongla Port, is located in Bagerhat. It is also the largest commercial producer of shrimps in Bangladesh destined mostly for the export markets.

Bagerhat has converted its access to sea to its advantage with the location of the Mongla Port and the establishment of the largest export oriented shrimp industry. As a resulted, average per capita income in FY2011 was BDT 48,696 which was 29% higher than the national average and 6th highest among the 64 districts. However, despite high per capita income, Bagerhat has a large incidence of poverty. At 43%, the level of poverty in 2010 was 33% higher than the national average. The distribution of poverty shows that while there is substantial variance, poverty rates in all Upazillas exceed the national average. The poverty rate is particularly high in Chitalmari, Sarankhola, Morrelganj and Mollahat. Although the poverty rate is somewhat lower in the shrimp production centers of Fakirhat and Rampal, the rates are still very high.



Map 2.7: Bagerhat District Map

Source: LGED, Local Government Division, Ministry of Local Government, Rural Development & Cooperatives

Table 2.22: Upazilla Level Poverty Distribution in Bagerhat District

Upazilla	UPL 2010 (%)	LPL 2010 (%)
Bagerhat Sadar	35.9	18.6
Chitalmari	50.0	30.0
Fakirhat	36.4	19.2
Kachua	42.5	23.6
Mollahat	46.1	26.7
Mongla	41.9	22.7
Morelganj	46.5	27.0
Rampal	41.1	22.5
Sarankhola	48.0	28.2

Source: HIES, 2010

A part of the reason for high poverty is the continued strong reliance of many parts of Bagerhat to traditional agriculture. Sarankhola, located near the Sundarbans, has very limited economic opportunities. Overall, at the District level, average rice productivity is very low owing to the high incidence of salinity and water logging. The expansion of shrimp production as an adaptation to salinity has given Bagerhat considerable income but the distribution of the benefits has been very lop-sided. Both Khulna and Bagerhat have responded to salinity problem by adopting large scale commercially oriented shrimp farming. However, the distribution of benefits to the poor has not happened. This is an important lesson for future adaptation strategies. Owing to high incidence of poverty and low income opportunities, Bagerhat has lost population to other districts. Remittance inflows as a source of household income are modest partly because most of the outmigration has happened to other districts within Bangladesh. The share of foreign remittances is very small.

2.6 Concluding Remarks

This chapter sets the stage for developing Delta scenarios, macroeconomic projections and investment priorities by providing lessons of past experience with the Bangladesh Delta in terms of socio-economic outcomes. The chapter provides strong evidence about the adverse effects of natural disasters and climate change on welfare. It identifies the most vulnerable Hotspots and Districts where policy and investment interventions are most needed. It shows that progress has been made in adjusting to the vulnerabilities of the Delta. Most progress has been made in addressing the drought prone hazard risks based on heavy public and private investment in mechanized irrigation. Indeed, the large gap in average rice productivity between Barind and Drought Prone District (Naogaon) and the saline plus flood-prone district of Patuakhali strikingly illustrate the adaptation success (drought prone) as well as the adaptation challenges (coastal belt). Thus, while Naogaon produces on average of about 1.59 tonnes of rice per acre, Patuakhali produces a mere 0.72 tonne, which is 55% lower.

The Chapter also illustrates some other highly positive adaptation experiences that have important implications for strategy formulation and policy design. The importance of economic diversification for employment and income is indicated from the experiences of Barguna, Bagerhat, Bogura, Patuakhali and all the urban hotspot Districts. Of particular mention is the experience of the Chattogram District that faces many of the risks as in other coastal Districts, but has achieved both high per capita income and low poverty by adapting to many of these risks through industrialization, port development, commercial activities and investments in health, education, power and transport. The importance of adaptation within agriculture from primarily crops-based to crops plus fisheries and other higher value-added activities is indicated by the positive experiences in Barguna, Patuakhali, Khulna and Bagerhat. The positive role of foreign remittances is indicated by the experiences of Noakhali and Feni.

The experience of districts in the southwest coastal belt and the river and estuary region show the role of out-migration to other districts as a natural adaptation option facing the affected population. This provides some relief to the out-migration district but creates challenges in the urban cities of Dhaka and Chattogram who receive this population. The urbanization challenge is already acute in these two metropolitan areas. Other urban cities including Khulna, Barishal, and Patuakhali are facing similar urbanization pressures with high incidence of urban poverty. While this is partly the result of spatial inequality in the distribution of economic development and over time urban concentration and urbanization will continue to increase, the out-migration owing to natural disasters can be slowed substantially through proper policies and investments aimed at lowering the adverse effects of natural disasters and climate change.

Chapter 3
Climate Change, Environment and Ecological Issues

Chapter 3: Climate Change, Environment and Ecological Issues

3.1 Overview

Bangladesh is a sub-tropical country and its climate, environment and ecology is enriched with much diversified flora and fauna. Due to its geographic setting, mostly low lying deltaic landforms and close proximity to the Bay of Bengal, the country is one of the most vulnerable countries to climate change impacts. As noted in **Chapter 1**, due to climate change, Bangladesh is already experiencing increased temperatures, erratic rainfall pattern and distribution, sea level rise and salinity intrusion at an accelerated rate as well as increased disaster intensity. These will become even more pressing issues in the future. Furthermore, the environmental and ecological setting is facing additional pressure from rapid, unplanned urban and industrial development without sufficient environmental protective measures. With the growing economy, these issues will also become more intense in the future, if adequate policy measures are not taken.

While long term goals of achieving UMIC status, elimination of extreme poverty and job creation are a part of long term development strategy of the Bangladesh Delta, the protection of the environment and ecological balance are important elements of sustainable development and better quality of life. These objectives will have to go hand-in-hand and are also correlated. Long term income growth and extreme poverty elimination are an important component of a long term strategy to preserve the environment and the ecological balance. Unsustainable use of water, land and forest resources and destruction of the biodiversity are partly caused by poverty as the search for livelihood often creates tensions and conflicts between these two sets of objectives. Unsustainable use of natural resources and non-protection of the environment, ecological balance and biodiversity will reduce agricultural productivity and intensify the impact of natural disasters, thereby reducing the productivity of capital and GDP growth. This also identified some of the critical environmental, ecological and biodiversity issues. This Chapter builds on that discussion and provides in greater detail the nature of these major environmental concerns and ecological issues and also the nature of climate change risks. Therefore, this chapter focuses on what are the implications of those climate change factors for environment, biodiversity and ecology.

3.2 Climate Change: Challenges, Opportunities and Response Actions

Bangladesh is a disaster-prone country owing to its hydrological and geo-morphological realities. The remarkable development gained over the last few decades are being gradually eroded due to negative impacts of climate change. Given the evolving nature of climate change, the country has been facing extreme climatic events more frequently. These climatic events cause adverse socio-economic consequences to the affected people and therefore are a major concern for national socio-economic growth. Climate change will exacerbate many of the current problems and natural hazards the country faces. Fifth Assessment Report (AR5) of IPCC (Intergovernmental Panel on Climate Change) states that Bangladesh is among the countries that will be most at risk from extreme events. The Global Climate Risk Index 2016 analysed to what extent countries have been affected by the impacts of weather-related loss events (storms, floods, heat waves, etc.). This index ranked Bangladesh at 6th position among the most at risk countries from extreme events due to climate change.

The IPCC (AR5) warns that if global society continues to emit greenhouse gases at current rates and in the absence of robust climate mitigation policies, the average global temperature could rise by 2.6-4.8°C by 2100 (according to the IPCC's high emissions scenario). It also warns that global warming at the end of the 21st century is likely to be at least 1.5°C in all except the low-emissions scenario. Over the period 1901 to 2010, global MSL rose by 0.17 to 0.21 meter. Global MSL will continue to rise during the 21st century and it will rise by 26 cm–98 cm by the end of the 21st century. This will have consequences for South Asia's coastal settlements, as well as for coastal economies, cultures and ecosystems. Low lying, densely populated coastal areas in South Asia, including in Bangladesh, will be at increased risk of storm surges. Accordingly, approximately 40 million people of 70 Upazillas under 19 coastal districts of Bangladesh are under the direct threat of displacement being homeless. A recent study conducted by the DoE reveals that the overall trend of sea level rise in the coastal zone of Bangladesh in the last 30 years has been 6-21 mm/year (IWM 2008).

The major challenges of climate change are:

- **increasingly frequent and severe tropical cyclones,** with higher wind speeds and storm surges leading to more damage in the coastal region;
- **heavier and more erratic rainfall** in the Ganges-Brahmaputra-Meghna basins, including Bangladesh, during the monsoon season resulting in:
    - **higher river flows,** causing over-topping and breaching of embankments and widespread flooding in rural and urban areas as well as drainage congestion,
    - **river bank erosion** resulting in loss of homes and agricultural land to the rivers;
    - **increased sedimentation** in riverbeds leading to drainage congestion and water logging;
- **melting of the Himalayan glaciers,** leading to higher river flows in the warmer months of the year, followed by lower river flows and increased saline intrusion after the glaciers have shrunk or disappeared;
- **lower and more erratic rainfall,** resulting in increasing droughts, especially in drier northern and western regions of the country;
- **sea level rise** leading to submergence of low-lying coastal areas and saline water intrusion up coastal rivers and into groundwater aquifers, reducing freshwater availability; damage to the Sundarbans mangrove forest, a World Heritage site with rich biodiversity; and drainage congestion inside coastal polders, which will adversely affect agriculture.
- **warmer and more humid weather** leading to increased prevalence of disease and infections.

Over the last decades, the GoB with the support of development partners, has invested over $10 billion to make the country less vulnerable to natural disasters. These investments include flood management schemes, coastal polders, cyclone and flood shelters, and the raising of roads and highways above flood levels. In addition, the Government of Bangladesh has developed state-of-the-art warning systems for floods, cyclones and storm surges, and is expanding community-based disaster preparedness. Climate resilient varieties of rice and other crops have also been developed. The challenge Bangladesh now faces is to scale up these investments to create a suitable environment for the economic and social development of the country and to secure the well-being of the people, especially the poorest and most vulnerable groups, including women and children.

3.2.1 Observed Impacts of Climate Change in Bangladesh

Extreme temperatures, erratic rainfall, floods and droughts, more intense tropical cyclones, rising sea levels, and ocean acidification are causing serious negative impacts on lives and livelihoods of millions of people of Bangladesh, and gradually outweighing the remarkable socio-economic development gained over the past years. The Global Climate Risk Index (GCRI) 2010, covering the period 1990-2008, estimated that, on an average, 8,241 people died each year in Bangladesh while the cost of damage was around US $ 1.2 billion per year and loss of GDP was 1.81% during the period (MoEF, 2012). According to a study conducted by ADB, Bangladesh is projected to face 2.0% loss of annual GDP by 2050 and more than 9% of GDP by 2100 under the BAU scenario (Ahmed and Suphachalasai, 2014). IPCC (AR5) states that Bangladesh would experience a net increase in poverty of approximately 15% by 2030 (IPCC, 2014) due to the impacts of climate change.

Due to climate change, Bangladesh has been facing extreme climatic events like **cyclones** and **storm surges** with higher intensity and frequency. For example, mega cyclones Sidr in 2007 and Aila in 2009 caused huge losses and damages affecting a large number of people and consumed noteworthy budgetary resources in relief and rehabilitation, thereby constraining the country's development prospects by reducing resource availability for development activities. Cyclone Sidr caused thousands of deaths and damages to agriculture, estimated to be around US$3 billion (Hasegawa, 2008). The cyclone Sidr and Aila affected people have been fighting till today to recover the losses and damages incurred due to these extreme climatic events.

Floods are one of the major causes of crop devastation in Bangladesh almost every year. Devastating floods of 1987, 1988, and 1998 inundated more than 60% of the country (Ahmed and Suphachalasai, 2014). The 1988 flood inundated 61% of the country, estimated damage $1.2 billion, caused more than 45 million homeless (BCCSAP, 2009) . The 1998 flood alone caused 1,100 deaths, inundated nearly 100,000 square kilometers, rendered 30 million people homeless, damaged 500,000 homes (Ahmed and Suphachalasai, 2014), caused heavy losses to infrastructure, caused estimated damage $2.8 billion (BCCSAP, 2009) In 2004, floods inundated 38% of the country (Ahmed and Suphachalasai, 2014) and affected nearly 3.8 million people, caused 700 deaths, and estimated damage over $2 billion (BCCSAP, 2009). The 2007 flood inundated 32000 square kilometer, caused 640 deaths, destroyed over 85,000 houses and damaged almost 1 million houses, destroyed or partially damaged approximately 1.2 million acres of crops (BCCSAP, 2009). This flood caused damages of an estimated over $1billion. Every year, climate-induced natural disasters cause either partial or total loss of crops in different areas of Bangladesh.

Climate change is likely to have serious affect on agriculture (crops, livestock and fisheries) due to variability of meteorological parameters (precipitation, temperature), extreme events (floods, cyclones, and storm surges) and slow onset events (salinity intrusion, drought). The higher temperature and changing rainfall patterns, coupled with increased flooding, rising salinity in the coastal belt and droughts are likely to reduce crop yields and crop production, and expected to negatively impact food security and livelihoods in the country. Past **droughts** have typically affected about 47% of the area of the country and 53% of the population (Ahmed and Suphachalasai, 2014). About 5.46 million ha of land have been estimated as drought affected area in Bangladesh (DoE, 2005) while 1.06 million ha are salinity affected (SRDI, 2013).

The coastline of Bangladesh is 710 km long. The zone has diverse natural resources and contains several ecosystems that have important conservation value. It is known as a zone of vulnerabilities as well as opportunities. It is prone to natural disasters like cyclones, storm surges, floods and water logging. The coastal population is projected to grow to about 43.9 million in 2015 and 60.8 million in 2050 (Ahmed and Suphachalasai, 2014). If sea level rise is higher than currently expected and coastal polders are not strengthened and/or new ones built, millions of people could be displaced by 2050.

All of these changes threaten the food security, livelihoods, health and education of the poor. People living on river islands (Chars), along the coastline and floodplains and wetlands (baor) are among the poorest people in the country. Extremely poor households, including many female-headed households, will suffer most from climate change. Bangladesh government has been working hard to reduce the poverty level. The Government typically spends around 6% to 7% (MoP, 2012) of its annual budget on climate change sensitive activity which equates to around US$ 1 billion. Climate change impacts are seriously affecting Government's efforts in reducing the poverty level.

3.2.2 *Major National Responses to Tackle Climate Change Risks*

(a) Constitutional Provision of Bangladesh

Bangladesh Constitution was amended in 2011 to include a constitutional directive to the State to protect the environment and natural resources for current and future generations, and thus creating the path to achieve climate resilience sustainable development.

> ***Article 18A****: The State shall endeavor to protect and improve the environment and to preserve and safeguard the natural resources, biodiversity, wetlands, forests and wild lives for the present and future citizens.*

(b) Bangladesh Climate Change Strategy and Action Plan (BCCSAP)

Bangladesh Climate Change Strategy and Action Plan (BCCSAP, MoEF 2009) is a 10 year strategy for addressing climate change in Bangladesh. It was formulated under the direct guidance of Prime Minister Sheikh Hasina in 2009. This was one of the most credible initiatives of any developing country to address climate change in a comprehensive manner. Bangladesh Government adopted BCCSAP with the vision to eradicate poverty and achieve economic and social wellbeing through a pro-poor climate change resilience strategy. The BCCSAP 2009 was built on six themes/pillars, (Theme 1: Food security, social protection and health; Theme 2: Comprehensive disaster management; Theme 3: Infrastructure; Theme 4: Research and knowledge management; Theme 5: Mitigation and low carbon development; Theme 6: Capacity building and institutional strengthening) with 44 programmes. The current BCCSAP will expire in 2018. The MoEF is in the process of updating the BCCSAP.

(c) Bangladesh Climate Change Trust Fund

To implement the programmes and projects under BCCSAP, in the fiscal year 2009-10 the Government established Bangladesh Climate Change Trust Fund (BCCTF). Bangladesh is the first country to set up its own Climate Change Trust Fund from its own resources. The Government has allocated nearly $ 400 million (BD Tk. 3,100 crore) to the BCCTF. The following outputs have been achieved in the water resources sector:

- 16.4 kilometers of coastal sea dykes have been constructed;
- 352.12 kilometers of embankments have been constructed and 156.792 kilometers of river bank protective works completed;
- 872.19 kilometers of canals have been excavated/re-excavated and
- 65 water control infrastructures have been constructed.

(d) Nationally Determined Contributions (NDC)

In pursuant of Article 4 of the Paris Agreement, Bangladesh submitted its NDC on 25 September, 2015 and ratified the Paris Agreement on 21 September 2016.

Bangladesh NDC consists of 4 major elements;

1) Mitigation Contribution
2) Adaptation Component
3) NDC Development and Implementation; and
4) Support for NDC Implementation

Table 3.1 shows Bangladesh's determined contribution for reducing GHG emissions.

Table 3.1: Bangladesh's Determined Contributions for Reducing GHG Emissions

Contribution Type	Reduction in GHG Emissions
Unconditional contribution *(assuming no additional international support)*	Bangladesh will reduce its GHG emissions in the power, transport, and industry sectors by 12 $MtCO_2e$ by 2030 or 5% below BAU emissions for those sectors.
Conditional contribution *(assuming additional international support)*	Bangladesh will reduce its GHG emissions in the power, transport, and industry sectors by 36 $MtCO_2e$ by 2030 or 15% below BAU emissions for those sectors.

Source: MoEFCC, 2017

(e) Initiatives on Renewables

Solar Power: Around 4.4 million solar home systems (SHSs) across the country have been installed, meaning that almost 18 million beneficiaries are getting solar electricity which is around 11% of the total population of Bangladesh. According to Renewable Energy Policy of Bangladesh, government has a target to supply of 10% energy from renewable sources by 2020. Furthermore, the Government has exempted all taxes from the devices and equipments used for the utilization of renewable energy, in particular solar energy.

Improved Cook Stoves: In order to reduce emissions from biomass burning, more than 1.5 million Improved Cook Stoves (ICSs) have already been distributed to rural households.

Improved Rice Parboiling System: Government has taken initiatives to promote improved rice parboiling system in order to reduce carbon emissions and ensure energy efficiency. With the support of GIZ, initial survey and assessment of technology requirements have been assessed. DoE is in the process of preparing future investment project on rice parboiling.

3.3 Environmental Challenges in Bangladesh

There are many environmental challenges facing Bangladesh including water shortages, land degradation, deforestation, air pollution, as well as surface water and groundwater pollution. Water shortages and land issues are discussed in **Chapter 4**, **Chapter 6** and **Chapter 7**. The issues of surface water quality, groundwater quantity and quality and air pollution are discussed in this section. Forest issues are discussed along with other ecological factors in the next section.

3.3.1 Surface Water Pollution

Different parts of Bangladesh have distinct environmental features and are susceptible to different levels of environmental pollution and degradation. Those are mostly due to the establishment of different patterns of industries and population densities in different areas. The major causes of surface water pollution are related to land based activities, including industrial effluents, agrochemical usage, faecal pollution as well as oil and lube spillages. Since the rivers are frequently used as dumps, overall inland surface water quality drops below the permissible limit of Department of Environment (DoE) standards in the dry season whereas it improves in the wet/monsoon season due to dilution by rain and flood waters.

Industrialization has developed in the vicinity of the major rivers due to the facility of availability of water source, river navigation and easy dumping of effluents. Industrialization boom began in the early 1980s with the beginning of investments in the garments sector. However, most of the industries were unaware of the dangers of dumping effluents into rivers without any treatment. This has led to a serious degradation of river water quality over the years and it still continues today.

The main surface water parameters considered are the acidic level of water (pH), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). The analysis is based on river water quality data of 2012 and 2011 published by DoE (2012 and 2013). The pollution levels of the major rivers located besides the major cities of Bangladesh are shown in **Table 3.2**. By and large, the pollution level of rivers exceeds the safe levels for many of the indicators.

Bogura is one of the districts of Barind area where industries are rapidly growing due to government initiative to establish an economic zone. Besides, there are many medium size agro-equipment industry and brick kilns. The brick kilns are major point source of air pollution in the area. Bogura is situated beside Karatoa River and this river is heavily polluted by industrial and municipal effluents from the city. The pH of this river is over 7 and the DO is around 0.4 mg/l (Zakir et al., 2013). Jamuna is one of the major rivers of Barind and Drought Prone Areas. In wet season, it has pH of around 8.5 (Uddin et al., 2014), which is well above the standard value of 7.

Table 3.2: Water Quality Indicators of Selected Rivers

Parameters					
Sl. No.	Rivers	pH	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)
1	Buriganga	6.58-7.98	0-5.7	0.6-35	4.83-124.3
2	Shitalakhya	6.66-7.97	0-5.5	2-16	0.8-18
3	Turag	6.14-8.79	0-5.9	1.86	17-233
4	Meghna	6.5-7.47	4.7-8.1	1.0-7.0	3.8-58
5	Jamuna	6.5-7.84	5.0-7.6	0.3-5.2	11-15
6	Padma	7.25-7.69	5.8-8.5	2.1-3.3	163.5-1569.5
7	Kirtonkhola	7.1-7.5	6.5-7.1	1.1-2.5	2.0-4.75
8	Passur	7.54-8.2	5.0-6.8	0.8-1.2	<200
9	Rupsha	7.72-8.5	5.1-6.7	0.7-1.2	20-22
10	Moyuri	7.52-8.0	0.4-3.8	6-20	46-676
11	Karnaphuli	7.0-8.2	5.1-5.8	9.0-144.5	109-489
12	Halda	6.92-7.9	5.3-7.2	0.2-0.45	8.0-105
13	Surma	6.4-7.6	5.2-6.7	1.6-32	32-138

Typical reference values: pH: 7; DO: >3.5; BOD5: <1; COD: >200

Note: Reference values of pH, DO & BOD of inland surface water for fisheries according to Environmental Quality Standards (EQS) of Environmental Conservation Rules 1997. Environmental Quality Standards (EQS) of COD is for wastewater after treatment from industrial units.

Source: DoE, 2012 and 2013

As a result of continuous pollution, environment of the Barind and Drought Prone Areas is under stress. The water of this hotspot is seriously affected by contamination of heavy metals (Cd, Cr, Cu, Fe, Pb, Ni, Zn, etc). If the pollution continues at this rate, in future it will cause a great harm to the people and aquatic life dependent on these rivers. This pollution is concentrated around the industrially developed and urban areas. In the rural areas, the rivers have much better water quality. However, with the increasing industries and urban population, such polluting trends will result in severe disastrous situations.

The Urban Areas Hotspot is becoming heavily industrialized with most of the existing industries located in Dhaka, Narayanganj, Narsingdi and Chattogram. Buriganga and Turag River are the two major rivers of Dhaka. They are most susceptible to water pollution as tannery (24 nos.), fabric dying and chemical processing (34 nos.), fabric washing (68 nos.), garments (1,621 nos.), plastic products (50 nos.) industries are located on the banks of these two rivers (CEGIS, 2015). Dumping of untreated effluent has caused major degradation of water quality of these rivers. In many places sewerage lines end up in this river carrying sewage and municipal solid wastes. The pH of Buriganga river is around 7 (Saifullah et al, 2011) and Turag river is between 6.18 and 7.46 (Mobin et al., 2013). The DO varies along the stream of Buriganga. In wet season DO is around 4.9 mg/L and in dry season around almost 0 mg/L. The BOD of Buriganga River is over 25 mg/l in most places and it can go up to 38 mg/l (Saifullah et al., 2011). Also, the COD level is very high indicating severely contaminated water.

Mymensingh and Netrokona Districts are beside the Old Brahmaputra River. There are 712 industries in Mymensingh. The pH of surface water of Mymensingh is over 6 in most of the locations and DO is around 4.5 mg/l (Ferdous et al., 2015).

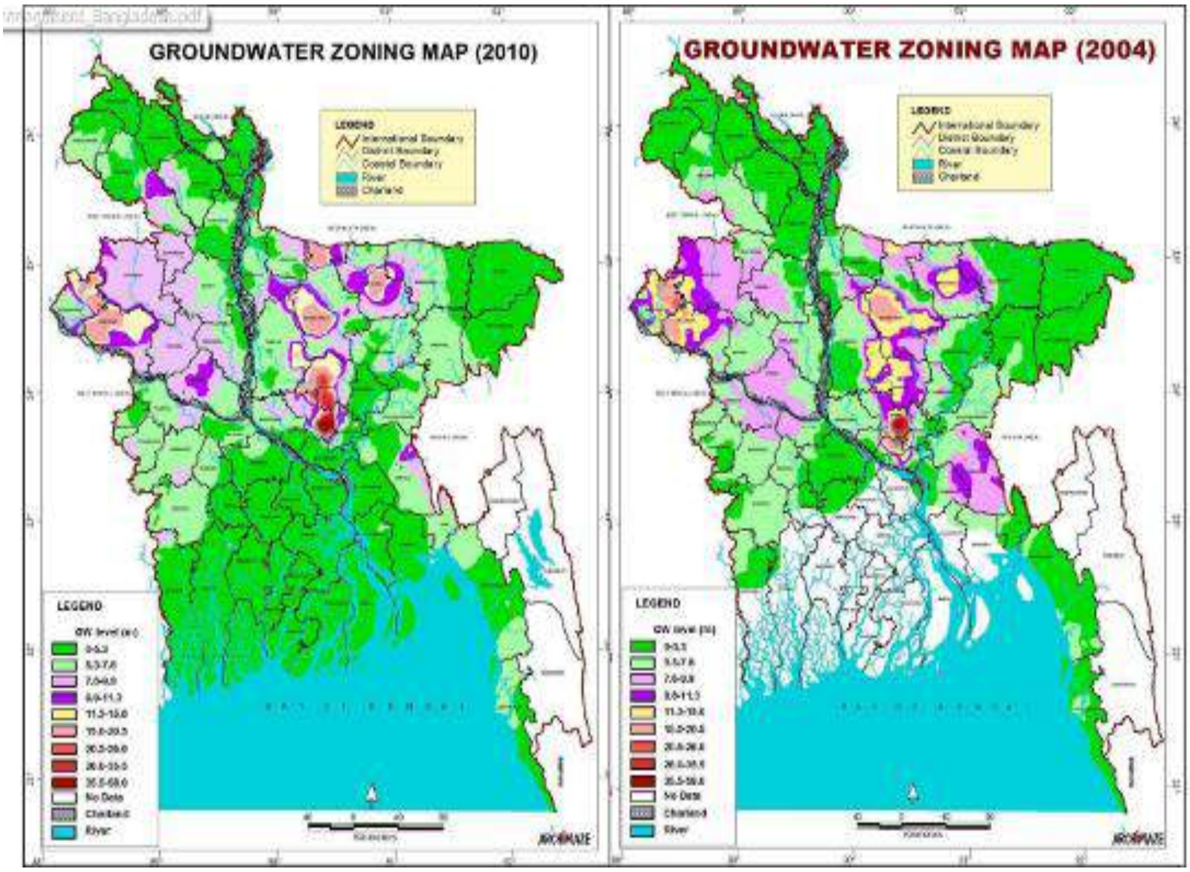
Haor and Flash Flood Area of Bangladesh has the highest annual average rainfall. Of this hotspot, Sylhet is one of the rapidly developing urban areas in the hilly region of the country. Gas based industries have boomed in Sylhet region. Surma and Khushiara are the two main rivers of this Hotspot. The unplanned urbanization of Sylhet city is a threat for the environmental quality and economic gains of the city dwellers. The pH of river water in this region varies between 6.5 and 8.5, DO value varies between 5.28 mg/l to 6.88 mg/l and BOD ranges from 27.33 mg/l to 44.33 mg/l (Rahman et al., 2013).

The main cities of west part of Coastal Zone are Kushtia, Jashore, and Khulna. Khulna is a port city and it has a direct navigation route to Bay of Bengal. This hotspot has various natural resources including marine fisheries and shrimp, forest, salt, minerals and potential onshore and offshore natural gas. Shrimp industries have boomed in this Hotspot due to the abundance of shrimp fry in the Bay of Bengal and creeks and rivers near the coast (Haque et al., 2010). The major rivers of this hotspot are Padma, Gorai-Madhumati, Chitra, Rupsha, Kaliganga, etc. Shrimp culture is the common practice in this area. Usually the water has higher salinity in the areas where shrimp farms are located. The pH of surface water varies from 7.29-7.46 in summer season which is higher than the groundwater pH (6.46-6.71). However, pH of both surface and groundwater was found to be slightly lower during the rainy season. The salinity of the groundwater was higher than the surface water both in the summer and in the rainy seasons. The average groundwater quality of the area is not good (Haque et al., 2010). Most of the shallow aquifers in this hotspot are found to be saline. People can get fresh water where deep tube well technology is available.

The eastern part of Coastal Zone is comprised of some of the biggest industrial cities of the country. The major industrialized cities in this hotspot are Chattogram and Cumilla. Meghna is one of the major rivers of this region. The other rivers of this region are the Gumti, the Titas the Karnaphuli and the Dakatia. Chattogram is industrially developed due to its large sea port. Ship breaking industry plays a significant role in this region's environmental quality. Ship dismantling is a reason of concern due to its economic values and environmental hazards. Annually, up to 2.2-2.5 M tonnes of national steel production comes from the ship breaking industry (Talukder et al., 2015). The DO of the rivers in this region is between 4-6 mg/l and pH is around 7 (Ahmed et al., 2010). The ship breaking yard has profound effect in its surrounding area. In the perimeter of the ship breaking yard area, DO level is low (1-5 mg/l) at some points and the pH is around 7. As ship breaking industry has a significant impact on the economy ,it is important to mitigate the adverse environmental effect of this industry by taking sustainable measures. Salinity is also a problem of central part of Coastal Zone as like the southwest region. As a result, shrimp culture has intensified in some of the southern districts.

3.3.2 Groundwater Quantity and Quality Issues

Groundwater is the major source of water supply and irrigation in Bangladesh. Some 80% of irrigation originates from groundwater (FAO Aquastat, 2011), particularly for the cultivation of Boro rice. Groundwater quality exhibits both seasonal and spatial patterns. Generally water quality degrades from wet to dry season and spatially from the North to South and South Western parts of Bangladesh. Bangladesh is underlain by a deep aquifer system with both deep and shallow groundwater resources (CSIRO, 2014). Groundwater levels are at or near ground level during the period August-October and lowest in April-May. Groundwater rises as a result of recharge starting fom May and usually reaches its highest in late August each year. Between September and October groundwater levels are constant and maintain a balance between surface water levels and the fully recharged aquifers. Groundwater levels fall from October in response to rapid drainage of surface water and changes in base levels. The rate of fall is highest in October-November but equally large changes may take place after January when withdrawal of groundwater for irrigation starts. During the dry season most of the minor rivers are sustained by groundwater outflows. The groundwater zoning map of Bangladesh is shown in **Map 3.1**.



Map 3.1: Groundwater Zoning Maps of Bangladesh, 2004 and 2010

Source: Bangladesh Agricultural Development Corporation (BADC), 2011

Dhaka city extracts large amount of groundwater for urban water supply. Therefore Dhaka has lower groundwater levels both in the pre- and post-monsoon seasons than other regions. The groundwater table in Barind is also relatively low compared to other regions due to excessive irrigation abstractions. Nation-wide comparison of the water tables from the 2004 and 2010 groundwater zoning, carried out by BADC, shows an increase of deep groundwater levels, as illustrated in **Table 3.3** and **Map 3.1**. A good indication can also be derived from the analysis carried out as part of the recent Integrated Water Resource Assessment (CSIRO, 2014) showing that both pre- and post-monsoon levels show declining trends. Although further detailed research is needed, at the present rate of abstraction and recharge, groundwater use in many areas is not sustainable.

Table 3.3: Areawise Comparison of Groundwater Tables 2004-10

GW Level (m)	Area in 2004 (km^2)	Area in 2010 (km^2)	Difference	Percentage %
0.1-5.3	41,958	35,769	6,189	14.75
5.3-7.6	31,778	34,671	2,893	9.10
7.6-9.8	14,441	13,691	750	-5.19
9.8-11.3	5,503	6,849	1,345	24.44
11.3-15.0	4,812	5,099	287	5.96
15.0-20.5	1,464	3,787	2,323	158.73
20.5-26.0	200	452	251	125.47
26.0-35.5	112	209	96	85.77
35.5-60+	76	91	15	19.80
River	10,856	10,856	0	0
RHF	31,836	31,836	0	0
Char Land	4,260	4,260	0	0

Source: BADC, 2011

Due to high spatial and temporal variability in surface water availability and quality, groundwater is increasingly used to meet domestic, industrial and irrigation purposes. The quality of groundwater resources is a serious concern in Bangladesh. In absence of required quantities of surface water, farmers overexploit groundwater for irrigation and other uses, resulting in exposure of arsenic in groundwater. Use of arsenic contaminated groundwater is a serious public health issue in some areas. Although the most important quality concern is arsenic, but iron, manganese, boron, barium, uranium, bacterial contamination and nitrate and other trace metals also pose serious challenges in different parts of Bangladesh (Khan and Siddique 2000; BGS and DPHE, 2001).

The groundwater of Bangladesh is heavily contaminated with Arsenic. Some 61 of 64 districts in Bangladesh have arsenic levels above 0.05 mg/L (NWMP, 2004). The people in 59 out of 64 districts comprising 126,134 km^2 of Bangladesh are suffering due to the arsenic contamination in drinking water. An overview of arsenic contamination in the groundwater of Bangladesh (Hossain, 2006) is represented in the **Figure 3.1**.

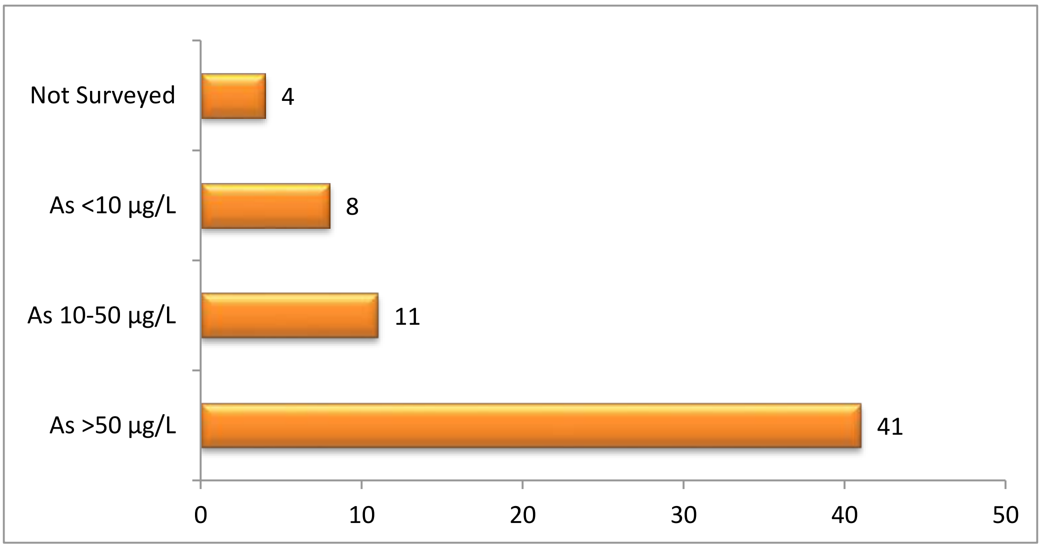


Figure 3.1: District-wise Incidence of Arsenic Poisoning

Source: Hossain, 2006

Among the hydrologic regions, the south east (SE) and south central (SC) regions are worst affected by arsenic. The groundwater of Cumilla (1.7 mg/L), Chandpur (1.3 mg/L), Feni (1 mg/L) are well above the standard for Bangladesh which is 0.05 mg/L. Among the districts of central part of coastal zone, Faridpur (0.16 mg/L), Madaripur (0.12 mg/L), Barishal (0.18 mg/L) are heavily contaminated with arsenic. Though the southwest region is in a relatively better state than the other two regions. Khulna has an arsenic contamination of 0.31 mg/L. The arsenic contamination in Haor and Flash Flood Area is in the range between 0.022 mg/L to 0.09 mg/L. Dhaka's groundwater has arsenic contamination of around 0.035 mg/L where as Narayanganj has up to 1.76 mg/L of arsenic in the groundwater. The eastern portion of coastal zone has overall good quality of groundwater in terms of arsenic within ranges between 0.013 mg/L to 0.02 mg/L (Hossain, 2006).

As evident, arsenic poisoning presents a serious health threat to a large segment of the population. Flanagan et al. (2012) reports that over the next 20 years arsenic-related mortality in Bangladesh (1 of every 18 deaths) could lead to a loss of US$ 12.5 billion assuming a steady economic growth and an unchanged population exposure to arsenic contamination.

3.3.3 Air Quality

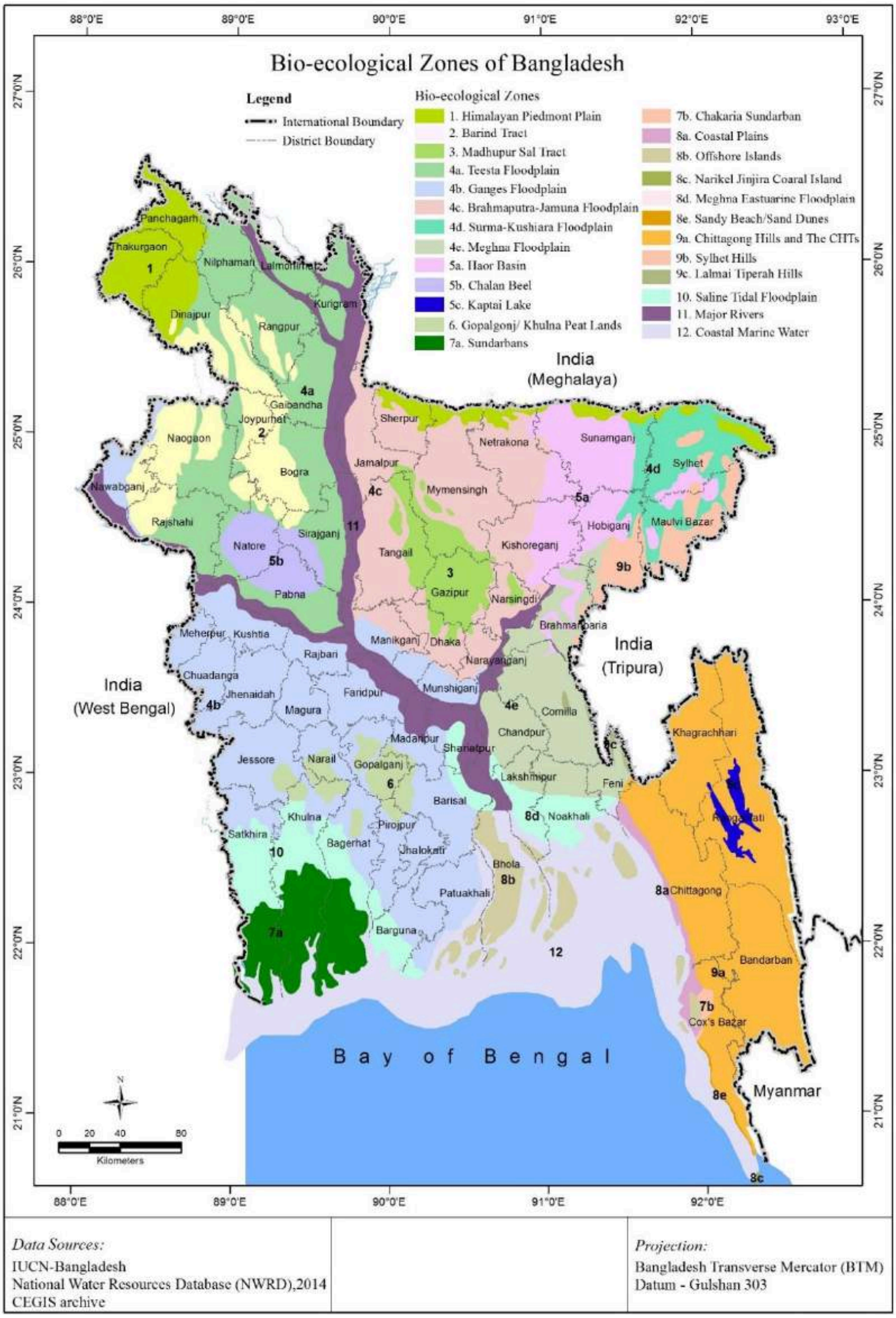
Air quality is an important parameter for overall environmental condition of an area. Air pollution in Bangladesh is mainly happening due to emission of black carbon from vehicular emission, brick kilns and industries as well as dust pollution due to constructions and vehicular movement. The two major air quality parameters are PM (particulate matter) 2.5 and PM10. The national ambient air quality standard for these two parameters are 65 and 150 μg/m^3 (24 hour average), respectively. There are 11 continuous air quality measuring stations in 8 cities in Bangladesh. All of them show that the PM2.5 and PM 10 concentrations are higher than the standard value during dry season, which is dangerous for the environment and public health. Only Haor and Flash Flood Area is comparatively safer than the other hotspots. However, other air quality parameters like CO, SOx, NOx, O_3 are within national standard almost round the year.

Urban Areas Hotspot is most affected by air pollution. Air quality of Dhaka is deteriorating because of high concentration of particulate matter. Dhaka has been densely populated over the years with unplanned urbanization and industrialization. Many industries do not follow any guideline while emitting gases and smoke into the environment that has led to a degradation of the air quality. Chattogram has highest amount of steel industries, which emit a significant percentage of black carbon. There are several hundreds brick kilns around Dhaka city and a huge number of kilns are located in the western side adjoining the Turag River. Brick kilns are a major point source of air pollution in the region.

Haor and Flash Flood Areas have overall better air quality. It may be because of lack of industries and also for having greater number of trees compare to other regions. Chattogram Hill Tracts have also better air quality compared to the Urban Areas.

3.4 Ecology

Bangladesh is located in the complex interface of the Himalayan and the Southeast Asian Bio-geographical region. This country has different types of ecosystems, which support rich biodiversity. Torrential rains, regular flow from upper Himalayan, Meghalaya hilly terrain and regular tidal flow from the Bay of Bengal created an exceptional diversified ecosystem. The major rivers and the surrounding areas comprise different landforms like floodplain, char land, swamp forest, homestead, canal, baor, haor, beels, etc. The landforms have varied vegetation patterns which create diverse habitats for different wildlife. As a result, Bangladesh has several internationally recognized biodiversity hotspots like the Sundarbans, Tanguar Haor, and Sonadia Island.



Map 3.2: Bio-ecological Zones of Bangladesh

Source: CEGIS, 2014

On the basis of physiographical, hydrological, meteorological, and ecological features, the IUCN (2002) has delineated 25 bio-ecological zones for Bangladesh: i) Himalayan Piedmont Plain; ii) Barind Tract; iii) Madhupur Sal Tract; iv) Teesta Floodplain; v) Ganges Floodplain; vi) Brahmaputra-Jamuna Floodplain; vii) Surma-Kushiara Floodplain; viii) Meghna Floodplain; ix) The Haor Basin; x) Chalan Beel; xi) Kaptai Lake; xii) Gopalganj-Khulna Peatland; xiii) The Sundarbans; xiv) Chakaria Sundarbans; xv) The Coastal Plains; xvi) Offshore Islands; xvii) Narikel Jinjira Coral Island; xviii) Sandy Beach/Sand Dunes; xix) Chattogram and the CHT; xx) Sylhet Hills; xxi) The Lalmai-Tipperah Hills; xxii) The Saline Tidal Floodplain; xxiii) Major Rivers; xxiv) Coastal Marine, and xxv) Meghna Estuarine Floodplains. The Bio-ecological zones of Bangladesh are shown in **Map 3.2**.

For analytical purposes, the ecosystem of the country can broadly be divided into 2 categories; aquatic ecosystem (coastal and marine water, river, haor, baor, beels, floodplain, canal, mangrove and freshwater swamp, estuary, marine, etc.) and terrestrial ecosystem (homestead, forest, roadside, crop field, etc.).

3.4.1 Aquatic Ecosystem

As a part of a deltaic region, aquatic ecosystem is the prime feature of the country's ecological settings. The aquatic ecosystem of the country is derived from river hydrology and water characteristics (freshwater and saline water). Hence, the aquatic ecosystem can be divided as fresh water and saline water ecosystems. Except Coastal Zone, Bangladesh has a vast freshwater riverine area including perennial channels, floodplains, char lands, backwater swamps (Haor), etc.

Fresh water riverine system: More than two thirds of the country may be classified as wetlands according to the definition enunciated in the Ramsar Convention (IUCN, 2005). On the basis of salinity, the wetlands of Bangladesh can be broadly classified into the inland freshwater and tidal brackish water wetlands (**Table 3.4**). Floodplains, *beels*, *haors* and *baors* are the parts of the inland freshwater wetlands category. These wetlands support a diverse category of flora and fauna and millions of people depend upon them for their subsistence and income. However, these aquatic resources have been subjected to rapid degradation due to the increasing population pressure, habitat destruction and other anthropogenic as well as natural causes. The Government formulated the National Environment Management Action Plan (NEMAP) to reverse this degrading trend. It was a cost-effective process and tries to ensure people's participation in national planning.

Rivers are the major type of natural wetlands in Bangladesh. Intricate networks of rivers contribute to drainage as well as flooding its surrounding areas and performs ecosystem sustainability. Many species of fish, invertebrate, algae and birds depend on the riverine ecosystem. For example, the riverine ecosystem supports the complete life cycle of different species of tern, skimmer, ducks, otter and Ganges River Dolphin. Rivers are the major breeding habitats of inland fisheries. The Halda River is the only natural source for Carp breeding in Bangladesh.

Table 3.4: Types of Wetlands and their Estimated Area during the Wet Season

Wetland types	Area ('000 ha)
Permanent rivers and streams	480
Estuarine and mangrove swamps	610
Shallow lakes and marshes	120-290
Large water storage reservoirs	90
Small tanks and fish ponds	150-180
Shrimp ponds	90-115
Seasonally-flooded flood plains	5,770

Source: A directory of Asian wetlands, 1989

Floodplains are the landforms which are inundated in each monsoon and cover a large portion of the country. Vegetation of the floodplains is changing its forms with fluctuation of water level and supports numerous species of fishes, molluscks and birds. This type of seasonal wetland is dominated by grasses and rooted floating plants. Floodplains are the main location for agriculture in Bangladesh and are highly variable in nature and depth of flooding. Floodplains contain some depressions as well as *beel* area, which hold water for whole of the year. In Bangladesh, *beels* are the common forms of wetlands over the country. *Chalan Beel* is one of the largest in the country and comprises a series of depressions interconnected by various channels to form more or less one continuous sheet of water in the rainy season when it covers an area of about 368 km^2. The *Chalan Beel* is rapidly silting up. During the last century and a half, it has shrunk at least 19.32 km from the southern side due to annual deposits of silt from the Ganges. Deterioration of its other feeder rivers like the Gur and the Baral are also major contributory factors in reducing the size of the beel.

Haor is another type of ecosystem that depends on seasonal inundation and variation of land elevation. This is an important reservoir of natural resources in the northeast region of Bangladesh. *Haor and Flash Flood Areas* is located in between two major ecosystems/biomes like foothills and plain lands. *Haor* is the habitat of fresh water swamp forest with flood-tolerant evergreen trees. The total area of haor-type wetland ecosystem in Bangladesh is 80,000 km^2 (IUCN Bangladesh, 2007). Tanguar Haor and Hakaluki Haor are the two important and major wetland systems in the country, which were declared as Ecologically Critical Area (ECA) by the Government in 1999. These two haors are located in the greater Sylhet region.

Kaptai Lake: This is an artificial waterbody created by a dam, which was constructed in 1962 and has since flooded over 68,800 ha of forest valleys and arable land in Chattogram and the Chattogram Hill Tracts (CHT) Districts. This wetland is surrounded by evergreen forests. However, the aquatic diversity of this lake is not well known. Aside from the immediate ecological damages such as inundating croplands, villages and forest, the lake has had far reaching ecological consequences since its creation. This includes loss in natural habitats for native flora and fauna as well as downstream salinity issues along the Karnafuli River.

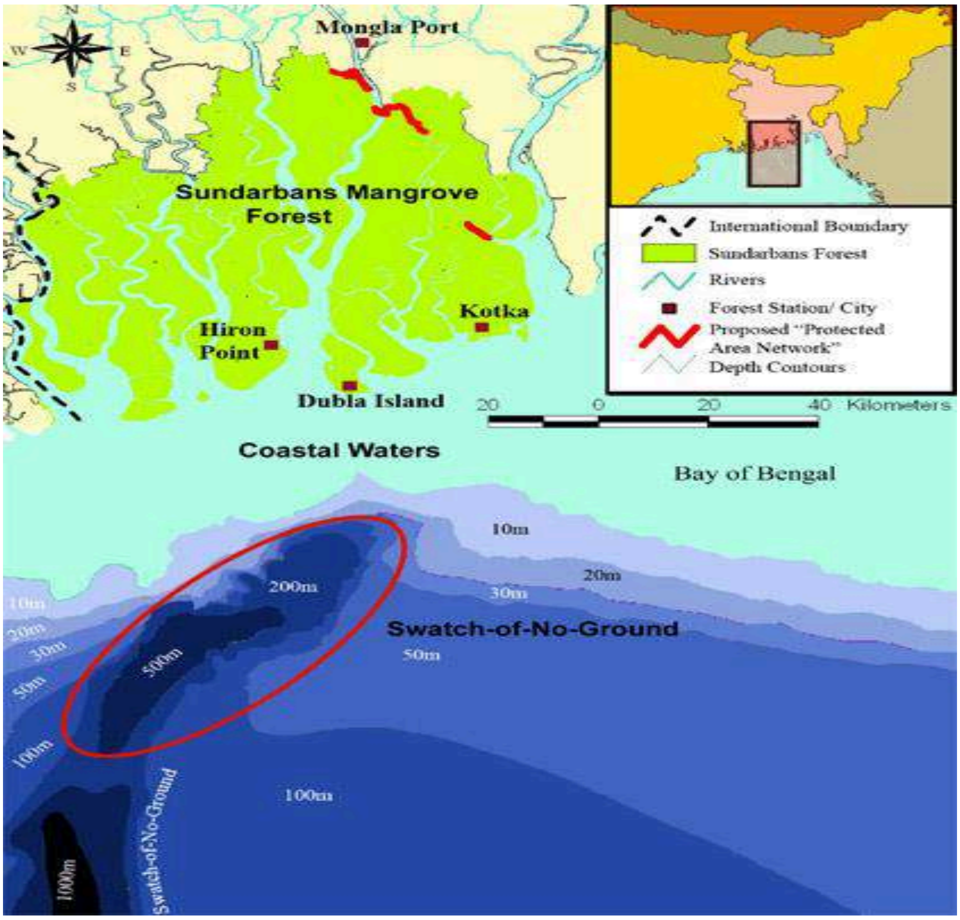
Char lands: The river channel is continuously shifting within its active floodplains, eroding and depositing large areas of new char lands in each flooding season. A good succession of plants and animals in new char lands has been observed. Chars are good habitats for some of the avian fauna and amphibians because of noise and disturbance-free conditions. Char lands support a good number of avifauna like cisticola, prinia, warblers, grassbirds, larks, pipits and munias. Char lands also support numerous mollusks, which are the feed for water birds, fishes and other aquatic faunal species. The pattern of succession depends on how long the char land has been permanent. A major part of these char lands are seasonally inundated in monsoon and deposit more sand on the land surface. During dry season, large portions of the land are used for paddy, maize, sugarcane and groundnut cultivation.

Saline water ecosystem: Among the saline water area, mangroves, tidal rivers and marine estuaries are the major phenomena of aquatic ecosystems.

Mangroves: Mangrove ecosystems exist along intertidal areas of southwest and south-central parts of the country. Sundarbans Reserve forest is the largest mangrove forest of the world that extends over an area of about 6,017 Km^2. A part of the Bangladesh Sundarbans, an area of about 1,39,700 ha under three wildlife sanctuaries, was designated as the 798th World Heritage Site (WHS) by UNESCO in 1997 and classified as natural heritage.

The floristic composition of the Sundarbans is rich compared to many other mangrove areas of the world. Historically, the existence of 334 plant species belonging to 245 genera of 37 families from the then Sundarbans and its surroundings has been reported. Of these, not fewer than 123 are available in the present reserved forest of the Bangladesh Sundarbans. Among the plants found in the mangroves of the Sundarbans, 28 out of 70 are true mangroves. The Sundarbans mangroves of Bangladesh are dominated by the Sterculiaceae and Euphorbiaceae. Sundari (*Heritiera fomes*), Gewa (*Excoecaria agollocha*) and Goran (*Ceriops decandra*) are the three most important commercial species in the Sundarbans. Sundari constitutes about 65% of the total merchantable timber. The loss and degradation of faunal diversity are also serious. Sundarbans is the habitat for *Royal Bengal Tiger* and according to Tiger Census 2005, there are 116 tigers residing in the Sundarbans of Bangladesh. Tiger preservation is a major challenge.

Bangladesh declared its first Marine Protected Area (MPA), **Swatch of No Ground**, located in the Bay of Bengal at the head of a submarine canyon. It spans approximately 672 square miles (1,738 km^2) and depth to the seafloor topography varies from 900 to 1459 m with 100-150 m thick levee sediments deposited on both the edges of the canyon as seafloor swells spreading over a distance of 10-20 km.



Map 3.3: Swatch of No Ground - Bangladesh's First Marine Protected Area

Source:WMF, 2014

The Swatch of No Ground is a highly biologically productive area created by upwelling currents and supports large groups of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), pantropical spotted dolphins (*Stenella attenuata*) and spinner dolphins (*Stenell alongirostris*), as well as a possible resident population of Brydes whales (*Balaenopter aedeni*). It is a key breeding and spawning ground for dolphins, whales, sharks and turtles. The marine protected area was established for the long term protection of cetaceans that inhabit waters offshore of Bangladesh

The Sundarbans and its southern face up to the Swatch of No Ground in the Bay of Bengal is Bangladesh's dolphin-whale gold mine. Ganges River Dolphin (*Platanista gangetica*), Indo-Pacific hump-backed Dolphin (*Sousa chinensis*), Irrawaddy Dolphin (*Orcaella brevirostris*) and Finless porpoise (*Neophocaena phocaenoides*) have made Sundarbans as their home. The Bangladesh Sundarbans is the only place in the world where both Ganges River Dolphin and Irrawaddy Dolphins species live together. In Bangladesh, possibly the largest population of Ganges River Dolphin lives in the Sundarbans and the world's largest population (about 6,000) of Irrawaddy Dolphins lives in the Sundarbans and adjacent coastal waters.

Coastal and marine ecosystems: Bangladesh is best known for its extensive coastal and marine ecosystems. A huge number of offshore islands are scattered in the Bay of Bengal. Saint Martin's Island is the only coral bearing island of the country, and therefore it is of significance in the context of coastal and marine ecosystems. Estuarine flood plains, sand dunes and beaches characterize the coastal ecosystems of Bangladesh. The Meghna flood plains of Noakhali and Lakshmipur districts are inundated by saltwater, seasonally, which attracts a wide variety of birds, including migratory ones. Rare species of birds including the globally critically endangered Spoon-bill Sandpiper and Indian skimmer (*Rhynchops albicollis*) visit this ecosystem. The beaches and sand dunes also attract sea turtles. This extensive open water ecosystem extends southwards into the Bay of Bengal. The coastline of Bangladesh is 714 km long and can be broadly divided into three regions: the eastern region (Pacific type), the active delta of the central region, and the stable deltaic western region (Atlantic type). The Bay of Bengal occupies an area of about 2.2 million km^2 and the average depth is 2,600m with a maximum depth of 5,258 m.

Sonadia is a small crescent shaped island located in the far southeastern corner of Bangladesh at 21° N and 91° E and its area is 9 km^2. This island lies a few kilometres north of Teknaf Peninsula, 7 km northwest of Cox's Bazar town. The island is a wildlife paradise, with beauty waiting around every corner, proving that sometimes there is more to a destination than meets the eye. The western part of this Island is sandy and different types of shells including window pane oysters are found on the beach. Sonadia Island and the majority of the adjacent Ghotivanga mouza were declared an ECA under the Bangladesh Environment Conservation Act (BECA) (1995). Bird Life International has declared the island its 20th Important Bird Area (IBA). This island is an important wintering ground for Critically Endangered Spoon-billed Sandpipers that fly over 8,000 km from their breeding ground in Eastern Russia. Experts think there are fewer than 400 mature Spoon-billed Sandpipers left in the wild, and nearly 10% of them can be found at Sonadia Island in the winter. Beside this, globally Endangered Nordmann's Greenshank, as well as other threatened birds such as Great Knot, Asian Dowitcher, Eurasian Curlew and Black-tailed Godwit, several marine turtles and dolphins have habitat in this island.

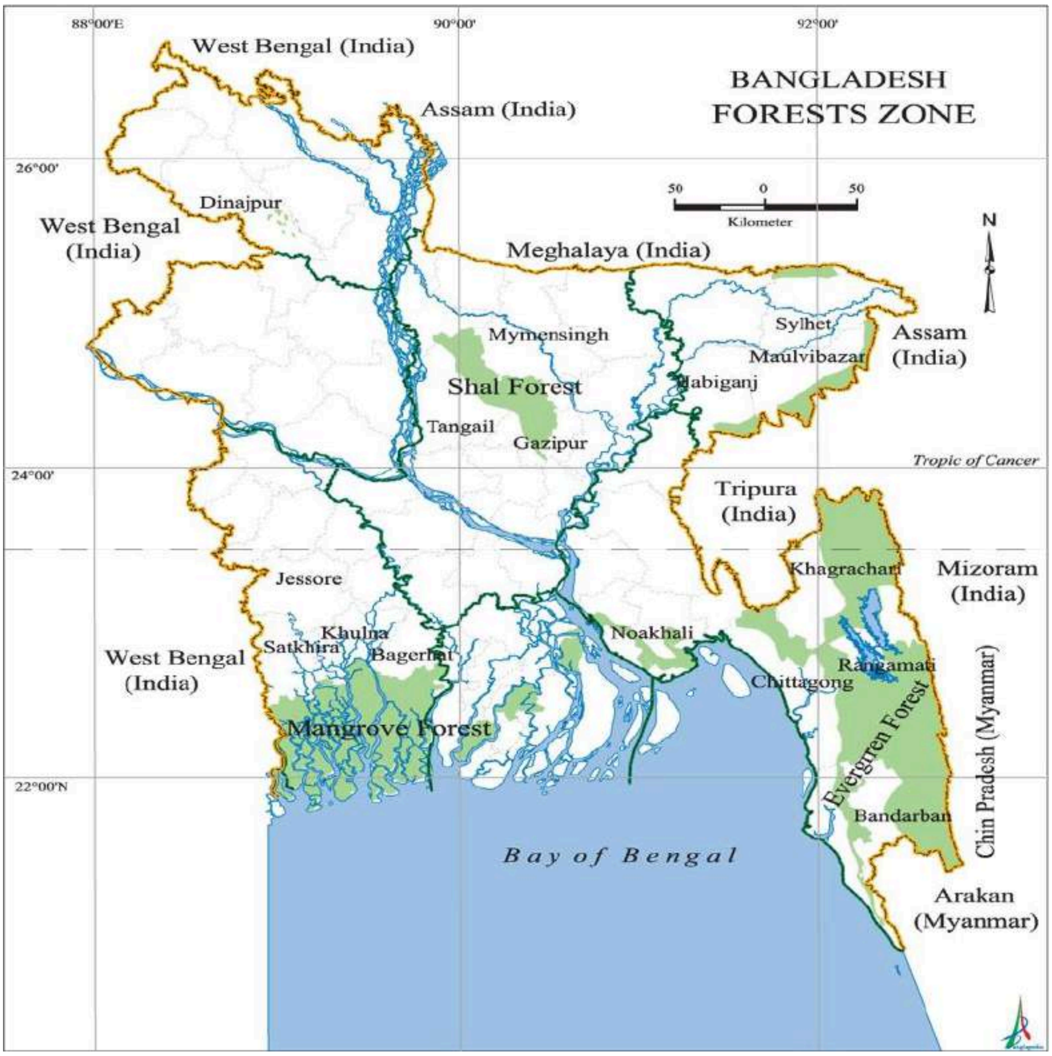
3.4.2 Terrestrial Eco-systems

A large area of the country is occupied with settlements, forests and agricultural lands represent the terrestrial ecosystems. Ecologically, Bangladesh delta is represented by five broad natural forest types: (1) tropical wet evergreen on eastern and northeastern hills (2) tropical semi-evergreen on eastern hills, (3) tropical moist deciduous/ sal forests on central and north western terraces, (4) mangrove forests facing the sea and (5) freshwater swamp forests in low lying areas of Sylhet. In addition, there are planted homestead forests, rubber plantation, and embankment/roadside plantations. In Bangladesh, the forests are distributed on the eastern hills, central and north western terraces and the mangroves facing the Bay of Bengal (**Map 3.4**).

In Bangladesh, homesteads cover about 20% (2.767 million ha) of the total land, of which 10% is covered with trees (National Forest and Tree Resources Assessment 2005-07) and the rest is covered with homestead vegetation, which is important for its wild shrubs and herbs as well as locally cultivated plants and as wildlife refuge. The site lower than homesteads but a little higher than the adjoining agricultural fields is locally called 'kanda'. Long ago, the kandas were occupied by swamp forest, reed swamps and grass. The village roads, highways and embankments provide a good habitat for woody and fruit yielding plants. Coastal embankment plantation has long been in practice in southern Bangladesh.

Forests: In Bangladesh, forests are distributed on the eastern hills, central and northwestern terraces and the mangroves facing the Bay of Bengal (**Map 3.4**). In addition to embankment/roadside plantations, there are rubber plantations. The Madhupur Sal Tract extending across the districts of Gazipur, Tangail and Mymensingh contains important timber species. However, 70% of the Sal forest area is either already degraded or encroached. Records show that the Bengal Tiger (*Panthera tigris*) and One-horned Rhinoceros (*Rhinoceros unicornis*), both of which have become extinct from this zone now, had healthy populations in the past. The Bengal monitor (*Varanus bengalensis*) and other common lizards inhabit in scattered patches of jungle throughout this zone. Among snakes, Madhupur Sal tract is a suitable habitat for cobras. In terms of diversity of bird species, this zone is still relatively rich.

The Chattogram Hill Tracts is composed of Tropical Evergreen and Semi Evergreen forests. The lower canopy consist mainly of evergreen species, and the upper canopy of the forest is Deciduous type (IUCN 2002). Tropical Evergreen Forest is found in the valleys of this zone. Knowledge on the diversity of Reptiles and Amphibians of this zone is rather rudimentary, as few surveys of these animals have been done. This zone possesses the richest Avian population of the country. Generally the hills are ragged, with steep slopes and about 600 m high (IUCN 2002). The tropical evergreen and semi-evergreen forests are not very distinct, and are often intermingled and merged into one another in this zone. The undergrowth is usually a tangle of shrubs, in which cane, bamboo and wild banana are the prominent species. Out of 66 families of birds existing in the country, as many as 55 are represented in this zone. Mammalian species is represented by Asian elephant (*Elephas maximus*), Smabar (*Cervus unicolor*), Slow loris (*Nycticebus coucang*), Leopard (*Panthera pardus*) and Asiatic Wild Dog (*Cuon alpinus*). In comparison, the Sylhet hillocks average 40-60 meter high. with the highest peak around 170 m (IUCN 2002). Tropical Semi Evergreen forest is found in this zone, particularly in the valleys. The Lalmai-Tipperah hills enjoy tropical semi-evergreen forests. This expanse remains largely evergreen with various species. The diversity of bird and mammal species is still considerably high but these species are increasingly under threat of extinction due to unhindered loss of habitats.



Map 3.4: Forest Zones of Bangladesh

Source: Banglapeida, 2015

3.4.3 Present Status of Eco-system Balance

Bangladesh possesses rich species diversity particularly for Angiosperms and Avian. There are total of 3,611 species of Angiosperm available in Bangladesh (**Table 3.5**). Out of which, 2,623 species under 158 families belong to Dicotyledons and 988 species under 41 families belong to Monocotyledons. As no systematic and complete survey has been recently conducted, it is very likely that the total number of Angiosperm species might have reached up to 5,000. A total of 653 fish species are recorded, of which 251 are freshwater fishes belonging to 61 families and 402 are estuarine and marine finishes including sharks and rays (**Table 3.6**). A total of 650 bird species have been reliably recorded in the country. The country is also inhabited by 34 amphibian and 154 reptile species. The mammalian species diversity in Bangladesh is represented by 121 species of mammals, however many of which are now endangered.

Table 3.5: Identified Groups of Plants (Number of Species)

Plants Group	World	Sub-continent	Bangladesh
Virus/Bacteria	8,050	850	470
Algae	40,000	7,175	1988+
Fungi	72,00	14,500	275
Lichen	13,500	2,223	data not available
Bryophytes	14,500	25,00	248
Pteridophytes	10,000	12,00	195
Gymnosperms	650	67	7
Angiosperms	2,50,000	17,527	3,611

Source: Encyclopedia of Flora and Fauna of Bangladesh, 2007

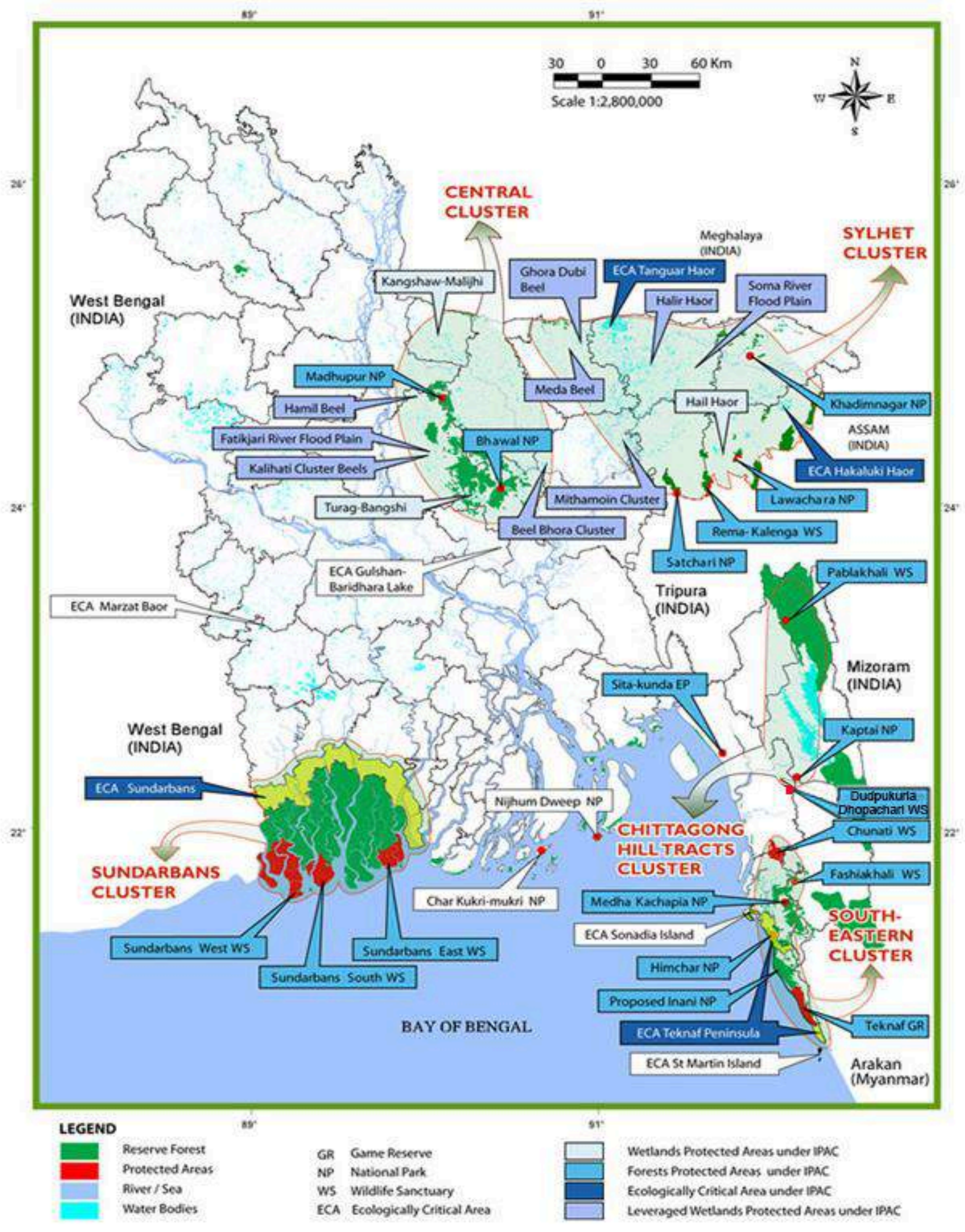
Table 3.6: Diversity of Faunal Species in Bangladesh compared to World and Subcontinent in Numbers

Taxonomic group	World	Sub-continent	Bangladesh
Protozoa	31,250	2,577	175
Porifera (Sponge)	4,562	500	29
Cnidaria (Coral, Jely Fish)	9,916	842	102
Ctenophora (marine animals)	100	12	10
Rotifera (microscopic aquatic animals)	2,500	330	76
Gastrotricha (Nematodes)	3,000	100	4
Platyhelminthes	17,500	1,622	126
Nematoda	30,000	2,850	176
Mollusca	66,535	5,072	479
Echinodermata	6,000	765	46+
Arthopoda	987,949	68,389	5000+
Fish	21,723	2,546	653
Amphibians	5,150	248	34
Reptiles	5,817	460	154
Birds	9,026	1,232	650
Mammals	4,629	397	121

Source: Encyclopedia of Flora and Fauna of Bangladesh, 2007.

In order to preserve ecosystem balance in the country, several types of protected areas have been established. For example, there are two RAMSAR sites, 13 Ecologically Critically Areas (ECA), 17 National Parks, 20 Wildlife Sanctuaries, 8 Eco Parks and 2 Botanical Gardens in Bangladesh (**Map 3.5**). Also, the International Ornithological Organization-Birdlife International identified 20 Important Bird Areas (IBA) in Bangladesh.

Human interference in the rivers and other wetlands has been damaging the fragile ecosystem and destroying the long term sustainability of the aquatic ecosystems. Rivers in the urban and sub-urban areas are severely polluted by different industrial effluents, human sewage and household garbage. Illegal encroachment is another issue for deterioration of river area and its ecosystems. Consequential siltation of major rivers and their tributaries due to loss of upstream flow has caused degradation of habitat suitability for fishes, dolphins and numerous aquatic creatures. For instance, in the southwest brackish water coastal plains of Bangladesh, the farmers used to have a single paddy crop during monsoon when surface water salinity depletes due to heavy rainfall and during rest of the months the fields are left for grazing. The practice evolved and was enriched by local knowledge for centuries. However, in the last two decades, this practice has been abandoned to provide space for more profitable shrimp farming. As a result, local ecosystems have been changed, in addition to rapid siltation of the channels and continuous inundation of land with saline water.



Map 3.5: Protected Areas of Bangladesh

Source: BDP 2100 Baseline Study Report: Ecological Setting, 2015

In Haor and Flash Flood Areas, large scale settlement was initiated in the mid-20th century from surrounding densely populated regions and since then the resources of the Haor basins are being exploited. Continuous exploitation of aquatic vegetation and plants like Makhna, Singara, Lotus, Waterlily, Hogla has been seen which are required for the habitat for fish and migratory birds in Haor and Flash Flood Areas. Similarly, embankments constructed for FCDI projects reduced floodplains and made obstacles to fish movement and migration from rivers and beels to the remaining floodplains for feeding and breeding. As a result, many fishers have lost their livelihood. **Table 3.7** shows the threat status of various vertebrates of Bangladesh.

Table 3.7: National Status of Inland and Resident Vertebrates of Bangladesh

Group	Species	Extinct in Bangladesh	Threat category (National)				Data Deficient (DD)
			Critically Endangered (CR)	Endangered (EN)	Vulnerable (VU)	Total	
Fishes	653	0	12	28	14	54	66
Amphibians	34	0	0	3	5	8	7
Reptiles	154	1	12	24	22	58	39
Birds	650	30	19	18	4	41	158
Mammals	120	10	21	13	6	40	53
Total (2000)	***1611***	***41***	***64***	***86***	***51***	***201***	***323***
Total (2015)	***1619***	***31***	***56***	***181***	***153***	***390***	***278***

Source: International Union for Conservation of Nature (IUCN), Bangladesh, 2000 & 2015

The area of settlement and consequently homestead vegetation is growing gradually for the last few decades with population growth, resulting in loss of other ecosystems. However, the quality of the homestead ecosystem has declined rapidly, because of the commercialization of the land. Species diversity reduces drastically with rapid increase of commercially valuable species. Loss of plant species diversity also reduces the quality of wildlife habitat by reducing food sources and other microhabitats essential for supporting the integrity of the food chain.

3.4.4 Knowledge Gaps

There is substantial knowledge gap in the area of biodiversity. Regarding biological resources and its conservation, following gaps have been identified in Bangladesh:

- Lack of a complete inventory of species.
- Lack of institutional arrangement for regular environmental monitoring
- Little knowledge for causes of extinction of wild species
- There is no data available for the harvest quantity of mollusks and turtles.

Addressing these knowledge gaps and establishing a proper monitoring and evaluation system for biodiversity and the environment are important agendas for BDP 2100.

3.5 Impact of Climate Change on Environment and Ecology

The social and economic implications of climate change, environment and ecological issues are widespread for Bangladesh. The society and economy are closely connected to the climate, environment and ecology. Due to climate change, disasters are going to pose serious threats to the people and economy in coming days. The changes in seasonal pattern and erratic climate behavior can heavily damage agriculture and livelihoods of people. The economically less developed areas in Bangladesh are mostly the disaster prone areas where people could not fight back with the recurrent natural disasters like, erosion, salinity, cyclones and floods. So, migration from these areas is a common trend. This might further increase in the future under climate change induced more frequent disasters.

As many poor people of Bangladesh depend chiefly on various natural resources for centuries for livelihood, so there is a strong linkage between ecosystem services, livelihoods and the socio-economic structure. Actually, biological resources and biological diversity form the basis of both the ecology and economy of Bangladesh. The country's agriculture, fisheries and livelihood, along with a number of other sectors are heavily dependent directly or indirectly on its biological resources. Thus, even a small alteration in its natural settings would have great impacts on socio-economic condition of the country.

Being an over populated country, conservation of biological environment and economic development tend to be in conflict in Bangladesh. For conserving wildlife, sufficient vegetation coverage is needed. On the other hand, more land is needed for food production, settlements and other developments for a rapidly growing population. As a result, existing vegetation coverage as well as habitat for wildlife is being encroached regularly. Over-exploitation of natural resources has caused habitat fragmentation and reduced floral and faunal diversity that have adversely impacted ecosystem services. Monoculture of plants and fish for achieving high productivity and economic value is also a major cause of biodiversity loss. Infrastructural development like land filling, construction of civil structures, industrialization is causing biological habitat conversion. In this way the country looses its wetland area and gross production of indigenous fish have been reduced.

Services from different ecosystems are not clearly assessed in Bangladesh. However, habitat degradation and conversion have an influence to perform services of different ecosystems. As a result local livelihood would be impacted. Proper guidance for accumulation of ecological services can help establish the optimum use of natural resources and ensure sustainability of those ecosystems. Legal instruments for conservation of biological environment are essential for wise utilization of natural resources. Regarding conservation, legal bindings may conflict with livelihoods and thus impact on the socio-economic aspects of an area.

Major issues regarding biological environment are as follows:

- *Biological diversity and population of different species:* Biological diversity and population size of different flora and faunal communities/species is changing in Bangladesh delta due to change of landuse and land type (erosion and accretions), over harvesting, illegal poaching and lack of knowledge regarding biodiversity conservation.
- *Habitat suitability and their sustainability:* Suitability of wildlife and plant habitats is changing with landuse, environmental pollutions, change of river hydrology, climate change, deforestation, urbanization etc. This issue needs to be given more importance in the context of Bangladesh as a highly populated country and consequential growth of land demand for agricultural extension, settlement expansion and other infrastructural developments.
- *Habitat conversion*: Biological habitats are frequently converted agricultural extension, human habitation and industrialization. Cumulative pressure on land and waterbodies caused by habitat conversion should be addressed on a priority basis.

- *Utilization of ecosystem services*: Proper utilization of ecosystem services is not ensured for monoculture, lack of knowledge, over exploration etc. Proper plan should be prepared for sustainable utilization of ecosystem services.
- *Existing policies, law and institutional arrangements for conserving biological resources:* To protect biological resources against different negative effects, appropriate policies and laws need to be adopted and enforced. Government of Bangladesh has promulgated several important laws/policies, strategies for the protection and conservation of renewable natural resources and ecosystems. All the policies give special attention towards conservation and wise use of wetlands and its vast biological resources. The Government has also prepared National Biodiversity Strategy and Action Plans where wetlands conservation is given a priority for sustainable development. In addition, existing environmental institutions like Forestry Department (FD), Department of Environment (DoE), Bangladesh Water Development Board (BWDB) and related NGOs need to enhance their capacities and coordination. A positive trend in the past decade has been mainstraining of climate change issues in these institutions. This process needs to continue and be updated with the latest knowledge and understanding of climate change issues.

3.6 Review of Strategies, Policies and Institutions

3.6.1 Strategies and Policies

Over the past few decades biodiversity has become a global concern due to its rapid reduction worldwide and Bangladesh is no exception. Due to the country's tremendous population pressure, rural poverty and unemployment problem, the natural resources base have been decreasing alarmingly. To alter this situation and to preserve ecosystem and biological diversity, various strategies, policies and institutional initiatives have been taken by different government and non-government agencies. Bangladesh is a signatory to many international treaties, laws, legislations and policies related to conserving its biological diversity. Bangladesh has signed the five major conventions and agreements related to biodiversity conservation (i.e. CBD, CITES, CMS, RAMSAR and WHC). As a signatory to these conventions, the government has undertaken various initiatives to conserve the biodiversity in both the ecosystem and at the species level.

Till now, various initiatives have been taken by the government to conserve biodiversity. These can be broadly regarded in two major ways namely *ex-situ* conservation and *in-situ* conservation. *In-situ* conservation has been carried out in few protected areas like National Parks, Wildlife Sanctuaries, and Game Reserve Areas, etc. as well as in World Heritage Site (The Sundarbans) and in RAMSAR site (Sundarbans and Tanguar haor). There are some eco parks and safari parks that are managed and conserved by both *ex-situ* conservation and *in-situ* conservation practices. Government has established and declared these eco parks and safari parks to conserve biodiversity and genetic materials mainly for research and other purposes. The government has also declared some ECA affected adversely by the changes brought through human activities. In this country, ex-situ conservation efforts are mainly limited to Bangladesh Forest Research Institute (BFoRI) and some areas like Botanical gardens (Mirpur, Baldha Gardens, etc).

There are several legislative policies and initiatives that provide provisions for regulating, harvesting and protecting plants and wildlife in Bangladesh.

Bangladesh Wildlife (Preservation) (Amendment) Act, 1974

Bangladesh Wildlife (Preservation) Order, 1973 was promulgated under Presidential Order No. 23 in 1973 and was subsequently enacted and amended as the Bangladesh Wildlife (Preservation) (Amendment) Act, 1974. The law provides for the preservation, conservation and management of wildlife in Bangladesh. According to the Act the term wildlife or 'wild animals' means 'any vertebrate creature, other than humans beings and animals of usually domesticated species or fish, and include the eggs of birds and reptiles' only. The law itself is not sufficient to provide legal protections to the significant aquatic biodiversity component of the ecosystem. For example, by this definition, the important components of the coral species in the St. Martin's Island, and also fishes and mollusks, remain outside the legal protection of this Act.

Bangladesh Forest Act, 1927 and Subsequent Amendments

The law provides for protection and development of forests. The government may assign a reserved forest to any forestland or wasteland, or any land suitable for afforestation, which is the property of the government, over which the government is entitled. Subsequently, the Forest Law has been amended and updated a number of times in response to changing needs. The Forest Act, 1927, the Forest (Amendment) Act 1990 and the amendment in 2000 may be mentioned in this regard. These contribute to the conservation of biodiversity, although not enough, and much more remains to be done.

Forest Policy and Forestry Sector Master Plan

The government first formulated the National Forest Policy in 1979. But as the situation began to change with demand for forestry products and consequent depletion of forest resources and degradation of the overall environment, the Government had to update it and formulate a revised policy which is known as the Forest Policy 1994. The biodiversity issue has been given increased importance in the latest policy. The policy stated that attempts will be made to bring about 20% of the country's land under the afforestation programs of the government and the private sector by 2015. In order to achieve self-reliance in forest products and maintenance of ecological balance, the government will work hand in hand with the NGO's and people's participation will be encouraged. The policy further stated that the priority protection areas are the habitats that encompass representative samples of flora and fauna in the core areas of National Parks, Wildlife Sanctuaries and Game Reserves. A target to increase the extent of these protected areas by 10% of the reserved forest area by 2015 as also made. To achieve the objectives and targets as stated in the policy, the government has also formulated the Forestry Sector Master Plan (1995-2015). The financial requirements to implement the plan have been estimated to be about Tk. 80,000 million.

National Environment Management Action Plan (NEMAP), 1995

Ministry of Environment and Forests (MoEF) prepared the NEMAP, which is based on a comprehensive participatory planning process ranging from grassroots up to national level. Inputs were provided from local communities, government agencies, NGOs, professional groups, academics, parliamentarians, lawyers and journalists. Together, this cross-section of concerned stakeholders identified key institutional, sectoral, location-specific and long term issues and actions. The NEMAP thus constitutes a synthesis of perceptions of the government, NGO's and the people of environmental problems and the actions required to address them. The NEMAP provides the policy framework and action plan for Department of Environment in combination with a set of broad sectoral guidelines that emphasise, inter alia, the following:

- Maintenance of the ecological balance and overall progress and development of the country through protection and improvement of the environment
- Protection of the country against natural disasters
- Identification and control of all types of activities related to the pollution and degradation of the environment
- Undertaking environmentally sound development program in all sectors
- Sustainable and environmentally congenial utilization of all natural resources
- Activities in association with all environmental-related national and environmental initiatives

National Conservation Strategy (NCS)

The need for a National Conservation Strategy first emerged in September 1986. Its primary goal was to provide a national strategy for conservation of all concerned sectors. It provides specific strategies for sustainable use of natural resources as well as sustainable development in 18 different sectors. The National Conservation Strategy Implementation Project Phase-I (1994–1999) was a five-year project implemented by the MoEF, with financial and technical support from NORAD and IUCN. Through this NCS Phase 1, one major program was implemented in four distinct ecosystems—tropical and mangrove forest areas, St. Martin's Island, Tanguar Haor and Barind Tract. The main objective of all these activities was conservation of biodiversity.

The Bangladesh Environment Conservation Act, 1995 and Environment Conservation Rules 1997

The Bangladesh Environment Conservation Act (BECA) of 1995 was enacted for environmental conservation, environmental standard development and environmental pollution control and mitigation. BECA 1995 is currently the main legislative framework relating to environmental protection in Bangladesh. The Environment Conservation Rules, 1997 (ECR 1997), are the first set of rules which have been promulgated under the BECA 1995. The major aspects covered by ECR 1997 are the National Environmental Quality Standard; requirements and procedures to get environmental clearance; requirement of Initial Environmental Examination and Environmental Impact Assessment for selected categoried of projects. However, the protection environment and declaration of the ECAs are the most important applications of BECA 1995.

Sustainable Environment Management Program (SEMP)

Sustainable Environment Management Program, supported by the UNDP and implemented by MoEF for a five-year period (1998-2002), was a response to the concerns, needs and actions identified through the National Environment Management Action Plan (NEMAP) process. It focused on community-based resource management in wetlands. In the NEMAP several major priority areas of environmental concern were identified and the SEMP was designed to address these priorities. The program consisted of 26 components on five major themes and was implemented by 22 organizations from the government, NGO's and private sector. The community-based "Haor and Floodplain Resource Management Project" was implemented by the IUCN with the MoEF, in two well-defined degraded areas of haor and floodplain ecosystems. The major focus of the program was to involve community people in the planning and implementation of activities for the management of natural resources that maintain biodiversity and human well-being.

National Biodiversity Strategy and Action Plan (NBSAP), 2014

National Biodiversity Strategy and Action Plan (NBSAP), 2004 was updated and published in 2014 as NBSAP 2016-2021 taking into account of Aichi Biodiversity Targets. NBSAP included 20 targets to be complied by 2021, conservation and sustainable use of Biological Diversity. The main objective of NBSAP included:

- Formulate strategies and action plans for conservation and sustainable use of country's biological diversity.
- Identify the current pressure on the biological resources, and options and priority actions for the conservation and sustainable use of national biodiversity by the stakeholders.
- Complement and build on the NCS (National Conservation Strategy) as well as the NEMAP (National Environmental Management Action Plan) and other sectoral plans, through participatory processes involving representativeness from different sectors of the society.
- Raise community awareness of the sustainable use of biodiversity
- Sixteen strategies were developed to shape and direct actions towards achieving the goals and objectives of the NBSAP. Out of these strategies, Strategy-10 emphasized the wise use of wetland resources.

As Ministry of Disaster Management & Relief (MoDMR) will be a key implementing partner of BDP 2100, Disaster Management Act, 2012 and National Disaster Management Policy, 2015 need to be revised considering the emerging climate change scenarios.

Bangladesh Biological Diversity Act 2017

- Bangladesh Biological Diversity Act 2017 was enacted towards ensuring conservation and sustainable use of Biological Diversity as well as ensuring fair and equitable sharing of benefits arising out of use of genetic resources.

Environmentally Critical Area Management Rules, 2016

- Environmentally Critical Area Management Rules, 2016 come under the purview of Bangladesh Environment Conservation Act, 1995. The rules aim to protect the ecology of any area that is critical or likely to be critical.

Bangladesh National Action Program for Combating Desertification, Land Degradation and Drought, 2015-2024

- Bangladesh National Action Program (NAP) for combating Desertification, Land Degradation and Drought (DLDD, 2015-2024) has been formulated to support and enhance the implementation of UNCCD strategy 2008-2018. Its vision is 'to forge a global partnership to reverse and prevent desertification/land degradation and to mitigate the effect of droughts in the affected areas in order to support poverty and environmental sustainability'.

Investment Plan on Environment, Climate Change and Forests (2016-2021)

MoEF has formulated an Investment Plan on Environment, Climate Change and Forest for a five year period. This strategy will address the sustainable development and management of natural resources as well as the resilience towards climate change impacts.

Integrated Coastal Zone Management (ICZM)

In December 2000, the Government developed an ICZM policy. Among other objectives, the ICZM policy attempted to rationalize and coordinate more effectively a number of environmental and development initiatives taking place in the coastal zone. A number of donors, including the World Bank and the Netherlands Government, have expressed interest in supporting the development of the policy over the coming years.

3.6.2 Programme/Projects for Biodiversity Conservation

The Government of Bangladesh has undertaken and implemented several biodiversity related programs and projects aided by various international donor countries and organizations. Some of the noteworthy ones are described below:

Nishorgo Support Project (NSP)

This pilot protected area management program was a Forest Department's Project and was financed by USAID under a Strategic Objective Grant Agreement. This was a five year project (2005-2010) and primarily implemented in five national parks of the country (Lawachara National Park, Rema-Kalenga Wildlife Sanctuary, Satchari National Park, Chunati Wildlife Sanctuary and Teknaf Game Reserve). The overall objective of this project was conservation of biodiversity within the national parks. The project worked to achieve six separate but closely related objectives in support of this overall objective:

- Develop a functional model for formalized collaboration in the management of Protected Areas.
- Create alternative income generation opportunities for key local stakeholders in and around national parks..
- Develop policies conductive to improved national park management and build constituencies to further these policy goals.
- Strengthen the institutional system and capacity of the Forest Department and key stakeholders so that improvements under the project can be made permanent.
- Build or reinforce the infrastructure within national parks that will enable better management, and provide limited visitor services.
- Design and implement a program of habitat management and restoration for national parks.

Coastal and Wetland Biodiversity Management Project

Bangladesh completed a Pre-investment Feasibility (PRIF) study funded by the Global Environmental Facility (GEF). It was a preparatory initiative to develop a project proposal to implement a reserve, and a multiple-use management program for the protection, sustainable management, and integration of at least three priority biodiversity sites in Bangladesh. The primary focus was to integrate conservation and development in order to protect and manage the priority areas in a sustainable way. The Project Brief and the outcome of the said PRIF study project have already been approved by the Project Steering Committee, and subsequently accepted by the GEF. The product of the follow-up project entitled "Coastal and Wetland Biodiversity Management in Cox's Bazaar and Hakaluki Haor" has also been prepared, and approved by the GEF council for funding. This project is currently under process of execution by the Government of Bangladesh.

Management of Aquatic Ecosystem through Community Husbandry (MACH)

The natural resources in the floodplains and wetlands throughout Bangladesh are in decline. Thus, to conserve these resources the Government of Bangladesh and the United States of America have jointly developed a program called MACH. An agreement to implement this program was signed in May 1998. Its goal was to ensure the sustainable productivity of all wetland resources such as water, fish, plant and wildlife over an entire wetland ecosystem.

Sundarbans Biodiversity Conservation Programme

The Asian Development Bank funded the project in 1998. The objective of the project was to establish an effective system for the participatory and sustainable management of the ecosystem of the Sundarbans Reserved Forest. The scope of the project included biodiversity conservation, sustainable resource management, community development, participatory resources management program, development of ecotourism infrastructure, and establishing a new multi-sectoral management agency that would work for an integrated conservation and development approach.

Biodiversity Surveys in Different Protected Areas

A biological study was conducted in 13 protected areas by the Bangladesh Centre for Advanced Studies, in collaboration with the Forest Department. The survey was conducted to assess the biological resources available in the designated areas. The potential value of each protected area was evaluated through determination of the species present, the relative abundance of the species and the species diversity. The critical habitats in each of the protected areas were identified for protecting the threatened species, and also for developing protective area management plans.

Conservation and Management of Medicinal Plants

A project on the conservation and management of biodiversity of medicinal plants for their sustainable utilization will be executed in Rangamati Hill district. This project is in the process of final approval by the GEF. The specific objectives of the project are:

- Development of an inventory of medicinal plants in the project area;
- Documentation of traditional uses by the local people;
- Conservation of medicinal plants and their ecosystem;
- Capacity building of concerned agencies in the sustainable use of the medicinal plants.

Implementation of the National Biosafety Framework (INBF)

Bangladesh, as signatory of the Cartagena Protocol on Biosafety to the Convention on Biological Diversity, is committed to conserve its indigenous biodiversity, the traditional knowledge and practices. Thus, Bangladesh is internationally committed to develop and implement the Biosafety regulatory regimes. Bangladesh has developed Biosafety Rules, 2012, Biosafety Guidelines, 2008, National Biosafety Framework, 2007 and other documents to support the biosafety regulatory system. Still Bangladesh has lack of biosafety infrastructure and statutory regulations to protect the potential adverse effects of modern biotechnology. The main constraints to implement Biosafety regulatory regime in Bangladesh are the absence of statutory rules-regulations, well-managed infrastructures, adequate laboratories, and insufficient trained manpower on risk assessment and management of GMOs.

The Community Based Adaptation in the Ecologically Critical Areas through Biodiversity Conservation and Social Protection Project (CBA-ECA Project)

This project has been implemented in three ECAs namely, Teknaf Peninsula (Cox's Bazar-Teknaf Sea Beach), Sonadia Island and Hakaluki Haor for the period of 2010-2015 with financial support from Bangladesh Climate Change Trust (BCCT), UNDP Bangladesh and the Embassy of the Kingdom of the Netherlands (EKN). Through these projects an institutional mechanism for Ecologically Critical Area (ECA) management has been established.

Multilateral Environmental Agreements

Bangladesh has signed different environmental agreements to protect the country's biodiversity. Some of the important agreements are:

- Convention on Biological Diversity, 1992
- RAMSAR Convention on Wetlands came into force for Bangladesh on 21 September 1992
- Convention Concerning the Protection of the World Cultural and Natural Heritage, 1992
- United Nations Conventions to Combat Desertification, 1994
- Convention on International Trade in Endangered Species, 1981
- East Asian Australasian Flyway Partnership, 2010
- Asia Pacific Network for Sustainable Forest Management, 2010
- Nagoya Protocol, 2010
- Mangrove for Future, 2010
- South Asia Wildlife Enforcement Network, 2013
- Asia Protected Area Partnership, 2014

3.7 Strategies and Policies for Moving Forward

The review of past policies suggests that there is a growing awareness of the environmental and biodiversity concerns related to development. This sensitivity is being increasingly translated into policies and programmes to address these concerns. Yet, the record of merging issues and challenges relating to protection of the environment and biodiversity suggests that implementation of past and ongoing policies will need to be strengthened with stronger monitoring and research. Additionally, new initiatives will be necessary as a part of the BDP 2100 implementation.

In order to ensure environmental sustainability, disaster and climate change resilience, protection of the ecosystem, biodiversity and wise use of wetlands, initiation of strategic options on ecosystem, biodiversity conservation and sustainable environmental management is needed. To ensure these, the following strategies could be applied.

3.7.1 Strategies

- Establishment of zoning of the region on the basis of ecological attributes distribution of biological resources and the land use patterns. These new land use zone may be established by considering the historical biophysical changes and present scenario. Special attention is necessary for wise use of wetlands resources and conservation of aquatic resources genomes. Swamp and reeds natural regeneration and protection are significant issues. Against this backdrop, the ongoing over exploitation trends of the swamps has to be stopped by any means. Secondly to determine the sustainable resource harvesting quota. And finally, plantation of indigenous species of aquatic and wetlands plants.

- Development of Management Plan and implementation of that plan at identified ecosystem regarding global significance.
- Immediate protection of important mother fisheries and their migration routes between rivers and *beels*.
- Implementation of threatened species wild flora and fauna recovery programme.
- Establishment of wetland protected areas and network nationally and globally.
- Assessment of degradation of wetlands ecological values and functions at regional level.
- Establishment of Sundarbans Research Center for research, education, conservation, awareness, networking, recreation, monitoring and evaluation.
- Strengthening local institutions for wetland and biodiversity management.
- Implementation of biodiversity enhancement and sustainable management programme.
- Identification of ecologically important area within the region to protect the biodiversity and mitigate conflicts over resource exploitation and providing legal arrangement.
- Establishment of a national monitoring programme to recognize wetlands' changing ecology, i.e. changes of flora and fauna, hydrology or chemistry, in response to climate change, pollution and other long term impacts. Habitat/land use studies on a national or regional scale should be initiated for evaluation of the success of direct conservation initiatives and allow to identify wetland loss still occurring or not and the reason behind it.
- Development of a structured approach to implementing coordinated national wetland programmes that will foster effective wetland projects to ensure proper maintenance and management of protected wetlands after designation, acquisition and/or retention.
- Promotion of effective wetland science; establishment of national priorities for scientific research on wetland with regular review of comprehensive national inventory.
- Creation of wetland data management system for comprehensive national inventory to achieving the wise use of wetlands, documentation of wetland losses, and identification of wetlands with potential for restoration.
- Coordination and rationalization of government development programmes to minimize their adverse effects on wetlands and to encourage watershed conservation. Create incentives programme that will encourage the landowner and conservation agencies to maintain wetlands.
- Adoption of flood and erosion protection along the Brahmaputra/Jamuna River reach to protect communities and their livelihoods. This is an important task under increasing disaster events due to climate change effects.
- Protection of coastal population and their livelihoods that are under threat due to sea level rise and salinity intrusion due to climate change. Programmes like polders/ embankments with proper design and O&M, salinity control through increasing upstream river flow by implementing the Padma Barrage, etc. could be considered.
- Undertaking steps to augment water availability for agriculture, domestic and industrial activities during dry season. In this regard, better management of available water resources would be required in future.
- With frequent heat waves and intensifying thunderstorms, studies on climate change induced temperature rising and intensity of cyclones may be conducted.

3.7.2 *Policies and Programmes*

The above mentioned strategies can be implemented through the following activities:

- Strengthening legal and policy provisions for ecosystem and biodiversity management through Revising policies and rules related to ecosystem and biodiversity conservation, especially for protection of endangered and threatened species.
- Setting up/updating standards for soil and water quality.
- Adopting habitat preservation programmes for wildlife, fisheries and migratory birds through maintaining existing protected areas and establishing new protected areas for preserving habitat of wild plants and animals including migratory species on the basis of life cycle analysis of the species.
- Controlling and monitoring plant and animal population for food chain management within protected habitats.
- Monitoring and maintenance of water and soil quantity through water flow regulation in the protected areas.
- Undertaking research and education programmes on ecosystem, biodiversity conservation and management by doing baseline study on biodiversity status by specific regions and research on valuation of ecosystem services of every ecosystem.
- Characterization of "Eco-hydraulics"/ "Eco-hydrograph" for ecosystems.
- Developing ecosystem health/quality monitoring methods (e.g. bio-indicator for water/ soil quality).
- Undertaking research on evolution and life cycle of key species as well as endangered and threatened species; sustainable production of goods and services of ecosystems; impact of climate change on ecosystems, wetlands and biodiversity; and on the impact of pollution on wetland habitat and biodiversity.
- Establishment of gene bank of all plant and animal species.
- Sustainable management of commercially important species and ecosystems.
- Promoting eco-tourism as alternative income source from ecosystems.
- Promoting plantation programmes, farming of medicinal plants and sustainable pearl farming.
- Undertaking pollution control and prevention from agriculture, industry, infrastructure development and urban settlement.
- Controlling use of chemical fertilizer and pesticides in agriculture
- Implementing restrictions over solid waste and wastewater disposal from industries, mechanized boats and urban settlements to wetland areas.
- Implementation of flood and erosion protection programme along the Brahmaputra/ Jamuna River.
- Promoting integrated approach towards disaster and climate change resilience in national and sectoral planning.
- Strengthening and ensuring proper management and functioning of the coastal polders/ embankments.
- Stregthening Fish Act implementation to conserve fish and fisheries resources.

Chapter 4
National and Transboundary Water Management

Chapter 4: National and Transboundary Water Management

4.1 Water Resources Setting and Water Availability

The sources of water in Bangladesh can be classified as surface water, rainfall and groundwater. Bangladesh, being the lower most riparian country in the the Ganges-the Bhramaputra-the Meghna basins and crisscrossed by around 700 rivers including 57 transboundary rivers, shares its transboundary water resources with the upper riparian countries like Bhutan, China, India and Nepal. Out of a total catchment area of 1.72 million km^2 of the the Ganges-the Bhramaputra-the Meghna basins, only around 7% basin area falls within the Bangladesh territory (Amarsinghe and Sharma, 2010). Out of the 57 Transboundary rivers of Bangladesh, 13 rivers fall under the Ganges basin fully or partially in the four Hydrological Regions; 11 rivers fall under the Brahmaputra basin lying fully or partially over the seven hydrological regions and 25 rivers covering six Hydrological Regions lying fully or partially in the Meghna Basin (JRC, 1990; CEGIS, 2015). The annual cross border river flows entering the river systems are estimated to be 1,200 Billion Cubic Meter (BCM) (CEGIS, 2015), of which the three main rivers contribute some 981 BCM (i.e. almost 78% of the total cross border flow), 85% of which enters the country between June and October (CSIRO, 2014). Out of 981 BCM, some 54% is contributed by the Brahmaputra, 31% by the Ganges, nearly 14% by the tributaries of the (upper) Meghna and 1% is contributed by other minor rivers of the Eastern Hills. Only 15% of the total transboundary flow i.e. 148 BCM is available during the dry season (CSIRO, 2014) where only 1% (11 BCM) of the total flow (Ahmed and Roy,2004) is received in the critical month of February, thus showing the vulnerability of the transboundary flow to meet the water demand during dry season.

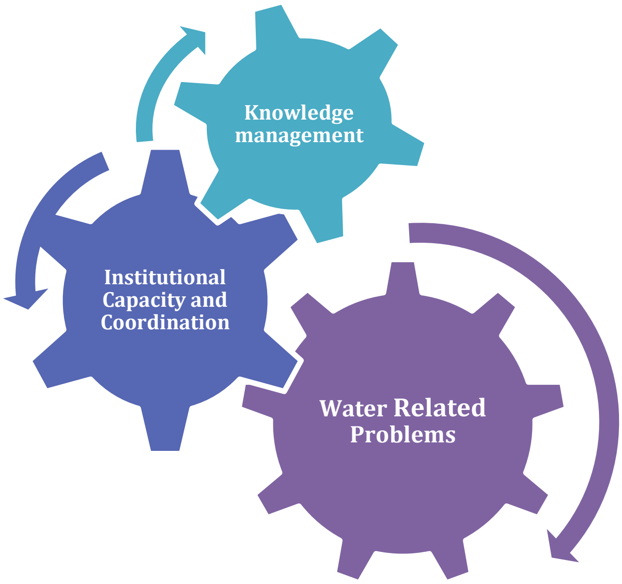
On the other hand, the total renewable water resources on an annual basis amount to approximately 1,211 BCM. Of these, 1,190 BCM are surface water and 21 BCM are groundwater resources. Internal renewable water resources, those generated inside the country are estimated to be 105 BCM, of which 84 BCM originate from surface and 21 BCM from groundwater. Externally renewable water resources account for a total of 1,106 BCM, of which 0.03 BCM from groundwater and the remainder from transboundary river flows. Being the lower most riparian country of the Ganges-the Bhramaputra-the Meghna basins, Bangladesh is highly dependent on the cross border water flow which varies greatly in wet and dry seasons of the country. However, reduction of dry season flows in Bangladesh due to increasing upstream withdrawal is causing severe water shortage across the country. The reduced stream flow is also accelerating salinity intrusion and environmental degradation, particularly in the South West region, while about 25% of the country is flooded to varying degrees during May through September each year.

The water availability of the country is also dependent on the rainfall which varies in wet and dry season. In Bangladesh, on the basis of water availability and demand, the period from June to October is called as the wet or monsoon season while the period from November to May is called as the dry season (NWMP, 2001). During the June-October monsoon, Bangladesh receives about 80% of annual precipitation, averaging 2,300 mm, but varying from as little as 1,200 mm in the west to 5,800 mm in the east (Ahmed and Roy, 2004; Ali, 2006). About 20% of the average annual rainfall occurs in dry season (November-May) in northwest (NW) region with a highly uneven monthly distribution of rainfall (Ahmed and Roy, 2004). However, the annual average rainfall varies as 1,927 mm in the NW region, 1,950 mm in the south west-south central (SW-SC), 2,133 in the north central (NC), 2,447 mm in the Southeast (SE) and 3,091mm in the Northeast (NE) region (CSIRO, 2014).

Groundwater is an important source of drinking and irrigation water in Bangladesh. The major source of groundwater is the recharge from surface water in the unconfined aquifer that has been formed in most of the area of the country from the sedimentary alluvial and deltaic deposits of three major rivers. According to the Master Planning Organization (MPO, 1997) an estimated 21 BCM of groundwater resources is produced within the country. FAO estimated in 2008 that the total water withdrawal in Bangladesh was about 36 BCM, of which 31.5 BCM was for irrigation and 3.6 BCM for domestic water use and 0.8 BCM for industry. Seventy nine percent of this 36 BCM water was sourced from groundwater and 21 % from surface water. In future, water demand in the country is likely to be on the rise due to rapid urbanization, high demographic growth, adverse impacts of climate change, etc. Due to climate change, irrigation water demand is projected to increase from less than 1% for 2030 in average condition, to maximum 3% for 2050 in dry condition (Mainuddin et. al., 2013). Although agriculture sector is and will remain the major water consumer, domestic and industrial uses are on the rise and are likely to grow by 100% and 440% respectively by 2050.

4.2 Issues and Challenges

Effective and efficient management of water resources in Bangladesh requires thorough identification of issues and challenges. The issues and challenges of water resources in Bangladesh can be classified under three broad categories: issues related specifically to water (e.g. water related disaster, water availability, etc.); institutional capacity, management and coordination and knowledge gap. In this section, the problems and challenges under these categories are briefly discussed.



4.2.1 Issues

Water Related Issues

Before formulating any strategy for the water system of the country, the issues and challenges need to be considered first. While some issues and challenges are prevalent and dominant in the specific hotspots of the country namely: *Coastal Zone, Barind and Drought Prone Areas, River Systems and Estuaries, Haor and Flash Flood Areas, Urban Areas, Chattogram Hill Tracts and Cross-cutting Area*. Some issues and challenges are required to be addressed at the national level. Moreover, spatial location of the hotspots over eight hydrological regions of Bangladesh are also analyzed to facilitate the strategy formulation process.

Water availability, problems, issues and demand for each of the hotspots varies from one another which have been presented in **Table 4.1**. The location of these hotspots in regards to the hydrological regions is also shown there. In the last column the priority areas are indicated. These priorities and related water strategies are discussed in detail in **Chapter 6**.

Table 4.1: Hotspots wise Issues and Challenges

BDP 2100 Hotspots	Description	Issues	Challenges	Priority Area in Hotspots
Coastal zone	**Area:** 27,738 km^2 **Administrative Boundary:** Covers partially or fully around 19 districts including Bagerhat, Barguna, Barishal, Bhola, Chandpur, Chattogram, Cox's Bazar, Feni, Gopalganj, Jashore, Jhalkati, Khulna, Lakshmipur, Narail, Noakhali, Patuakhali, Pirojpur, Satkhira and Shariatpur. **Hydrological Region:** South Central, South East, South West, River and Estuary, Eastern Hill. **No. of Rivers: 99** **Major Rivers:** Arial Khan, Madhumati, Muhuri, Meghna (Lower), Meghna (Upper), Passur, Sibsa, etc.. **Basins:** The Ganges, the Meghna & the Brahmaputra Basins.	• Sea level rising • Flooding due to tides, cyclonic storm, tidal surges, overspill of lower Meghna river • Salinity intrusion in Khulna, Bagerhat, Satkhira districts. • Drainage congestion in polders and in Greater Noakhali • Water logging in Satkhira, Jashore, Khulna, Bagerhat, Noakhali Districts. • Lack of fresh water • Arsenic contamination. • Insufficient safe water supply and sanitation. • Water deficit in the dry season • Loss of Biodiversity and ecosystem, especially in Sundarbans. • Environmental degradation particularly in Sundarbans.	• Maintaining fresh water flow, • Polder management • Sediment management in polder areas • Safe drinking water supply. • Providing enough fresh water for irrigation. • Flood management • Drainage management. • Restoration and modernization of old polders, • Involvement of local stakeholder for operation and maintenance, • Re-excavation of canal (inside polders) and river outside polders • Strengthening (internally and externally) sea dykes against the increased tidal prism and sea level rise respectively • Increasing employment • Land reclamation • Establishment of economic zones • Land use planning • Improved communications	• Sundarbans • Laksmipur • Bhola • Noakhali • Sandwip • Satkhira

BDP 2100 Hotspots	Description	Issues	Challenges	Priority Area in Hotspots
		• Coastal erosion in Central Meghna Estuary.	• Increasing average life length • Increasing dairy firm in the sea shore areas etc	
Barind and Drought Prone Areas	**Area:** 22,848 km^2 **Administrative Boundary:** Covers partially or fully around 21 districts including Bogura, Chuadanga, Dinajpur, Gaibandha, Jhenaidah, Joypurhat, Kurigram, Kushtia, Lalmonirhat, Meherpur, Naogaon, Natore, Nawabganj, Nilphamari, Pabna, Panchagarh, Rajbari, Rajshahi, Rangpur, Sirajganj, Thakurgaon. **Hydrological Region:** South West, North West, River and Estuary. **No. of Rivers:** 128 **Major Rivers:** Atrai, Brahmaputra-Jamuna, Teesta, Dharla, Dudhkumar, Ganges, Garai, Ichamati Matabhanga, Mohananda **Basins:** The Ganges & the Brahmaputra Basins.	• Droughts & Water scarcity in Kurigram, Nilphamari, Lalmonirhat, Gaibandha, Bogura, Rangpur, Naogaon districts. • Flooding in wet season in Sirajganj, Pabna, Naogaon, Bogura districts. • Groundwater Depletion • Breaches in the Teesta and Brahmaputra right embankments. • Breaches in the embankment of Jamuna River in Sirajganj. • Domestic water supply shortage • Water and environment pollution. • Diminishing freshwater flow from Gorai river. • No legislative act or framework for guiding the groundwater extraction	• Controlling groundwater mining. • Groundwater recharge • Maintaining connectivity of river system and flood plains.	• Drought prone areas • Barind Area • Chalan Beel

BDP 2100 Hotspots	Description	Issues	Challenges	Priority Area in Hotspots
River systems and estuaries	**Area:** 35,204 km² **Administrative Boundary:** Covers partially or fully around 30 districts including Bhola, Barishal, Brahmanbaria, Barguna, Bogura, Chandpur, Chattogram, Cumilla, Dhaka, Faridpur, Feni, Gaibandha, Jamalpur, Kurigram, Kushtia, Madaripur, Lakshmipur, Manikganj, Munshiganj, Natore, Narayanganj, Narsingdi, Noakhali, Pabna, Nawabganj, Patuakhali, Rajbari, Tangail, Sirajganj, and Shariatpur. **Hydrological Region:** North Central, North West, South Central, South East, South West, Eastern Hill. **No. of Rivers:** 49 **Major Rivers:** Brahmaputra-Jamuna, Meghna (Lower), Arial Khan, Dhaleswari, Dharla, Dudhkumar, Ganges, Gorai, Matabhanga, Meghna (Upper), Old Brahmaputra, Teesta Old Dhaleswari, Padma, **Basins:** The Ganges, the Meghna & the Brahmaputra Basins.	• Embankment breach. • Illegal encroachment of lands. • Erosion along the major rivers. • River bank flooding. • Sedimentation and loss of Navigability • Loss of Connectivity of rivers. • Water pollution. • Decreasing Fresh water flow in Gorai and Meghna Rivers. • Operation and maintenance of the embankments. • Loss of fish habitats.	• Operation and maintenance of the embankments • Stabilization of rivers • Ensuring equitable transboundary flows • Sediment management • Restoration of Connectivity of Rivers, particularly Old Brahmaputra River • Effluent Treatment • Ensuring flow diversion during high discharge • Retention of water during dry period for environmental, irrigation and navigation purpose	• Bangali river • Gorai
Haor and Flash Flood Areas	**Area:** 16,574 km² **Administrative Boundary:** Covers partially or fully around 7 districts including Brahmanbaria, Kishoreganj, Netrakona, Sunamganj, Sylhet, Habiganj, Maulvibazar. **Hydrological Region:** North Central, North East **No. of Rivers:**	• Flash floods. • Excessive monsoon flooding • Drainage Congestion • Insufficient pre-monsoon water shortage • Encroachment of haor and	• Proper sediment management in the Sylhet basin. • Maintaining fresh water flow in the major rivers. • Erosion control • Ecosystem management and • Coordination to mitigate conflicts • Spatial planning	• Haors of the Haor region

BDP 2100 Hotspots	Description	Issues	Challenges	Priority Area in Hotspots
	93 **Major Rivers:** Meghna (Upper), Surma, Old Brahmaputra, Someswari, **Basins:** The Meghna & the Brahmaputra Basins.	flash flood areas • Avulsion of rivers in Sunamganj, Sylhet, Habiganj districts • Insufficient safe water supply and sanitation • River siltation • Loss of biodiversity and eco-system. • Social Conflicts, • Fish Reduction, • Water Pollution, • Soil Erosion, • Unplanned inhabitation (households, villages, business Centre etc in the wetlands)	• Framework for land use management • Early warning system for flash floods	
Urban Areas	**Area:** 19,823 km² **Administrative Boundary: urban area/ city of** Dhaka, Chattogram, Khulna, Sylhet, Rajshahi, Barishal, Rangpur, Mymensingh. **Hydrological Region:** South Central, South West, North Central, North West, North East, River and Estuary, Eastern Hill. **No. of Rivers:** 11 **Major Rivers:** Atharobanki, Bhairab, Ganges, Halda, Karnafuli, Old Passur, Pabijuri-Kusi Gang-Kusiya, Rupsa (Khulna), Buriganga, Balu,	• Unplanned development • Flood, water logging and drainage congestion • Groundwater depletion and water supply shortage • Pollution and Environmental Degradation • Waste management • Loss of biodiversity and ecosystem services	• Groundwater Recharge • Pollution control • Water Supply and Sanitation • Wetland Protection	• Dhaka city and the rivers surrounding it. • Dhaka-Narayanganj-Demra (DND) area • Chattogram • Barishal

BDP 2100 Hotspots	Description	Issues	Challenges	Priority Area in Hotspots
	Sitalkhaya, Sugandha, Surma, Tongi Khal, Ghaghat, Old Brahmaputra. **Basins:** The Ganges, the Meghna & the Brahmaputra Basins.			
Chattogram Hill Tracts	**Area:** 13,295 km^2 **Administrative Boundary:** Covers partially or fully 5 districts including Chattogram, Cox's Bazar, Rangamati, Khagrachhari, Bandarban. **Hydrological Region:** Eastern Hill. **No. of Rivers:** 17 **Major Rivers:** Bakkhali, Matamuhuri, Sangu, Halda, Ichamati (Rangamati), Karnafuli. **Basins:** The Meghna Basin and Hilly River Basin.	• Flood and flash floods • Water supply shortage • Damages due to cyclone Landslides • Sedimentation • Water shortage for domestic and agricultural purposes in Chattogram, Rangamati and Khagrachari Districts. • Environmental pollution and loss of biodiversity and eco-system services • Riverbank erosion in Chattogram floodplain along Karnafuli river.	• Water supply, fresh water shortage and sanitation • Flooding, drainage congestion, cyclones	• Halda • Kaptai Lake • Rangamati and Khagrachari • Cox's bazar
Cross Cutting Areas	**Area:** 19,355 km^2 **Administrative Boundary:** Covers partially or fully around 20 districts including Bogura, Chandpur, Cumilla, Dhaka, Faridpur, Gaibandha, Gazipur, Jamalpur, Kurigram, Madaripur, Magura, Manikganj, Munshiganj, Narayanganj, Mymensingh, Narsingdi, Sirajgonj, Sherpur,	• River encroachment • Groundwater mining. • Maintaining regulated flow and connectivity of river system and floodplains. • Sedimentation in the off-takes of major rivers.	• Industrial development management • Increased water demands for growing population. • Appropriate interaction of land and water use. • Fresh water flow decreases in Gorai and Meghna Rivers.	

BDP 2100 Hotspots	Description	Issues	Challenges	Priority Area in Hotspots
	Rajbari, Tangail. **Hydrological Region:** North Central, North East, South Central, South East, South West, River and Estuary. **No. of Rivers:** 105 **Major Rivers:** Arial Khan, Brahmaputra-Jamuna, Buriganga, Dhaleswari, Ichamati, Madhumati, Meghna (Upper), Old Brahmaputra, Old Dhaleswari, Padma, Ganges, Gorai, Meghna.	• Flood management and drainage congestion. • Inadequate navigability of major rivers. • Degradation of natural resources. • River water pollution	• Development of efficient multimodal transportation system. • Industrial and other point source effluent treatment	

Source: BDP 2100 Technical Team Analysis, GED, 2015

Analysis of the issues and challenges of the six BDP 2100 hotspots and cross-cutting areas reveals that river flooding with variable degree and extent is most common in all the regions because of Bangladesh's geographical location. Similarly, dry season water scarcity is becoming prevalent almost in all the hotspots. Groundwater level is depleting at an alarming rate, generating concern for irrigation and safe drinking water supply in present and future. Moreover, both surface and groundwater quality is deteriorating throughout the country. Based on the investigation of the problems and issues of the BDP 2100 hotspots, the following seven crucial water related issues have been identified to be addressed at national level due to cross-cutting nature of the problems, challenges and possible measures.

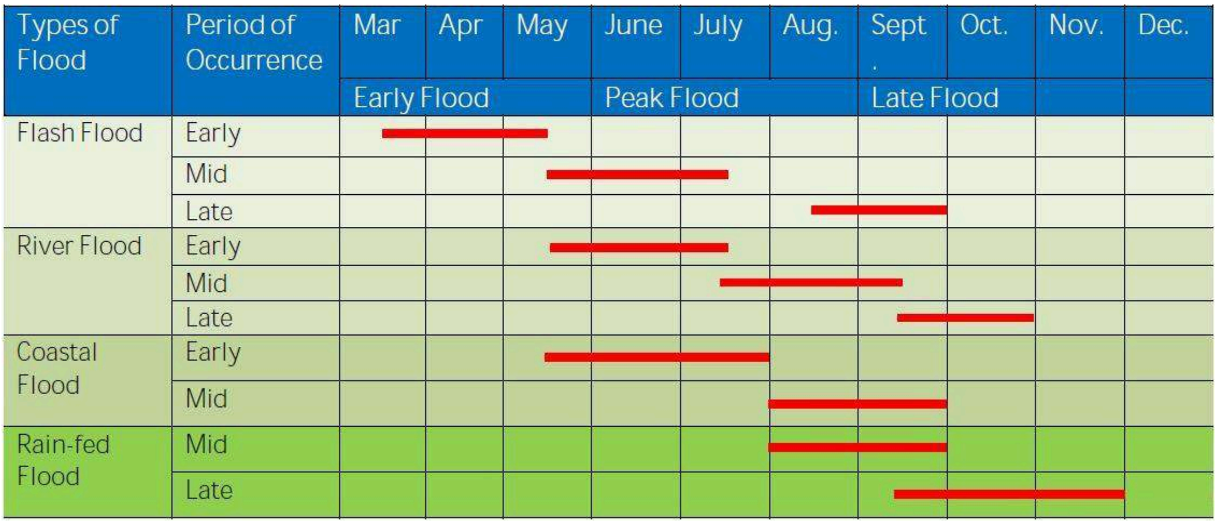
- Flood Risk Management
- Dry Season Water Availability and Irrigation Management
- River Management including pollution control
- Coastal Zone Protection and Management
- Fresh Water Supply
- Wetland Protection

Flood Risk Management

Bangladesh is one of the most flood prone countries in the world. Bangladesh experiences four different types of floods which are categorized based on spatiality, timing, intensity and duration into four groups such as flash floods, river floods, rainfed floods and storm surge inundation. The floods of Bangladesh can be further classified into two categories based on the frequency and level of impacts: high frequency floods with local impact (i.e. Flash floods (pre-monsoon); annual monsoon floods and water logging; urban flooding (local drainage congestion)) and low frequency floods with national impact (i.e. River floods (simultaneous rise of rivers & high tide)); cyclone-induced tidal floods (pre- and post-monsoon) and heavy rainfall in combination with high water levels in the rivers, which prevents drainage.

Different hotspots and hydrological regions of the country face different types of floods at different times of the year. North west, North central and South west regions are more susceptible to river flooding whereas North east and Eastern Hilly region as well as North west and North central region are vulnerable to flash floods (during April-May and September-November). Rainfed flooding and water logging occurs in many parts of the country but is mainly prevalent in the South Western part of the country. Coastal flood mostly occurs along the coastal zone of Bangladesh. Floods are annual events and generally have different return periods. More devastating flood reoccurs with more return periods. Approximately 20%, 30%, 37%, 43%, 52% and 68% of the country is inundated with floods of return periods of 2, 5, 10, 20, 50 and 100 years respectively (MPO, 1986). Due to climate change impacts, it is expected that ininduation areas will increase for the same return period flood event. The temporal and spatial extents of floods are shown in **Table 4.2** and **Map 4.1**.

Table 4.2: Flood Calendar of Bangladesh

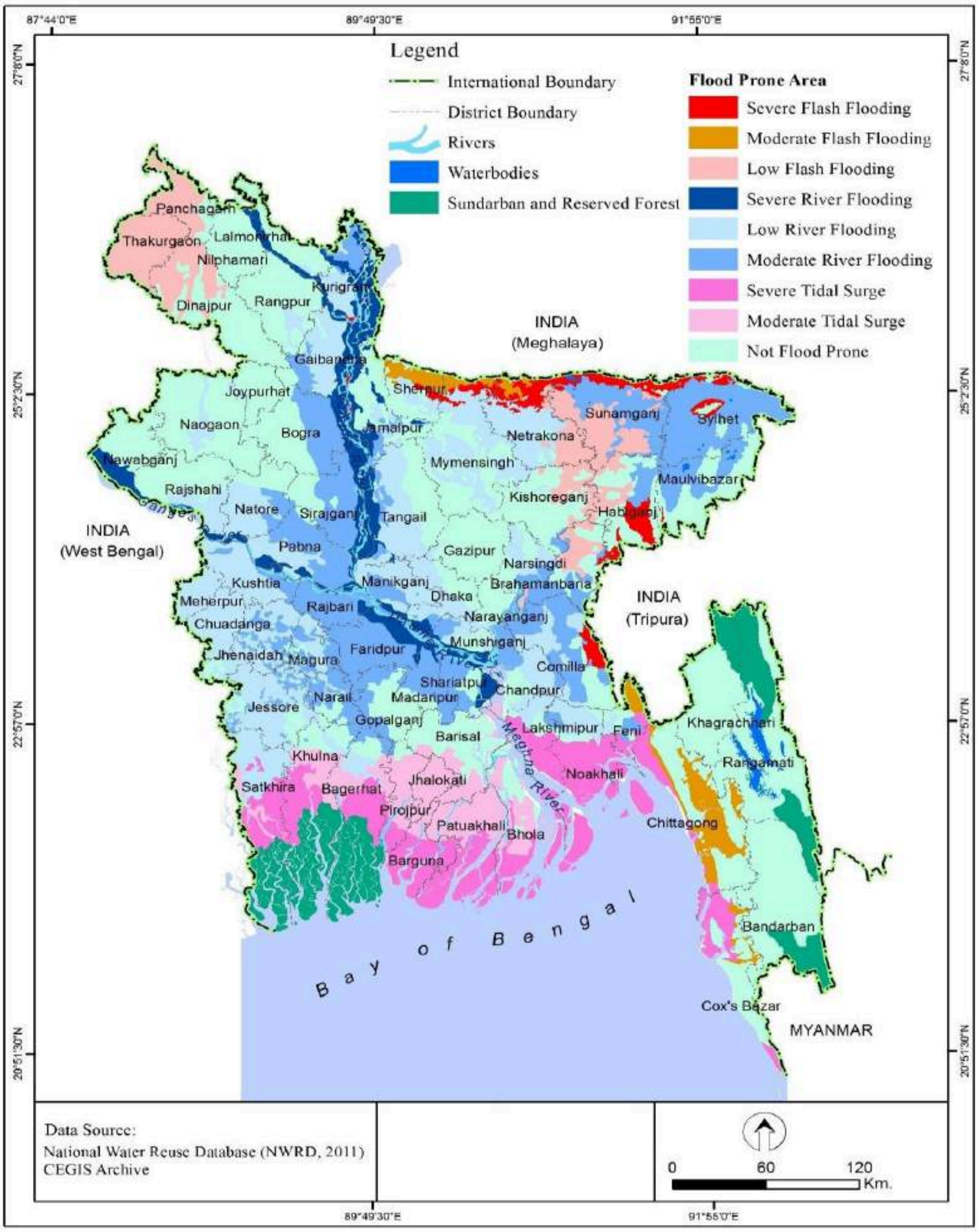


Source: Flood Response Preparedness Plan of Bangladesh, 2014

Dry Season Water Availability and Irrigation Management

At the National level, agriculture provides employment to approximately 47% of the labour forces and 41% take it as principal occupation. It contributes some 15% in the GDP in 2015 which was 50% in 1973. Water availability and habitat quality, especially in the dry season, and water quality, notably salinity, are key issues for the agriculture sector. Agriculture sector is already under pressure both from increasing demands for food, and from problems of agricultural land and water resources depletion. In addition to this, the impacts of climate change on food production are national as well as global concerns. Bangladesh needs to increase the rice yield in order to meet the growing demand for food emanating from population growth. In Bangladesh, droughts primarily occur in pre-monsoon and post-monsoon seasons, but in some extreme cases the pre-monsoon droughts have extended in monsoon season due to delayed onset of the monsoon rains. The Southwest and Northwest Hydrology regions of the country are most vulnerable to droughts.

In Bangladesh, drought is normally defined in terms of drought and severe drought, expressed as number of days without rainfall (10 and 20 days respectively). Moreover, it is important to further distinguish seasonal drought, even in the monsoon season, when overall rainfall is abundant and exceeds crop water requirements. Three types of droughts occur during the monsoon season: early-season, mid-season, and end of -season. Early-season droughts are due to delayed onset or early breaks of monsoon rainfall. This is particularly relevant in the Barind. The onset of the pre-monsoon season, upon which farmers decide to start 'Aus' rice cultivation varies widely from year to year. A break in the pre-monsoon season may therefore lead to crop loss or complete crop failure. Mid-season droughts are caused by intermittent, short or extended dry spells. End of season droughts are caused by early withdrawal of monsoon rainfall, affecting the 'Aman' rice crop. High Yielding Varieties are particularly sensitive to these droughts.



Map 4.1: Spatial Extent of Different Types of Floods in Bangladesh

Source: CEGIS, 2011

In recent years, the rapid adoption of mechanized tube well technology in the Barind and drought prone areas based on the government's Barind Area Development Programme along with other many mega projects in last six decades (e.g. Thakurgaon Deep Tube Well Pilot Project) have changed the rural landscape of the region with a diversified crop of different varieties of rice, fruits and vegetables. Yet, the issue of the sustainability of this strategy has come to the fore owing to rapid depletion of groundwater with little sources of water recharge. This water recharge issue of the Barind and drought-prone hotspot is a critical development challenge for the BDP 2100.

River Management

Most of the water related challenges in Bangladesh are somehow related to the mighty rivers that are both blessings and threats to its society and economy. Reduction of dry season flows in Bangladesh due to increasing upstream withdrawal is causing severe water shortage across the country and in the Southwest region in particular. Only 15% of the total transboundary flow i.e. 148 BCM is available during the dry season (CSIRO, 2014) where only 1% (11 BCM) of the total flow is received in the critical month of February (Ahmed and Roy, 2004). Reduced stream flow is also accelerating salinity intrusion and environmental degradation. Restoration of major rivers and their offtakes as well as enhanced regional cooperation in the the Ganges- the Brahmaputra- the Meghna basins will ensure availability of more flow in dry season. Increased dry season flow will positively affect the entire country. However, these strategies will in particular help to mitigate the negative impacts such as droughts and water scarcity affecting the dry season irrigation initiatives, excessive extraction of groundwater and its depletion in Northcentral Hydrological Region; salinity intrusion of Southcentral and Southwest region as well as enhance domestic water supply sources of the Northwest Hydrological Region.With the Main Rivers being the backbone of the country's hydraulic system, the formulation of a long term strategy for the Main Rivers is of national importance.

Coastal Zone Protection and Management

The coastal zone covers the southwest, south-central and southeast areas (including plains of Eastern Hills region) of Bangladesh, which, in its natural state, is often subjected to inundation by high tides, saline water intrusion, cyclonic storms and associated tidal surges. Most of the coastal areas are protected by coastal polders, however, their vulnerability in the long term due to climate change induced hazards make them a prime development domain within the BDP 2100. Water supply for domestic and other purposes is severely restrained, and the coastal zone's sanitation coverage is below the national average. Poor communication, lack of education and health care facilities, prolonged absence of safe drinking water and insufficient cyclone shelters contribute and multiply the dimension of vulnerability. Furthermore, increasing population pressure increases the competition for limited resources. On the other hand, the coastal zone of Bangladesh has a tremendous potential to create opportunities of national importance through intensification of agriculture, aquaculture and marine fishery, exploration of gas and oil resources, development of the ship building industry, ecotourism, renewable energy and deep sea port development.

In order to control flood and resist salinity intrusion towards agricultural activities, polderisation began in the 1960s. So far 139 polders[9] have been built in the coastal zone. In the beginning, polders played a significant role as strategic instruments in the management of this Delta through prevention of salinity intrusion in the coastal agricultural lands. But with time, the polders have been dilapidated due to erosion and lack of proper maintenance and it began to affect the coastal rivers' drainage capacity and siltation in the delta region. At the polder level, land subsidence and water logging also occurred with time. This impact is further exacerbated by population growth and urbanization.

Moreover, the coastal zone, especially the flat and unprotected areas will severely be impacted due to cyclones and storm surge events and further climate change induced problems like sea level rise, heavy monsoon downpour, unavailability of fresh water and saltwater ingression. Due to sea level rise, the salinity frontier of the country will move upstream gradually over the years. Polders are particularly sensitive to two factors that may be affected by future climate change and sea level rise: changes in the landward boundary and seasonal distribution of saline water and changes to tide levels. Both of these factors may result from the combined effects of sea-level rise and climate change on intra-polder channel configuration and future water management schemes including possible river flow augmentation. Therefore, the management of all such issues depends greatly on the proper management of the polders concerning storm surge, sea level rise and salinity intrusion.

Several areas in the coastal zone, especially Western part and Noakhali mainland suffer from extensive and permanent water-logging. The problem of water-logging is severe in the coastal polders, particularly in the Satkhira, Jashore, Khulna, Bagerhat and Noakhali Districts. Reasons behind water-logging are complex and differ between regions. Drainage capacity of the area and peripheral-rivers is a main concern and is expected to be heavily impacted in future conditions. Water logging within the polders, FMDI project areas or backswamps lead to unproductive land, large nuisances, health issues and livelihood insecurity for the inhabitants.

Fresh Water Supply

Access to water is a basic human right and it is a crosscutting issue for sustainable development. Bangladesh is on the road to development, driven by an upcoming industrial sector and the resilience of its population and labour force in the country and abroad. Economic sectors such as agriculture, industries, fisheries and transport depend on the availability of sufficient, clean and reliable fresh water supplies if they want to continue to grow. However, Bangladesh's water supply system is vulnerable both in terms of quality and quantity.

Salinity in the coastal zone is a normal hazard, but in the southwest it has been accentuated by the reduction in dry-season flows entering the Gorai distributary. A reduction in freshwater inflows from the Ganges River, siltation of the tributaries of the Ganges, and siltation of other rivers

[9] A polder is a low-lying tract of land enclosed by embankments known as dykes that form an independent hydrological entity which has no physical connection with outside water other than through manually operated devices (water control structures).

following the construction of the coastal polder system has resulted in a significant increase in river salinity during the dry season. Also, increase in irrigations abstractions (surface and groundwater) near river corridors have reduced river baseflow. Salinity in the coastal zone increases steadily from December to February, reaching a maximum in late March and early April. Surface water salinity in coastal Bangladesh is also related to salinity of the Bay of Bengal and the circulation pattern of the coastal waters induced by the ocean currents and the tidal currents in the coastal waters[10]. Salinity now reaches as far as Khulna, and affects the supply of both potable water and fresh water for industrial use, particularly for cooling water use. Salinity is also a problem for Chattogram when there are no releases from Kaptai Lake, as the saline front approaches the abstraction point for the city water supply.

Large areas (mostly western) in the coastal zone suffer from a deficit of freshwater availability, mostly in the dry season. Fresh water supply is a severe problem for southwestern regions creating shortages of fresh water for agricultural production (autonomously leading to more aquaculture production) as well as for domestic purpose. Projected decreases of transboundary freshwater inflows, sea level rise, as well as possible unprecedented increases in specific demands make freshwater availability an important key issue for the Coastal Zone.

The salinization front in the Coastal Zone may further move north and eastwards in the Ganges tidal floodplain, with unreliable and decreasing the Ganges and the Brahmaputra (transboundary) dry season flows. Sea level rise will further aggravate the situation, making the southwest region particular difficult to live in, as well as the biodiversity within the Sunderbans being at threat. Increased or more specific (in time and location of) water demands (domestic, industrial, agricultural) will make the situation in the future more difficult. A sustainable coastal freshwater strategy is required for the nation and the Coastal Zone specifically, in order to improve living conditions, sustain agricultural and aquacultural production, as well as maintain environmental sustainability.

Access to safe drinking water in Bangladesh is limited due to wide spread contamination of arsenic in groundwater and pollution of surface water. Most of the people in rural areas of Bangladesh depend on groundwater for drinking and in major cities like Dhaka, Khulna, Rajshahi, Barishal, Chattogram and Sylhet; people have piped water supply systems where the main source is groundwater. In villages and urban slums people also suffer from lack of water for sanitation that leads to hygiene problems. Besides, there is a huge demand for industrial water uses that are mostly met through surface water sources. In this scenario a sustainable water supply system for domestic and industrial purposes is necessary throughout the country. Pressure on groundwater and natural water sources need to be lessened by incorporating reuse of water in domestic, commercial and industrial purposes. Moreover, the combination of salinity, arsenic, and relative poverty, makes the coastal zone particularly vulnerable.

[10]A more detailed discussion of these processes can be found in the Baseline studies on Water Resources and Coast

On the other hand, both ground and surface water in Bangladesh has become susceptible to pollution in various degrees. Groundwater of Bangladesh is largely contaminated by arsenic that makes it unsuitable for drinking and the surface water sources like river, canals, and estuaries are being heavily polluted by industrial sources. The major causes of water pollution are related to land based activities, including industrial effluents, agrochemical, faecal pollution and oil and lubricants spillage. Since the rivers are frequently used as dumps, overall inland surface water quality drops below the permissible limit of DoE standards in the dry season whereas it improves in the wet/ monsoon season. Most of the major rivers around the big cities like Dhaka, Khulna, Chattogram, Rajshahi, Sylhet suffer from severe pollution. Water quality of the Buriganga, Shitlakhya, Rupsha, Karnafuli, Karotoa and Surma Rivers are severely degraded and most of them have Dissolved Oxygen below the standard level in the dry season. Many of the wetlands are also at serious environmental risk due to pollution, encroachment, and disconnection between wetlands and the river system, particularly in the Northwest hydrological region.

Wetland Conservation

Wetlands play a crucial role in maintaining the ecological balance of ecosystems, flood management and work as retention basins in the wet season. Wetlands contain very rich components of biodiversity of local, national, and regional significance and it also supports millions of people's livelihood. Wetlands, which are locally called haors, baors (oxbow lake), and beels (depressions), are disappearing due to population pressure, ill planned infrastructures that prevent wetlands from maintaining their ecological and hydrological functions, etc. The total area of wetlands in Bangladesh is estimated to be 7 to 8 million ha, or about 50% of its total land surface. However, wetlands are reducing at an alarming rate and it is important to conserve and restore these wetlands.

4.2.2 *Institutional Capacity and Coordination*[11]

MoWR is the apex body of the Government for the development and management of water resources of the country. WARPO is responsible for national water resources planning and centrally coordinating and monitoring the implementation of the NWMP. BWDB is the national organization mandated for sustainable management and development of the country's water resources. However, the country has more than 35 central government organizations, affiliated with about 13 Ministries/ Divisions, which are working for water sector planning, development and management, with several large, medium and small water management projects to offer irrigation, flood management and drainage. The capacities of most of these organizations in terms of manpower, technical knowledge, budget, etc. are not sufficient to undertake their mandated tasks efficiently as well as increased scope of work considering the existing problems and future challenges. Operation and maintenance (O&M) work of most of the existing structural interventions are not duly performed because of shortage in human and financial resources. Moreover, inter-agency coordination and partnership are limited during the planning, implementation and post implementation (e.g. monitoring and updating) phases for most of the

[11] Institutional issues are discussed fully in Chapter 12.

water related projects which are basically multi-sectoral and multi-disciplinary in nature and require integrated approach of the relevant organizations.

Prevailing institutional arrangements are inadequate to respond to the needs of IWRM implementation. There is limited consensus on the formulation and implementation of IWRM schemes in Bangladesh. Institutional and organizational versatility is an absolute prerequisite for integration across different sectors and spatial boundaries in considering interdependency of natural systems and social response to increasing demands. Stakeholder involvement and participatory approach is inadequate in water resources management scenario of Bangladesh. Necessary decentralization has to be done to facilitate institutional change and organizational adaptability to swap the more conventional supply-driven approach in current water management with more demand-driven management keeping in mind that water is a scarce commodity.

4.2.3 Knowledge Gaps

Water resources of the country are mostly dependent on external sources. So, management of the water resources largely relies on upstream developments by the upper riparian countries. The country does not have adequate information on the upstream development of the riparian countries (e.g. construction of hydro-power plants, dams, irrigation and river linking projects, etc). Water resources within the country (e.g. water bodies) are continuously being encroached and such resources are not being protected and preserved due to lack of timely acknowledgement of these issues by the relevant agencies. Moreover, researches on existing issues such as flood management, erosion prediction, channelization of rivers, sediment balancing, impact of climate change and identification of adaptation techniques etc. are being conducted in limited scale. However, in-depth and detailed researches on these issues should be conducted in an integrated manner for real application. With climate change in mind, BDP 2100 suggests conductiing of studies on transboundary river flows and hydrology. Additionally, research on effective institutional arrangement and functioning is also needed.

4.3 Future Water Challenges

Management of water resources has become a preeminent necessity in Bangladesh with the ever-growing demand for water and the escalating conflict over its alternative uses over the decades. Thus, for efficient utilization through better management, identification of the various multidimensional challenges that might occur in the future is of utmost importance.

4.3.1 Challenges due to Climate Change

It is estimated from IPCC that due to climate change, temperature of the country may rise within a range of 1.4 to 1.9°C under better conditions and for worst conditions it might rise up to 2°C by the year 2050. As temperature rises higher, more erratic behavior of rainfall along with changes in rainfall amounts is predicted in the future. Impacts of such climate change on the country's water resources are assumed to affect the most in the coastal zone. Water availability will be reduced and natural hazards like cyclone, storm surges and coastal flooding will increase. The salinity level of groundwater along with the surface water will rise rapidly due to the sea level rise as a direct impact of climate change. The local communities and their livelihood would be greatly vulnerable to these impacts of climate change.

4.3.2 *Physical Challenges*

Physical challenges of water resource management will be greatly exacerbated by deterioration of infrastructures which mostly perform flood control, drainage and irrigation functions. From CEGIS (2015) analysis, it was found that over 50% of flood area increase is anticipated by the year 2050 in the Coastal area (Southwest region) of Bangladesh. Such extreme change will definitely cause severe deterioration to the FCDI structures. Deterioration of such structures may result in the inefficient and non-pertinent planning of water uses. Unless an integrated approach is instigated, efficient water management and its sustainability will not be achieved.

4.3.3 *Institutional Challenges*

Sustainability of the water institutions will be a real challenge in water resources management. The two crucial factors are the resources mobilization for operation and maintenance activities and its execution. These crucial factors greatly depend on the multidisciplinary participation, cooperation and partnership of the water related institutions.

4.3.4 *Challenges due to Population Growth*

Domestic water demand is estimated to increase up to 50% by 2030 and 100% by 2050 considering the population growth (BDP 2100 Population Growth and Management Baseline Study). The population growth of Bangladesh will increasingly stress the water resources management of the country. Thus, it has the potential to be the dominant environmental and possibly the most important development challenges in the coming half of the century. Significant investments in infrastructure will be required to provide potable water to the expanding urban centers. Urban and industrial pollution around these urban centers will affect the fresh water quality. With the growing population sanitation will become a major issue both in the urban and rural areas.

4.3.5 *Challenges due to Upstream Development*

The country's water resources management will increasingly face challenges due to upstream river basin developments. Infrastructural developments in upstream countries particularly in India have significantly reduced the dry season flow of the transboundary rivers. The reduction of the Ganges flows has severely affected the fresh water supply to the communities, agriculture, navigation, hydro-morphological dynamics, etc. in the southwestern region of Bangladesh and especially on the ecology of the Sundarbans. Further effects are also assumed to escalate in the future due to ongoing and proposed hydropower development in the upper riparian countries regional basin scale as well as on the national scale are discussed in this chapter.

4.4 Transboundary Water Management Issues

Bangladesh has been formed as one of the greatest deltaic plains of the world at the confluence of the Ganges, the Brahmaputra and the Meghna rivers and their tributaries and is characterized by highly variable climate and hydrology over its 147,570 km^2 terrain. Although the three rivers of this system have distinct characteristics and flow through very different regions for most of their lengths, they share social, economic and political connections, joining only just a few hundred kilometres upstream of the mouth of the Bay of Bengal. These mighty rivers dominate to water resources planning and development in Bangladesh.

Among the 57 transboundary rivers, 54 are shared with India. The annual cross-border river flows in Bangladesh are estimated to be 1,260 BCM, of which the three main rivers contribute around 981 BCM. Of the latter amount, some 54% is contributed by the Brahmaputra, 31% by the Ganges and nearly 14% by the tributaries of the Meghna. As Bangladesh is located in the low-lying delta of the Ganges- the Brahmaputra- the Meghna basins, water resources management is complex and highly sensitive to upstream developments. The various issues that arise, both on the regional basin scale as well as on the national scale are discussed in this chapter.

4.4.1 The Ganges- the Brahmaputra- the Meghna River Systems

The Ganges, the Brahmaputra and the Meghna (rivers emanate from the Himalayas, are international rivers having a total basin area of about 1.72 million km^2, of which only 7% is located within Bangladesh. The Ganges, the Brahmaputra and the Meghna are independent river basins. They originate from three different sources and their geographical, hydro-meteorological, hydrological and morphological characteristics are different as well. The high and low water flows of the Ganges and the Brahmaputra occur at different times of the year. The Brahmaputra is a braided river whereas the Ganges is a meandering river. More than 2000 years ago the Ganges, the Brahmaputra and the Meghna emptied in the Bay of Bengal separately. As a consequence of tectonic forces in conjunction with fluvial dynamics, the courses slowly shifted and took up its present form through the three major systems.

The Ganges is the combined flow of the rivers Alaknanda and the Bhagirathi. Originating from the Gangotri Glacier in the Uttaranchal Himalayas, which then flows across the broad plains of north India and enters Bangladesh about 50 km downstream of Farakka, joining the Brahmaputra further downstream, near Goalanda Ghat in Bangladesh as the Padma and further down, joins with the Meghna at Chandpur; ultimately falling into the Bay of Bengal with a combined length of approximately 2,500 km. The Brahmaputra originates in the Jima Yangzong glacier near Mount Kailash with major portion of its discharge fed from the snowmelt of the Himalayas. It flows eastwards into India through Arunachal Pradesh, then westwards through Assam and Meghalaya and then enters Bangladesh; flowing south as the Jamuna River into the Padma River. It eventually meets up with Meghna near Chandpur and flows into the Bay of Bengal as Meghna. The source of Meghna originates from the Barak River in northeastern India and flows through the Surma-Meghna Kushiyara system in Bangladesh. The Surma joins with the Meghna near Kuliar Char and then the Kushiyara joins in near Ajmiriganj; ultimately flowing into the Bay of Bengal near Bhola District.

4.4.2 Historical Overview of Transboundary Issues

British India & Pakistan Period

The Ganges- the Brahmaputra- the Meghna combined, comprises the second largest riverine drainage basins in the world. These basins are jointly shared by Bangladesh, Nepal, China, India and Bhutan. Myanmar, although outside of the GBM basin, is also an upstream neighbour. Bangladesh and India share some of the most intricate and complex river systems. Bangladesh, being the lower riparian countries, has faced a multitude of water management related issues over the past decades, primarily due to various upstream interventions.

Initially river management schemes in the undivided sub-continent were addressed by the British rule. The primary focus then was on the Ganges as it was extensively used by both the British for navigational purposes as well as for irrigation and other forms of livelihood. The earliest major intervention on the Ganges was the Bhimgoda Barrage built initially in 1854 at the headworks of the Upper Ganges Canal. Although its primary purpose was irrigation, the barrage also contributed in hydroelectric power generation and flood control. Since then, India has constructed barrages and dams on tributaries of the Ganges and the Brahmaputra, while also diverting water from these structures for irrigation purposes.

Immediately after 1947 partition, these upstream developments posed serious problems as probable consequences were mostly unforeseen by the then downstream governments. These sparked the initial India-Pakistan talks in 1951 on past and probable future interventions in the Ganges; which was subsequently followed by talks for interventions on the Teesta in 1955 and also on the Mahananda, Gumti, etc. The governments of India and the then Pakistan held several round of talks between 1950-70s in resolving the disputes at different administrative levels ranging from ministerial to technical levels. Discussions and correspondence also took place at the highest echelons of the Government. The Farakka barrage over the Ganges in 1975 was among the first of the upstream interventions that came in that period.

Post-Independence Period

To ensure the continuation of this bilateral dialogue process, the Joint Rivers Commission (JRC) was established on a permanent basis pursuant to the joint declaration of the Prime Ministers of Bangladesh and India in March, 1972. The JRC has held 37 meetings at the ministerial level and discussed various issues such as sharing of transboundary waters, joint river basin management, sharing of data, control interventions, embankment & river bank protection, works adjacent to the international border and other pertinent issues of the transboundary rivers. JRC is authorized to address technical issues of common rivers, resolve minor issues and facilitate communication between both countries. On the operational level, the JRC monitors the implementation of the Ganges Treaty at the Farakka Point.

Present Transboundary Issues

Being highly dependent upon upstream flows, diversion, use or storage of flows from the transboundary rivers are of major concern to Bangladesh. Impacts on dry and monsoon flows, salinization, siltation of rivers and sediment deposition in the Meghna estuary are the most critical issues. Moreover, the frequency and intensity of flooding is increasing owing to the changing climate.

For Bangladesh, about 87% of the total annual water availability comes from the three main rivers, where the primary contribution among the major three rivers comes from the Brahmaputra. But as this amount gets severely reduced down to about 7% during the dry season, arrangements for equitable sharing of water become one of the most crucial aspects. Also, as the downstream country, Bangladesh is prone to river flooding due to increased upstream flow during monsoon. Deterioration of quality of water due to upstream interventions is further restricting access to safe drinking water. Initiatives and discussions need to be undertaken both at bilateral and multilateral including all the upper riparian countries.

Although, India and China's policy was driven towards bilateral negotiations with other riparian countries, this generic viewpoint however, is witnessing a shift in India's attitude towards a more multilateral approach with regard to the country's transboundary rivers. The state level visits between India and Bangladesh in 2010, 2011 and 2015 paved the way for initiatives involving Nepal, Bhutan, India and Bangladesh to jointly manage the Ganges and the Brahmaputra rivers. So far, these initiatives are in an initial stage but seem as a promising development in regard to water diplomacy practices in the Ganges- the Brahmaputra- the Meghna basins.

4.5 Regional Co-operation Framework and River Basin Organization

Water is the most important natural resource for the survival of the mankind. Globally, about 97.50% of the water is saline and only 2.50% is fresh water (UNESCO, 2017). Out of this 2.50%, only 0.30% is available as surface water in river systems, lakes and reservoirs. Even this freshwater system is undergoing continuous natural changes in terms of quality and quantity as the bodies bearing this water is under constant change both morphologically and hydro-dynamically. Thus, managing the sustainable development of such a precious resource can exert immense pressure both within as well as among international borders of the respective two or more nations sharing the same river basins. Although there are some good practice examples of regional water cooperation in different parts of the world, they remain a minority. Still to date, 60% of the shared river basins have no effective cooperative management framework based on the principles of equitable and reasonable distribution and utilization.

As the lowermost riparian recipient of water from the Ganges, the Brahmaputra and the Meghna, which also flows through India, China, Bhutan and Nepal, any intervening development upon the river dynamics and/ or morphology; either individually or bilaterally can further aggravate the already vulnerable scenarios Bangladesh is currently facing in terms of water availability. Spatial and temporal variation of the otherwise bountiful annual water resource is a major hindrance to the socio-economic development of Bangladesh. Proper utilization and management of river basin can only be ensured through the sharing of knowledge and resources equitably and planning holistic and integrated approach at river basin scale. To that end, the Governments of Bangladesh and India signed a "Framework Agreement on Cooperation for Development" in September, 2011.

This historical document encompasses number of areas of mutual interest, the highlights of which are as follows.

- To promote trade investment and economic cooperation;
- To enhance cooperation in sharing of waters of common rivers and exploring the; possibilities of common basin management of common rivers for mutual benefit;
- To cooperate in flood forecasting and control;
- To cooperate and provide necessary assistance to each other to enhance navigability and accessibility of river routes and ports;
- To develop mechanisms for technical cooperation and exchange of advance information with respect to natural disasters;
- To establish arrangements for cooperation in generation, transmission and distribution of electricity, including electricity from renewable or other sources;
- To promote scientific, educational, cultural and people to people exchanges and cooperation between the two countries, which will be implemented through programmes and joint initiatives in the areas of agriculture, education and culture, health, tourism, sports, science and technology;
- To develop and implement programmes for environmental protection and responding to the challenges of climate change through adaptation;

- To harness the advantage of sub-regional cooperation in the power sector, water resources management, physical connectivity, environment and sustainable development for mutual advantage, including jointly developing and financing projects;
- To cooperate closely on issues relating to their national interests; and
- To cooperate on security issues of concern to each other while fully respecting each other's sovereignty.

Both governments agreed on enhancing cooperation in sharing of water resource of common rivers and integrated river basin management in light of this frameworkwhich has opened the opportunity towards establishment of joint body River Basin Organizations (RBOs) to address the issue of common river basin management through implementation of Integrated Water Resources Management (IWRM) at river basin level and comprising representatives from the respective member riparian countries. Some examples of similar basin wide organizations are the Mekong River Commission, Nile Basin Initiative, and International Commission for the Protection of the Rhine, Lake Chad River Commission etc. Although presently, there are no such organizations in existence for the South Asia region, the following can be established in light of the above framework:

- Ganges River Basin Organization - comprising Bangladesh, India and Nepal;
- Brahmaputra River Basin Organization - comprising Bangladesh, India, Bhutan and China; and
- Meghna/ Barak River Basin Organization - between Bangladesh and India.

Joint Initiatives for Transboundary Issues

Bringing countries on board the river sharing negotiations is challenging in the Ganges- the Brahmaputra- the Meghna basins. Especially upper riparian countries do not always see the benefit of active involvement in river dialogues. So far, the strategy to invite upper riparian states has therefore, not been very effective. Furthermore, India and China are very explicit in their official documents and statements about their will to exclusively negotiate bilaterally on water issues; pointing at their size and upstream position for their lack of interest in being actively involved in water negotiations. Both countries are not openly interested in setting up multilateral agreements, and even though this approach has been prevalent for decades, a recent shift can be noticed in India's attitude towards a more multilateral approach with regard to the country's transboundary rivers. In line with the improving relationship between the Bangladesh and India, cooperation on water resources management and hydro-power has also been emerging recently on a more sub-regional level.

The Joint Working Group (JWG)

The year 2010 can be regarded as a tipping point for the relationship between India and Bangladesh. In September 2011, a Framework Agreement has paved the way for inter-alia basin wide management of international rivers, joint development of hydro power etc. State visits between India and Bangladesh in 2010, 2011 and 2015 paved the way for the "Joint Working Group", an initiative involving Nepal, Bhutan, India and Bangladesh to jointly manage the Ganges and the Brahmaputra rivers. The Joint Working Group (JWG) is the most tangible outcome of these successful state visits between India and Bangladesh; in which, Bangladesh, India, Nepal and Bhutan are currently actively participating. The willingness of India to take part in this multilateral initiative acted as the driving force for other countries to also partake actively in this sub-regional cooperation initiative.

Although, this joint-initiative is at an early stage, it does provide a promise of future developments with regard to water diplomacy practices in the Ganges- the Brahmaputra- the Meghna basins through enhancing cooperation in sharing of the waters of common rivers and exploring the possibilities of basin management of common rivers for mutual benefit. It ensures cooperation regarding flood forecasting and control and providing necessary assistance in enhancing navigability and accessibility of river routes and ports. It also aims at harnessing the advantages of sub-regional cooperation in the power sector, water resources management, physical connectivity, environment and sustainable development for mutual advantage, including jointly developing and financing projects.

JWG Meetings

The Joint Working Groups on sub-regional cooperation are headed by the Ministry of Foreign Affairs and supported by representatives from relevant Ministries and Organizations. The Joint Rivers Commission's Member is one of the members of the Joint Working group on water resources management and hydro-power. Meetings are organized around water resources and hydropower track and a connectivity track. So far three meetings have taken place for JWG alternatively in Dhaka and Delhi. The first meeting of the Joint Working Group took place in April 2013, where a sub-regional initiative on water cooperation was launched. The countries Bangladesh, Bhutan and India were present. The meeting attached highest importance on the directives of the Prime Ministers of Bangladesh and India for harnessing advantages of sub regional cooperation.

The second meeting of the JWGs on sub-regional cooperation between Bangladesh, Bhutan, India and Nepal (BBIN) on water resources management, hydropower and connectivity and transit was held in New Delhi in January, 2015. It reviewed the existing cooperation in these sectors and discussed the scope for power trade and inter-grid connectivity between the four countries as well as potential for closer cooperation in future power projects. It also took stock of existing bilateral arrangements between the four countries on data sharing for flood forecasting and ways of improving the same. The third meeting of the JWG for sub-regional cooperation between the BBIN was held in Dhaka in January, 2016. It was agreed to form a Joint Experts Group on sharing best practices of basin wide water resources management during this session. The Group will provide suggestions on potential project development and work on the specifics of identified projects. It will also work on power trade and inter-grid connectivity, flood forecasting, and areas of further possible cooperation.

Other Regional Organizations

The Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) is a regional organization comprising seven Member States lying in the littoral and adjacent areas of the Bay of Bengal constituting a contiguous regional unity. This sub-regional organization came into being on 6 June 1997 through the Bangkok Declaration. It constitutes seven Member States: five deriving from South Asia, including Bangladesh, Bhutan, India, Nepal, Sri Lanka, and two from Southeast Asia, including Myanmar and Thailand. In its 3rd Summit in Myanmar in 2014, BIMSTEC declared to continue cooperation in the area of fisheries, including inland fishers, and conservation and management and sustainable use of marine resources in the Bay of Bengal region. It also declared to continue and enhance cooperation in the field of agriculture, including crops, livestock and horticulture; and to intensify cooperative efforts by materializing short and long term joint research programmes towards increased productivity and yields of agricultural produce in the region. BIMSTEC members also signed a memorandum to establish a centre for weather and climate.

4.6 Review of Progress with Regional Water Cooperation

4.6.1 Cooperation between India and Bangladesh

Sharing of the Ganges Waters at Farakka

The Government of Bangladesh and India signed a Treaty for sharing the Ganges waters at Farakka on 12 December, 1996 for a period of 30 years and the two countries have been sharing the Ganges waters since 1997. Bangladesh has been receiving its guaranteed share of 35000 cusec of the Ganges water at Farakka in three alternate 10-day periods during the critical period (11 March to 10 May).Discussions are also being held with India for augmentation of the dry season flows of the Ganges at Farakka in accordance with the provision of the Treaty. The issue of augmentation of the Ganges flow at Farakka by constructing reservoir in Nepal was also discussed in the 37thmeeting of JRC in March, 2010.

Sharing of the Teesta Waters

Bangladesh and India have been implementing the Teesta Project for irrigation and other uses. The two countries have already constructed two barrages in their respective territory on the Teesta River for diversion of water. The Joint Rivers Commission (JRC) at its 32nd meeting held in Dhaka in July, 1997 set up a Joint Committee of Experts (JCE) headed by Water Resources Secretaries of both the countries for working out a formula for long term/permanent water sharing agreement of the common rivers with priority to the Teesta.

The Secretaries of Bangladesh and India have agreed to a framework in January 2011 for concluding interim agreements for sharing of the dry season flows of the Teesta River. During the visit of the Prime Minister of India to Bangladesh in September, 2011, the two Prime Ministers in their Joint Statement welcomed the progress on the principles and modalities of interim agreements on sharing of waters of the Teesta River on fair and equitable basis. The Indian Prime Minister during his visit to Bangladesh in June, 2015 assured that deliberations are underway involving all stakeholders with regard to conclusion of the Interim Agreements on sharing of waters of Teesta as soon as possible.

Sharing of Water of all other Transboundary Rivers including Dharla, Dudhkumar, Manu, Khowai, Gumti and Muhuri

Bangladesh and India exchanged available data of the Manu, the Muhuri, the Khowai and the Gumti in 1999 and that of the Dharla and the Dudhkumar in 2000 and also relevant technical parameters in the subsequent technical level meetings. The sharing of data of these six rivers is being discussed at the technical level.

Flood Forecasting and Warning

Pursuant to the existing arrangements, Bangladesh has been receiving flood related data and information of various transboundary rivers from India during 15 May to 15 October since 1972. In addition, data of flashy rivers are received from 01 April every year. On the basis of the data received from India, the Flood Forecasting and Warning Centre of Bangladesh Water Development Board is able to provide a maximum of 120 hours flood forecasting at the central part of Bangladesh.

4.6.2 Cooperation between Nepal and Bangladesh

After the two consecutive devastating floods in 1987 and 1988 a summit level meeting was held between Bangladesh and Nepal. In accordance with the decision taken at the summit level meeting a Bangladesh-Nepal Joint Study Team was set up. The joint study team prepared a report on "Flood Mitigation Measures and Multipurpose Use of Water Resources", which has already been endorsed by the two Governments. As per the recommendation of the Joint report, a Nepal-Bangladesh Joint Expert Committee was formed in 1998, to work jointly relating to mitigation of floods, flood damages, harnessing and development of water resources. The Joint Expert Committee has so far held five meetings. According to the decision taken at the 2nd meeting, the Nepalese side is providing flood season water level and rainfall data of the Kosi, the Narayani and the Kankai rivers to the Flood Forecasting and Warning Centre of Bangladesh Water Development Board since 2002.

The Joint Expert Committee in its 4th meeting held in June, 2006 decided to form a Nepal-Bangladesh Joint Technical Study Team (JTST) comprising expert representatives of the relevant subject of various departments to carryout joint studies, research and investigations on harnessing of water resources and mitigating flood damages of both the countries. The Terms of Reference (ToR) of the JTST was formulated in this meeting and decided to complete the study within a period of three years. Pursuant to the decision the Joint Technical Study Team of both the countries has already been formed.

The 5th meeting of JEC was held in Dhaka in February, 2008. The Committee finalized the work plan of the Joint Technical Study Team (JTST). The Committee noted that there exists huge potential in Nepal for harnessing of water resources by constructing reservoirs at suitable locations in Nepal. These would achieve flood peak attenuation at lower reaches, augment dry season flows and also generate huge hydro-power. The Nepalese side informed that they are currently conducting studies to harness its water resources with reservoirs options on some of the major tributaries of the Ganges in Nepal. The Bangladesh side, therefore, expressed its desire to participate in the joint initiative for harnessing the water resources of the Karnali, Gandaki and Kosi river basins and other Nepalese tributaries of the Ganges for common benefit of all.

The Governments of Bangladesh and Nepal discussed sub-regional co-operation including development of hydropower and water resources management. The two sides discussed to re-activate the Nepal-Bangladesh Joint Expert Committee on harnessing water resources and mitigating floods and flood damages.

4.6.3 *Cooperation between China and Bangladesh*

After the two flood catastrophes of 1987 and 1988 in Bangladesh, a summit level meeting was held between China and Bangladesh in November 1988. In the Summit level meeting, it was decided that both countries would cooperate with each other for exploring the possibilities for flood prevention and harnessing water resources in Bangladesh. As a follow up of this decision, a China-Bangladesh Joint Expert Team was set up. This team prepared a study report on "Flood Control and River Training Project on the Brahmaputra River in Bangladesh" in March 1991which has been endorsed by the two Governments.

In August 2005, a MoU was signed on cooperation in the field of water resources management between the Ministry of Water Resources of the People's Republic of Bangladesh and the Ministry of Water Resources of the People's Republic of China. As per the MoU the two sides agreed to cooperate in water resources management including relevant policies and regulations, research and development, trade and commerce, institutional capacity building and personnel training, etc. Concrete cooperation would involve the following main aspects:

- Cooperation and coordination in international water forum;
- Cooperation in areas of flood control, water induced disaster reduction, river training, water resources utilization and development;
- Enhancing the flood forecasting capability through exchange of flood related data and information of the Yaluzangbu/Brahmaputra river; and
- Utilize and protect the water resources of transnational rivers in the region keeping in mind the principles of equality and fairness.

Thereafter a meeting was held between the Water Resources Ministers of China and Bangladesh in February, 2006. In the meeting the two Ministers recognized the importance of integrated basin wise management of transboundary Rivers. As per decision of the meeting China is providing data of floods of three stations - Nugesha, YangCun & Nuxia of the river Yaluzangbu/Brahmaputra for the improvement of the flood forecasting and warning arrangement in Bangladesh from June, 2006. The two countries subsequently signed another MoU in September, 2008 titled "Provision of hydrological information of the Yaluzangbu/Brahmaputra River in flood season by China to Bangladesh" and renewed in June 2014.

Subsequently the implementation plan on the same has also been signed between the two countries in March, 2015 at Beijing. The signing of the above documents has further institutionalized the transmission of flood related data of the Yaluzangbu/Brahmaputra river from China to Bangladesh.

A meeting between the Water Resources Ministers of China and Bangladesh was held at Dhaka recently. In the meeting, the two Ministers emphasized the need to enhance bilateral cooperation in the field of Water Resources Development and Management.

4.6.4 *Cooperation between Bhutan and Bangladesh*

Bangladesh and Bhutan jointly conducted a study following the devastating floods of 1987 and 1988. The study recommended establishing a technical committee to pursue the recommendations of the report and to ensure proper implementation, which is yet to be established. During the visit of the Prime Minister of Bhutan to Bangladesh in December, 2014, the two Prime Ministers agreed inter-alia to enhance collaboration in Water Resources Management and Power/Hydro-power and

Connectivity in the sub-regional context. Both sides also agreed to enhance cooperation in tourism sector, agriculture, education, health and human resources development.

4.6.5 *Cooperation between Myanmar and Bangladesh*

Though Bangladesh and Myanmar share 3 international rivers, there is no specific institutional mechanism to address the issue of management of these rivers.

4.7 Strategy for Better Regional Cooperation

Being within the central position of the Ganges- the Brahmaputra- the Meghna basins and the recipient of substantial amount of transboundary flows from several neighboring countries, cooperation regarding water resources management with India, Nepal, Bhutan, Myanmar and China is essential for Bangladesh to foster further development. Closer cooperation has to be ensured with neighboring countries in view of the general understanding that joint cooperation outweighs individual development. Joint management of water resources has to be ensured at basin level through continued bilateral and multilateral dialogues. In particular, allocation of substantial amounts of water should be ensured for ecological maintenance of rivers, especially during dry season is required.

The historic Framework Agreement signed between Bangladesh and India advances the opportunity for equitable sharing and utilization of the common water resources through effective use of IWRM on a river basin scale. This is done by enhancing cooperation in sharing common river resources and integrated river basin management in light of the agreed framework in establishing water diplomacy. The following options can be considered to ensure proper management of river basin and utilization of available resources.

- Incorporation of multi-layered dialogues that will enable participating countries to initiate negotiations from new entry points and also link water related negotiations with other river interests and regional cooperation issues. They will be characterized by an open environment to enable participants to understand the viewpoints of other parties, where the contributors are not hampered by political or other power oriented position holders. Issues such as climate change and its consequences can be discussed in parallel in conjunction with other river basin management issues as it has a profound effect upon many aspects of water availability and management.
- Besides, multi-track water diplomacy has to be applied to prevent or peacefully resolve conflicts related to water availability, its allocation or use between and within states for better understanding of transboundary issues and to ensure effective formulation and implementation of common river basin management schemes related to joint usage and equitable allocation of water resources that are centered on the concept of benefit sharing.
- It is imperative that environmental flow is maintained in the rivers and as such, necessary initiatives have to be taken both on a bi- and multi-lateral basis and enacted accordingly. Discharge and quality measuring stations need to be established and regularly monitored at different locations on the river.
- Simultaneous negotiation of multiple treaties has to be done to ensure that the benefits given up on one treaty could be used as leverage for another more significant treaty. Instead of attempting to agree on one treaty at a time, negotiation of multiple treaties would be a better approach to gain optimal outcomes for Bangladesh. By applying the negotiation of multiple

treaties approach, both countries have more options to come to mutually agreeable and beneficial terms.

- Prioritization of rivers has to be done in implementing devised schemes regarding water sharing. Bangladesh and India have been sharing the Ganges water at Farakka since signing of the treaty in 1997. Discussions are also being held for augmentation of the dry season flows. Framework of agreement for sharing of Teesta needs to be developed as a treaty. Similarly, water sharing policy for the six other prioritized transboundary rivers namely the the Dharla, the Dudhkumar, the Manu, the Khowai, the Gumti, and the Muhuri need to be implemented at technical level.
- Demand based common river basin management schemes has to be initiated where the involved countries will weigh in their views regarding mutually beneficial river management and solve common issues both bi- and multi-laterally through construction of necessary infrastructure on optimal hydrological and ecological locations within the river basins.
- International approach can be implemented that will involve active participation of a third party, either an international organisation or a country. In order to ensure the effectiveness and acceptance of international involvement, both countries need to agree first to do so to ensure the legitimacy of the mediator to all concerned parties. An example can be the case for the Indus Treaty where the World Bank acted as the honest broker in maintaining negotiations between India and Pakistan (1960) towards the conclusion of the treaty. The World Bank also supported subsequent infrastructural development works. In much the same way, the Ganges-the Brahmaputra- the Meghna countries like Bangladesh, India, Nepal with the support of similar donor agencies may be able to harness the true water resources potential of the Ganges Basin and gain benefits across multiple platforms on or beyond water. Similar strategies may be adopted for other international river basins.
- Benefit-sharing "mutual gains" model has to be implemented that discourages unilateral actions and further encourages coordination between riparian countries. The concept behind mutual gains is to incorporate non-water issues into the negotiation process to augment the basket of benefits. The framework agreement has opened the opportunity for conducting negotiations through establishment of joint body river basin organizations in pursuing common river basin management. Involving various sub-regional cooperation issues such as in power sector or navigability and physical connectivity can greatly enhance the mutual gains basket.
- Legal and political-economy analysis has to be performed, focused on specific challenges to be encountered. Identification of key zones of possible effective cooperation can be done to develop concrete recommendations on how to foster effective cooperation.
- Strategies have to be devised to combat the implications of the adverse effects of climate change upon the river basins. Should there be a shortage on the availability of upstream flow, initiatives such as implementation of reservoir system to retain water to fulfill dry seasonal water demands has to be done.
- Furthermore, knowledge building on hydro-diplomacy would be useful for the trans-boundary water negotiations.

Chapter 5

Adaptive Delta Management, Delta Vision, Mission, Goals and Policy Options

Chapter 5 : Adaptive Delta Management, Delta Vision, Mission, Goals and Policy Options

5.1 Background

Having climbed the stairs to low middle income country, Bangladesh now aspires to move up to the upper middle income status. The past development record and outlook for the future are both positive indicators that this journey is possible. Yet, Bangladesh faces many development challenges. As noted in **Chapter 2**, in addition to the many policy and institutional challenges, Bangladesh faces many risks and vulnerabilities that are intimately linked with the geography of the country. The combination of climate change and sea level rise, the trans-boundary river flows, their paths to the sea, the ecological patterns emerging from these flows, the interaction with development involving use of land, water, forestry, fisheries and water transport for livelihoods all create opportunities and challenges for sustainable resource use as well as security of life and livelihoods. The frequency of natural disasters including cyclones and tidal waves combined with flooding, river siltation, water-logging, salinity, land erosion, drought, irrigation needs and drinking water shortages together present major policy, financial and institutional challenges. They also pose substantial downside risks to Bangladesh's development progress.

It is not entirely clear at this stage the extent of these delta-related uncertainties and their adverse effects on the economy and society. Yet, the development strategy has to anticipate these risks, analyze the likely adverse effects on development outcomes, and identify possible policy responses to counter these risks. The Adaptive Delta Management approach underlying BDP2100 involves essentially making policy choices to facilitate development under these uncertainties.

While global action on low-carbon development can influence climate change, from Bangladesh development planning perspective, climate change, weather pattern and natural hazards are all exogenous variables. The development planners will need to make assumptions about the likely behavior of these variables and study their likely development consequences. The policy responses to these exogenous developments to offset the adverse effects are another important set of variables. Thus, an essential element of the BDP 2100 is to develop various policy options that involve different combinations of exogenous variables (e.g. weather, natural hazard, climate change behavior, etc.), policy variables (investments, sectoral and macro-policies including policies for managing the delta-related variables, regulations and institutions) and development outcomes (endogenous variables: GDP growth, employment, poverty, water and food security, ecological balance etc.). This interactive relationship among exogenous, policy and endogenous variables is a meaningful way of projecting development outcomes under uncertainty.

Another important interaction that should be noted is the inter-relationship between endogenous variables and policy variables, especially investments. As the experience of the Dutch Delta management shows, considerable investments are needed to manage the various water-related risks. These investments will partly be financed by public sector from tax resources and partly by the private sector through the application of various forms of beneficiary pays principle. The ability to make these investments will critically depend upon economic prosperity of the country. Not only that tax revenues tend to increase with growth, with wealth increase the citizen's demands for better protection against natural hazards rises, which is reflected in willingness to pay for better protection services. Private investment capacity similarly increases. Low growth prospects reduce ability to do adequate investments resulting in lower protection against natural hazards.

Against the above backdrop, this chapter looks at BDP2100 vision, goals and targets and develops policy options that allow interactions among exogenous, policy and endogenous variables. It identifies the key exogenous assumptions, policy variables and long term development outcomes in terms of GDP growth, employment and poverty reduction. Details of investment programming and financing issues are provided in **Chapter 11**.

5.2 Adaptive Delta Management (ADM)

Adaptive Delta Management (ADM) is being introduced to clarify the strategic character and aims of BDP 2100 as a long term, holistic techno-economic water centric plan. ADM aims to support the development of an adaptive and integrated plan to enable robust and flexible decisions in deltas under uncertain changing conditions. This adaptive planning approach is directed towards the targets, and at the same time flexible in how and when to implement management interventions (Van Rhee, 2012). These questions of how and when to implement which investments need devising scenarios as investment appropriateness heavily depends on context prevailing at that point of time. As projections are no longer appropriate in longer term (especially interplay among drivers), scenarios are developed and updated regularly when new information and knowledge are available. ADM as applied in the BDP 2100 aims to support holistic water governance, planning and implementation in the Bangladesh delta under uncertainty, by anticipating short term and long term challenges and opportunities resulting e.g. from climatological, transboundary water flow and socio-economical changes. To do so, planners consider adaptation and development pathways based on scenarios instead of end-point solutions and time frames wherein actions are needed. In doing this, they seek from holistic and long term points of view connection with other investment agendas in different scenarios. ADM thus explicitly considers that decisions are taken over time concerning if, when and how to adapt and accepts the existence of deep (severe) uncertainty especially about external drivers and their future development which are being captured in different scenarios.

Within ADM a plan is conceptualized as a series of actions over time (pathways) depending on scenarios. The essence is the proactive planning for flexible adaptation over time, in response to how the future actually unfolds. The approach starts from the premise that policies/decisions have a design life and might fail as the operating conditions change (i.e. change of scenarios) and reach its tipping point. Once actions fail, additional or other actions are needed to achieve objectives, and thus a series of pathways emerge; at predetermined trigger points the course can change while still achieving the objectives. By exploring different pathways and considering path-dependency of actions, an adaptive plan can be designed, that includes short term actions and long term options which would survive or fit all or most of the extreme scenarios. The plan is monitored for signals that indicate when the next step of a pathway should be implemented or whether reassessment of the plan is needed.

To deal with uncertainties and to some extent to reduce it, ADM uses scenarios that describe narratives of plausible and possible (and not ‘desired’ or ‘preferred’) futures, upon which the performance, robustness and adaptivity of alternative strategies and pathways are evaluated. As such, they describe the external context (developments that cannot be influenced by the policy maker or planner) both in socio-economic and physical terms. The scenarios are used to evaluate the robustness and flexibility of strategies and pathways, and to design preferred pathways that include no- or low-regret measures and a number of alternative routes pathways that can deal with medium and long term changes. These are typical top-down vulnerability assessment as is done in scenarios analysis. Within ADM, not only top-down assessments but also bottom-up vulnerability and opportunity analysis can be used to identify adaptation tipping points (ATP). In a bottom-up analysis threshold conditions are defined that result in unacceptable performance. Scenarios are then used to assess a range of the timing of ATP's. For example, an adaptation tipping point may occur after 1 m of sea level rise. In a high-end scenario this may occur in 2080, while in a low-end scenario this may occur in 2100. The benefit of this approach is that the plan is much less dependent on the scenarios used. In case of new scenarios only the timing of the measures will change (and not the whole plan).

Although the approach is inspired by development in the Netherlands, Bangladesh has added specific features to the approach. While in the Netherlands the application of ADM focuses on the question: "How can we protect our country/city from adverse impacts resulting from uncertain changing conditions?" in Bangladesh the application of ADM focuses on development goals and thus aims to answer the question "How can we enable socio-economic development under uncertain changing conditions especially regarding climate change and (transboundary) water resources?

BDP2100 thus focuses on investments for achieving development goals that should be robust or adaptive under uncertain changing conditions. Adaptation actions are also explored. Another way to describe this difference is that in the Netherlands the focus is on the vulnerability (and not on the opportunities as the opportunities are not so much needed and the vulnerabilities are more urgent), while in Bangladesh both the opportunities and vulnerabilities are important. Moreover, the country's important needs are to invest in socio-economic development and enhance water security. Such investments need to be stress-tested against possible futures to ensure that they are robust and/or flexible to perform well or adapt if needed. Ideally, they should match within preferred development and adaptation pathways, meaning that they are a step in the right direction. The ADM is concentrated around two key drivers: 1) future water conditions based on transboundary developments and climate change and 2) socio-economic development and related land use changes. It follows the IPCC climate analysis approach and is both simple and effective and allows other key drivers to be included using a consistent approach.

The vision, mission, goals, scenarios and strategies are the elements of ADM. A brief of strategy formulation and related investment options are discussed here. The water related strategies have been described in **Chapter 6**.

5.2.1 Bangladesh Delta Stretegy Development

The aim of the BDP 2100 scenarios is to identify key bottlenecks and appropriate measures for each scenario. For each (set of) measures, the performance in the next decades is set against several key decision support indicators, which are qualitative and quantitative. The outcomes of the decision support indicators will be different depending on the strategy and scenario. Within the overall framework of the BDP 2100, the scenarios are inherently connected with the strategy identification, and form an integral part of the (strategy) assessment framework.

The main aim of scenario analysis is to identify key impacts and to address uncertainty. For this reason, a bandwidth of possible future developments is developed rather than a single or most probable future projection. This bandwidth of possible outcomes is used to evaluate the (cost-effectiveness of potential measures of adaptation to climate change. The scenarios enable uncertainty to be taken into account when selecting and evaluating strategies for adaptation in the future. In this way, a careful assessment can be made to decide which strategies should be prioritized. To properly carry out strategy assessments, the scenarios were therefore not designed as projections. Instead, they depict the 'extreme edges' of possible outcomes to identify those strategies that are well equipped and effective in all scenarios, and can thus be considered 'robust' or 'no regret' for today and tomorrow. In addition, it helps in identifying which measures are flexible versus measures that could create a certain 'one direction only' or 'lock-in' situation. This will create a well-informed basis for decision-makers to prioritize which strategies and measures should be implemented immediately (as 'no regret') and which measures could be postponed until it becomes clearer how the future of Bangladesh will evolve.

The strategy development approaches should be treated as a 'living document' and should be reviewed and updated regularly. In this context, combining the results of the BDP 2100 and ESPA Deltas[12] will be particularly valuable, albeit only for the Coastal zone covered under ESPA Deltas (the Ganges Floodplain). As the future unfolds it becomes clearer in which direction the economy and climate of Bangladesh is developing, and the scenarios can be adjusted accordingly. This should ideally be done in 5-year periods, connected to the 5-year master plans, and the different strategies and measures should be evaluated simultaneously. In this sense, scenario analysis can be considered as an integrated part of the process of creating a prosperous and sustainable delta.

5.2.2 Strategies

Reaching the Delta Vision and realize the Delta Goals throughout Bangladesh, requires both national planning and regional tailoring, because different parts of the country (the hotspots) have their own characteristics. Therefore preferred strategies have been developed for two national issues (Freshwater and Flood Risk Management) and for six hotspots (River Systems and Estuaries, Coastal Areas, Urban Areas, Barind and Drought Prone Areas, Chattogram Hill Tracts and Haor & Flash Flood Areas). The preferred strategy acts as a guide for implementing projects to warrant long term safety and prosperity in Bangladesh. Key principles are: adaptive, added value, robust, no-regret and integrated.

Basic Principles for the Preferred Strategy

In order to achieve the formulated goals under the BDP 2100, principles were identified that the preferred strategy should meet. The principles are:

1. The strategies should be *flexible* in their implementation to cope with unforeseen events and new information becoming available.
2. The strategies should be *adaptive* in the sense that they can be reviewed and updated in the Five Year Plans, based on the situation and development need.

[12] Further details can be found at www.espadelta.net

3. Projects that are part of the strategies should aim to be *'no regret'* projects in a sense of cost effectiveness, overall benefit and flexibility.
4. Implementation of strategies should be *integrated* in the sense that, all relevant stakeholders will be involved in the implementation process and that the implementation builds on advanced information technology, strengthening institutional capacity and innovative solutions.
5. Prioritization to *security* over economic growth, which means those projects will be implemented first that ensure attaining the food and water securities as well as safety against climate change and natural disasters. These short term projects are specifically nominated for the Investment Plan (Chapter 11: Investment Planning and Implementation Strategy). Depending on the developmental needs as per the scenarios and the availability of resources, projects for economic growth will be postponed and implemented *after* assuring water and food security and safety against climate change.

To warrant flexibility and adaptivity of the strategies, the time frame of the preferred strategy for the BDP 2100 is divided into three periods: short, medium and long term:

1. Short term (up to 2030): The projects for the time period of up to 2030 are called "short term" as these projects are based on the assessment of the present and near future needs and development targets. The aim of these projects is to ensure food and water security and fortify the foundation of becoming a middle income country by 2021.
2. Medium term (2030-2050): The sub-strategies for this timeframe are "indicative strategies" based on the country's growth target and plausible scenarios. The sub-strategies, with an in-built milestone of 2041, will be implemented through four consecutive Five Year Plans starting from 2031 and would be adaptive and more flexible in the sense that they will be reviewed and updated in every Five Year Plan based on the situation and development need. Connections need to be made with the SDGs and the upcoming Perspective Plan 2041. It is expected that the implementation of these strategies will help the country in achieving the target of becoming a developed country by 2041.
3. Long term (2050-2100): For the timeframe 2050 to 2100 long term projections of what is already ongoing and foreseen as well as "visionary" ideas are proposed which give direction to future strategy making. Given the uncertainty in environment and development, implementation will depend on the unfolding future scenario(s).

Two noteworthy sub-milestones will be 2021 and 2041, in support of the country's vision of becoming middle income country and developed country. This will ensure coherence with the Vision 2021 and Vision 2041 of GoB. **Figure 5.1** shows the BDP 2100 strategies with respect to its temporal dimension.

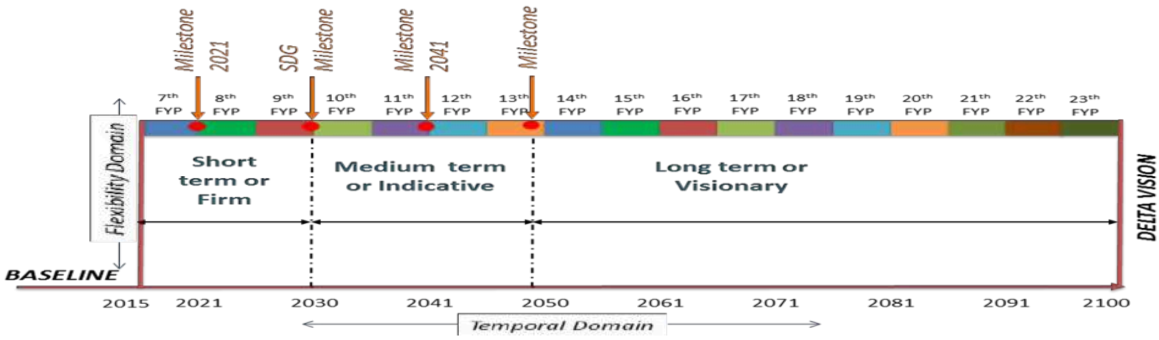


Figure 5.1: Temporal Domain of BDP 2100 Strategies

Finally, the preferred strategy has three levels of detail: Preferred strategy, sub-strategy and projects. A preferred strategy consists of sub-strategies, which in turn consist of projects necessary to realise and implement the sub-strategies. Based on the strategies and sub-strategies the Delta Investment Plan has been formulated.

Preferred Strategy

In the approach of the BDP 2100, strategy development not only focuses on solving the issues of today, projected into the future, but also with an end vision in mind and back casting towards the present. This is then matched with the issues faced today, amalgamating the two into a preferred strategy. This section offers the essence of the preferred strategy. As the BDP 2100 is a spatial plan, differentiated for hotspot regions in Bangladesh, the preferred strategy is summarized in text and in a series of maps, which cover respectively:

1. The Starting point for the preferred strategy: the current situation + the short term secured projects
2. The short term strategy (2030), in which the preferred strategy is illustrated by projects selected to reach the Delta Goals
3. The long term strategy (2100), visualized by two iconic endpoints of adaptation pathways: optimized water control, and adaptation by design.

5.2.3 Adaptive Pathways

Where uncertainty is important, adaptation or strategic pathways help understanding, scheduling measures and developing optimal combinations of measures to meet the policy goals. The Delta scenarios do not predict one single future; rather they describe different plausible stories of possible future developments. The scenarios have been developed to identify bottlenecks arising out of uncertain future developments and represent 'extreme edges' of possible outcomes. Measures that are affected strongly in terms of their effectiveness by external conditions (climate, economic development, technology innovation) may require further studies or can be delayed until actual conditions become apparent. Other measures, such as improved provision of safe drinking water and wastewater treatment for large urban centers, increasing conveyance capacity of small, medium and large rivers and rationalization of embankment along the rivers are considered basic measures which can and should be taken dependent of each scenario. Logically, the degree of uncertainty is very high for the timeframe beyond 2050, moderate to high between 2030 and 2050 and moderate up to 2030.

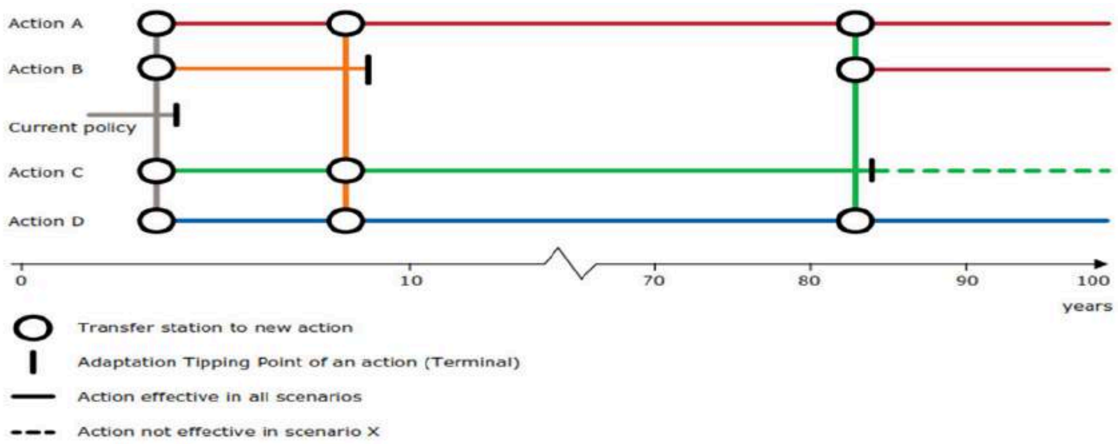


Figure 5.2: Principle of Adaptation Pathways; Source: Hassnoot (2013)

As can be observed from the scenario development (Annexure B), climate change is but one of the uncertainties, with socio-economic and upstream developments playing a significant role as well. The pathways are used to operationalize adaptive delta management (ADM) (Delta Program, 2012a): 'Development pathways or adaptation pathways offer a strong approach to show which options are needed, when they should be implemented and how long term objectives influence short term decisions'. Adaptation pathways are formulated in **Chapter 6** showing tipping points, dead ends and 'transfer stations'. Which pathway to follow depends on several factors, such as the cost of a strategy or action, but also the cost of shifting to another strategy once a tipping point has been reached.

5.2.4 Long term Intervention

The long term perspective is shaped by elaborating two *potential long term strategies* or *development philosophies.* The two long term potential strategies are called Optimized *Water Control and Adaptation by Design*. Both visions and associated strategies will never be implemented in their entirety. Each region will have a different mix and over time, when the water system has been developed to a sufficient extent, the vision will change, along with societal values and economic development. The two philosophies should therefore be seen as cornerstones **(Figure 5.3)**.

Figure 5.3: Cornerstones Strategies for the Future

Both end visions have the variable hydrology and climate in mind, and are based on an understanding of the multiple uses and functions of the water system. To gain control, the country needs to ensure the right amount of water at the right time, and of the right quality.

The Adaptation by Design approach:

i) tries to avoid interventions where possible by looking for alternatives, but does not exclude interventions;

ii) focuses on local solutions and strengthening of local communities and governance;

iii) puts great efforts in cooperation and transboundary negotiations;

iv) uses natural processes where possible (Building with Nature); and

v) based on differentiated flood zoning, rather than full embankment of the major rivers.

Whereas, a policy according to Optimized Water Control:

i) focuses on interventions as soon as knowledge, institutional capacity and finance permits;

ii) provides a basic safety against floods for all, allowing regular floods to enter by controlled gates; and

iii) aims for being independent from India by means of its own barrages and flow diversion projects.

Pathways close to an Adaptation by Design policy are more adaptive than policies that adopt the Optimized Water Control policy. An illustrative example is river bank stabilization and development of flood protection embankment, a measure in line with the Optimized Water Control policy. Once these sets of measures have been implemented and an area is protected against floods, it becomes difficult to remove the protection in favor of resilience or ecological values. People will have invested in economic activity that is not vulnerable to flooding because society relies on the protection or stabilization provided.

5.2.5 *Investment Options for the Short and Medium term*

Investment options for the short and medium term have been selected with the idea to keep the long term vision in mind while following two potential long term strategies and development philosophies. Secured projects up to 2021 are characterized by: i) on-going or already in the pipeline; and ii) included in the 7th FYP. Building on the short term measures (up to 2030) and the medium term measures (up to 2050) focused on three major aspects: *Infrastructure, Institutions* and *Innovation*. *Infrastructure* measures focus mostly on hard, physical interventions; *Institutional* measures consist of mostly soft measures related to water management organization, legislation, finance and capacity building. *Innovation* measures focus on addressing the knowledge gap and stimulating technological development. Chapter-6 describes the short and medium term investment options where over- and under-investments are being avoided. Under-investment occurs if the solutions are not adequate to protect society against damages in an extreme event. Over-investment happens when measures are over designed, which proves to be unnecessary and therefore too expensive.

5.3 Delta Vision, Mission and Goals

Setting long term goals in an uncertain environment: BDP2100 is envisioned as an integrated plan that considers how water management, climate change and environmental challenges affect long term development of Bangladesh. The opportunities, risks and vulnerabilities emerging from the interface of water, climate change and environmental issues are long term in nature. The strategies, policies and programs to counter the risks and build on the opportunities must also be formulated with a long term perspective. Yet there are immediate and medium term challenges that must also be addressed. The associated short to medium term strategies, policies and programmes will have implications for long term developments. Furthermore, long term planning is complicated by considerable uncertainties. Water, climate change and environment are heavily influenced by the behavior of nature that is not often predictable. How should strategies, measures and investments be formulated in the short to medium term to be consistent with the long term outcomes that are inherently uncertain? This is a major strategy challenge for the BDP2100, which has been addressed in **Chapter 6** on formulation of strategies that take into consideration different future scenarios.

The BDP approach to long term Vision: The BDP approach is to first develop a broad-based long term vision about the evolution of the Bangladesh Delta by the end of the 21st Century. This long term Vision emerges from the interface of the long term development goals of Bangladesh related to per capita income, poverty reduction and human development with the goal of reducing the vulnerability of the citizens from the interface of water, climate change and environment. Thus, an integrated, comprehensive and long term Delta Vision is:

"Achieving safe, climate resilient and prosporous delta"

The Mission for BDP 2100 formulated as:

"Ensure long term water and food security, economic growth and environmental sustainability while effectively reducing vulnerability to natural disasters and building resilience to climate change and other delta challenges through robust, adaptive and integrated strategies, and equitable water governance".

In order to achieve this long term Delta Vision, it needs to be translated into specific policy goals. The BDP2100 proposes 3 National level policy goals set by National Plans and 6 Delta goals of the BDP 2100 that contribute to these National level goals. The three National level goals and the six Delta goals to translate the Delta Vision into reality are as follows:

5.3.1 National Level Policy Goals

Goal 1: Eliminate Extreme Poverty by 2030

Bangladesh has secured considerable progress in reducing the incidence of poverty, especially since 2000. Both poverty and extreme poverty rates have come down sharply. The incidence of extreme poverty has fallen from 34.3% in 2000 to 12.6% in 2015 (BBS 2017). 2016). The target for the 7thFYP is to reduce this further to 8% by 2020. The extreme poor rely considerably on agriculture, fishery and forestry for their livelihood. As such, they are highly vulnerable to changes in water, climate and environmental hazards. Progress on the BDP2100 agenda will have a substantial impact on further reducing poverty and eliminating extreme poverty by 2030, as stated also in the Sustainable Development Goals (SDGs).

Goal 2: Achieve Upper Middle Income Country Status by 2030

Adopted in 2009, one major goal of Vision 2021 of the government was to reach low middle income status by 2021. Rapid growth since the 2000s, especially during 2010-2015, has enabled Bangladesh to reach the lower of the middle income threshold as defined by the World Bank in 2015. This is a remarkable achievement. The 7thFYP aims to build on this progress and move forward with a faster GDP growth rate to consolidate the progress with the middle income goal. Higher GDP growth is essential to reduce poverty and mobilize the resources needed to finance investments in infrastructure, human development, water resources management, as well as climate change and environmental management. In turn, the reduction of the various vulnerabilities and hazards associated with the Delta geography will be very important to support higher growth rates. The Government's target is to attain upper middle income country (UMIC) status by 2030. Accordingly, the BDP2100's support to helping Bangladesh reach UMIC status by 2030 would be a major long term goal.

Goal 3: Being a Prosperous Country beyond 2041

Bangladesh aspires to be a prosperous country beyond 2041as of Bangladesh's 'Vision 2041'.

Box 5.1: Assumptions on the Threshold of Upper Middle Income Country

According to World Bank estimates, the current per capita GNI threshold is USD 12,235 to be considered as a high-income country. Based on a review of the threshold values for the Upper-Middle-Income and lower-middle-income for the 20-year period 1997 to 2016, it can be seen that the upper-middle-income threshold value had increased at an average growth rate of 1.24% per year whereas the threshold for the high-income countries (HIC) increased at an average rate of 1.23% per annum. Assuming these average rates of increases remain unchanged over the long term, in FY41 the threshold values for per capita GNI for an upper-middle country and High-Income-country would USD 5,376 and USD 16,618, respectively. Accordingly, the main challenge for Bangladesh would be to grow at an average rate of 9.0% during the PP projection period of 20 years following the end of 7th Five Year Plan period for it to cross the projected HIC GNI threshold level by FY41.

Source: Chapter 5, Technical Annex

Source: Annex B: Technical Annex to Chapter 5

5.3.2 Delta Plan Specific Goals

Goal 1: Ensure Safety from Floods and Climate Change related Disasters

This goal focuses on managing the risks of floods in the wet season and other climate change related disasters in the Delta including the coastal zone at a well-defined and acceptable level. This level is set to facilitate i) a safe living environment for all, in urban and rural environments; ii) reliable water system conditions for long term economic development; and iii) the performance of key societal and economic functions. The risks of floods and climate change induced disasters are managed according to local knowledge base and spatially differentiated safety levels and include the combined approach of climate proofing, early warning and prediction, prevention, evacuation and disaster relief. The goal considers ensuring safety of lives and livelihood against flood, flash flood, drought, salinity intrusion, river bank erosion, cyclones, storm surge, etc. through introducing improved adaptation and mitigation options.

Goal 2: Enhance Water Security and Efficiency of Water Usages

This goal relates to water resources management especially during the dry season as well as water shortage during dry spells. Maintaining a balance between the economic developments, expanding population and the need to secure water for multifaceted uses is a core challenge of the BDP 2100. The goal aims to ensure reliable and adequate provision of freshwater to support equitable and sustainable economic development, environmental sustainability and livelihood security. This includes: i) sufficient and timely provision of safe surface and groundwater for drinking, agriculture, fisheries, environment, navigation, industry, etc.; and ii) controlling pollution, ensuring water quality and providing sanitation at acceptable levels in relation to defined standards as well as environmental, health, agricultural and industrial needs.

Goal 3: Ensure Sustainable and Integrated River Systems and Estuaries Management

This goal considers sustainable management of river systems and estuaries, considered as one of the cornerstones of the Bangladesh Delta. The river systems of the country offer key development ingredients for the economy, society and the environment. Sustainable river and estuaries management as a whole, contributes to i) long term solutions for navigation; ii) sufficient sediment supply to floodplains; iii) land reclamation in support of community development and economic growth; and iv) an inter-connected major and minor river systems for environmental and economic development. This goal seeks to foster sustainable river systems management by coping with its morphological dynamics and results in cost-effective, environment friendly and socially viable options for reclamation and developments of lands.

Goal 4: Conserve and Preserve Wetlands and Ecosystems and Promote their Wise Use

The goal uses the term 'conservation' as a more generic target to safeguard and maintain the wetlands, whereas 'preservation' is a more converging approach, to protect some sensitive ecosystem areas. Some of the components to be safeguarded under the goal are mangrove forests, water and riverine ecosystem, coastal greenbelt, seasonal and perennial wetlands, tidal freshwater frontier etc.

Goal 5: Develop Effective Institutions and Equitable Governance for In-Country and Trans-Boundary Water Resources Management

The goal aims to improve the existing water governance for tackling both the endogenous and exogenous challenges of water resources management. At the same time, the community level functioning of local institutions would also be rejuvenated. Key elements include: i) ensuring adequate financing for investment, operation and maintenance; ii) capacity building and institutional strengthening; iii) stakeholder and private sector participation at appropriate levels; iv) minimizing the gaps between planning and implementation; v) supporting integrated water resource management at regional and local levels, taking into account the interests of all prominent water users; vi) knowledge development for integrated decision-making though modeling, data and information sharing and management; and vii) trans-boundary negotiations on water resource management and building joint basin-wide cross-border platforms for cooperation initiatives.

Goal 6: Achieve Optimal and Integrated Use of Land and Water Resources

The primary quest of this goal is to ensure efficient integration and proper interaction between land and water use aspects. The goal would mainstream the inter-connected resources functions (drainage, navigation, etc.) as well. The key topics covered by the goal are land use, water use, and river transport network. Establishment of connectivity of water courses and inducing integration between different modes of resources interactions are emphasized under this goal.

BDP2100 adaptive planning approach to managing uncertainties: Given the inherent uncertainties of the long term behavior of the natural forces that influence water, climate change and the environment, it is essential to adopt a flexible and adaptive approach to converting the long term Delta Vision to short and medium term strategies. BDP2100 used the best available information and developed strategies and policy options under different assumptions about the external outcomes. These scenarios will change over time as new information is available. So, the scenarios and underlying strategies, policies and investments will need to be updated as new information is available on a 5-year cycle. These short term delta strategies and policies will provide the link to medium and long term strategies and policies in an adaptive manner.

As defined above, the BDP2100 goals are multi-sectoral in nature and relate to the following:

1. Goals related to socio-economic outcomes for the population. These concern the higher level goals. In the end, these are the ultimate goals that matter for all development efforts including the implementation of the BDP 2100.
2. Goals related to sustainability of long term development. It is essential to ensure that the socio-economic goals are achieved in a sustainable manner over the longer term. The sustainability issues relate to climate change, biodiversity, environment, water management and land management. The BDP2100 is primarily concerned with these sustainability questions. The BDP 2100 specific goals 1-6 above relate to these sustainability challenges.

The set of policy goals under one and two are inter-related. However, the methodologies to analyze and address these goals and related issues are different. While, it is relatively easy to project long term outcomes relating to the major socio-economic variables such as GDP growth, employment, poverty, using alternative assumptions about exogenous variables such as climate and policy variables such as investment, making quantitative projections of the sustainable use of water, land, biodiversity and environment is far more complex. Accordingly, this Chapter focuses on long term socio-economic outcomes for Bangladesh (national level policy goals 1-3). The Policy options developed in this Chapter concern the interactive relationship between the Delta-related exogenous variables, policy responses and implications for development outcomes (endogenous variables). More specifically, water and flood related goals and targets have been incorporated into the economic model as exogenous variables to assess the impact of these goals and targets on key macro-economic variables such as income generation (GDP), employment creation and poverty reduction.

The sustainability issues relating to water, land, environment and ecology (Delta specific goals 1-6) are discussed in **Chapter 3** (ecology, biodiversity and environment), **Chapter 4** (cross-boundary water management), **Chapter 6** (wet and dry water season problems including the water challenges in the coastal zone), **Chapter 7** (sustainable land use), **Chapter 8** (sustainable agriculture), **Chapter 9** (inland water transport), **Chapter 10** (urban water issues) and **Chapter 12** (governance and institutions). The related investment programmes and the criteria for selecting these investment interventions in relation to their relevance to these long term Delta goals are discussed in **Chapter 11**.

5.4 Delta Policy Options

5.4.1 Methodology, Data and the Proposed Analytical Framework

The proposed analytical framework for BDP2100 is the first attempt to quantify economic impacts of climate change by linking the real side (i.e. economic variables) to the environment or climate change parameters and estimate their implications for GDP growth, employment and poverty reduction[13]. A consistent macroeconomic framework has been used to generate the delta policy options. The framework consists of four linked models: (i) a macroeconomic model; (ii) an employment satellite model; (iii) a poverty model; and (iv) an environment model. For the purpose of this exercise, the models have been separated into 6 delta specific regions with varying region specific parameters (especially the environmental parameters). Data sets for the framework have been obtained from several sources such as:

- Bangladesh Bureau of Statistics (BBS)
- Ministry of Finance
- Ministry of Planning
- Ministry of Water Resources
- BDP 2100 Formulation Project
- Bangladesh University of Engineering and Technology (BUET)

Key features of the framework are discussed below:

Key Endogenous Variables and Targets

- Economic Growth
  - Upper middle income country by FY2030-31
- Employment
  - Create new employment in the formal manufacturing and services sectors and away from agriculture and informal services.
- Poverty rate
  - Eliminate extreme poverty by FY2030-31

Key Exogenous Variables

- Climate change
- Trans-boundary water resources
- Basin wide development

Policy Variables

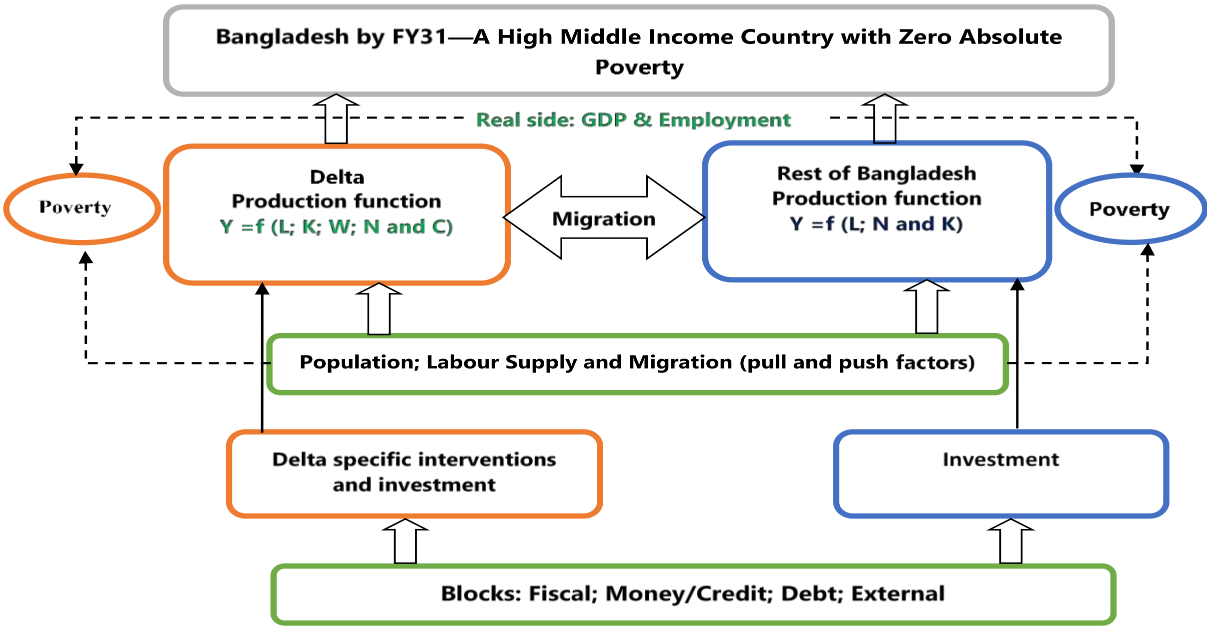
- Population and labor supply
- Overall investment (Public; Private; and FDI)
- River management and reservoir development

Specific investments considered for mitigating climate change and arresting (improving) deteriorating water and other natural resources. Also, specific investments in the following areas have been considered to ensure effective water resource management:

- Floods and climate change related disaster mitigation
- Water security and efficiency of water usages
- Sustainable and integrated river systems and estuaries management

[13] Annex B, Chapter 5 Technical Annex, provides a review of previous attempts to use a quantitative framework for modeling impact of climate change on development outcomes.

- Wetlands and ecosystems and promote their wise use
- Optimal and integrated use of land and water resources
- Effective institutions and equitable governance for in-country and trans-boundary water resources management



Legend: L: Labor; N: land; K: Capital Stock; C: Climate; W: Water

Figure 5.4: Schematic Presentation of the Analytical Framework

5.4.2 *Key Features of the Policy Options*

In order to illustrate the role of BDP2100 and its contribution to the long term development of Bangladesh, two policy options are considered.

- First policy option refers to the *Business As Usual (BAU) Policy option*. This policy option introduces the adverse effects of the climate change and natural hazards to the economic and social trends derived from the Perspective Plan and the 7thFYP to show how these effects change the base case outcomes with respect to growth, employment and poverty. All policies envisaged under the Seventh Plan are in place except the implementation of the BDP 2100. This represents the business as usual policy option of the present times where a coordinated effort to manage the delta risks and hazards does not exist. This BAU Risk Prone Policy option provides a description of long term socio-economic outcomes for Bangladesh in the event the projected natural hazards and climate change risks materializes and a concerted effort to counter these risks through the adoption of the BDP 2100 does not happen.

- Second policy option is the *Delta Plan Policy option*, requiring strong climate change and other delta related adaptation measures to achieve higher and sustainable growth trajectories in the face of the various weather-related natural hazards and risks, thereby ensuring that the government's long term objective of eliminating extreme poverty and the objective of achieving high middle income status by FY2030-31 and being a prosperous country beyond 2041 are secured.

Business as Usual (BAU) Policy option

Ignoring the risks posed by natural disasters and climate change would have serious adverse consequences for development outcomes in Bangladesh. As noted in **Chapter** 1, Bangladesh is one of the most vulnerable countries in the world considering the implications of global warming and sea level rise. Bangladesh would face huge risks because of increase in soil salinity, drought, cyclone, river erosion, water salinity and sedimentation of riverbed causing drainage congestion and floods, which would affect not only agriculture production but also other sectors.

Simulation Outcomes of BAU Policy Option

Possible Environment Risks in Bangladesh[14]

The specific risks faced by the various hotspots were discussed in detail in **Chapter 1** and **Chapter 2**. On average, the districts of the *River Systems and Estuaries Hotspot and the Coastal Zone Hotspot face the most intense risks.* The possible risks and likely impacts are shown in **Box 5.2.**

In the BAU policy option, an attempt has been made to capture all possible significant environmental risks that Bangladesh might be facing and their impacts on all major economic indicators are estimated for FY2016-41 period. It is envisaged that the impact of environmental risks would be more severe in the following important economic indicators: (i) per capita income; (ii) employment; (iii) infrastructure development; (iv) internal migration; and (v) poverty.

Box 5.2: Assumptions: Environmental Risk Parameters

Hotspots	Cyclone[1]	Flood[2]	River Erosion and Sea level Rise*[3]	Salinity[4]	Drought[5]	Siltation in water-ways[6]	Water shortage[7]
	% of loss	% of loss	% decrease in net cultivable area	% of loss in annual income	% decrease in net cultivable area	Distribution of loss in total loss of .20% of GDP	Distribution of loss in total loss of .05% of GDP
Haor and flash flood areas	5	10	0.30	0.0	0.0	10	0
Coastal Zone	45	20	0.50	0.30	0.0	20	0
River Systems and Estuaries	25	40	0.60	0.20	0.0	34	0
Barind and Drought Prone Areas	5	10	0.0	0.0	0.25	15	0
CHT	3	2.5	0.01	0.0	0.0	1	1
Urban Areas	12	10	0.10	0.05	0.0	10	90

[14]Earthquake is not included in this discussion

Less Disaster Prone Region	5	7.5	0.30	0.0	0.0	10	10

**Sea level rise is only for coastal zone*

Source: BDP 2100 Technical Team Analyses, GED, 2015

1. This framework takes the estimates of 'Cyclones in a Changing Climate: The Case of Bangladesh' (Dasgupta et al, 2011) to forecast the losses incurred due to Cyclone from 2016 to 2041. From their estimation of losses and damages where, damages refer to the potential complete or partial destruction inflicted on assets and losses refer to the potential flow of goods and services not provided and increased costs of continuing essential services, amount of losses (after adjusting them for 2005 prices) are taken into account as it is assumed that real GDP would be decreased by the amount of loss. To forecast the loss, it is assumed that loss increases at a rate of ten percent each year without any adaptive/mitigating measures.
2. To forecast the losses from floods till 2041, this framework takes into account the loss incurred in the past, modified from Choudhury et al (2003). In a fifty-year period the total reported loss from flooding was estimated to be Tk. 492 billion. To forecast for the period from 2016 to 2041, it is assumed that a total of Tk. 680.3 billion at constant prices loss would be incurred and it is assumed that it would increase at the rate of ten percent each year to accommodate increase in the intensity of lose as income increases. And this loss also includes the loss due to increase in rainfall, a consequence of global warming, and decrease in trans-boundary water flow.
3. To forecast the effect, this model assumes different percent of land loss across the region, according to their degrees of vulnerability, because of river erosion and sea level rise (only in coastal zone).
4. To forecast the intrusion of salinity, this model takes the forecast of Dasgupta et al (2014). They estimated that the income of Barishal Division would be decreased by a total of 10.5% in the period 2012-2050, which is the highest. Using their estimate, in this model it is assumed that in the coastal zone the loss would be 0.3% of income annually. It is also assumed the annual loss in river systems and estuaries and urban areas would be 0.2% and 0.05% of income, respectively.
5. Because of unavailability of the impact of drought in Bangladesh, this model takes the assumption of 0.25% of cultivable land is lost due to drought in drought prone areas.
6. It is assumed that siltation in water-ways would account for a total of 0.20% decrease in GDP.
7. It is assumed that water shortage would account for a total of 0.05% decrease in GDP.

Per Capita GDP

Incorporating climate change and natural disaster risks and subsequent loss in income due to these hazards provides a worrisome policy option. Real GDP growth slows down considerably from 7.2% in FY2017 to 7.1% per annum in FY2031 and further to 5.5% by FY2041, as losses from natural hazards and climate change reduce output and capital stock. As a result, per capita nominal income would reach only US$ 4,376 in FY2031, which would be US$ 379 lower than the per capita nominal income of US$ 4,755 required to achieve the upper middle income country (UMIC) status by that year (Figure 5.5). More importantly, there is an average loss of real GDP of 1.1% over the government's target of achieving 8% average GDP growth and 1.7% per year when compared with the Delta Plan Policy Option (Figure 5.6). This lower GDP growth not only will fail to achieve the target of UMIC by FY2030-31, but will have significant welfare loses in terms of employment and poverty outcomes.

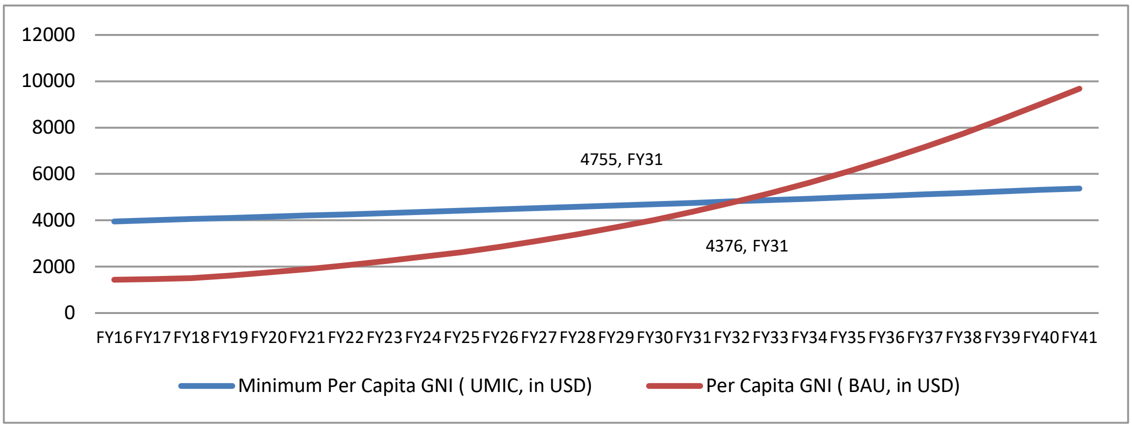


Figure 5.5: Per Capita GNI Comparison (US$)

Source: BDP 2100Projections, GED, 2017

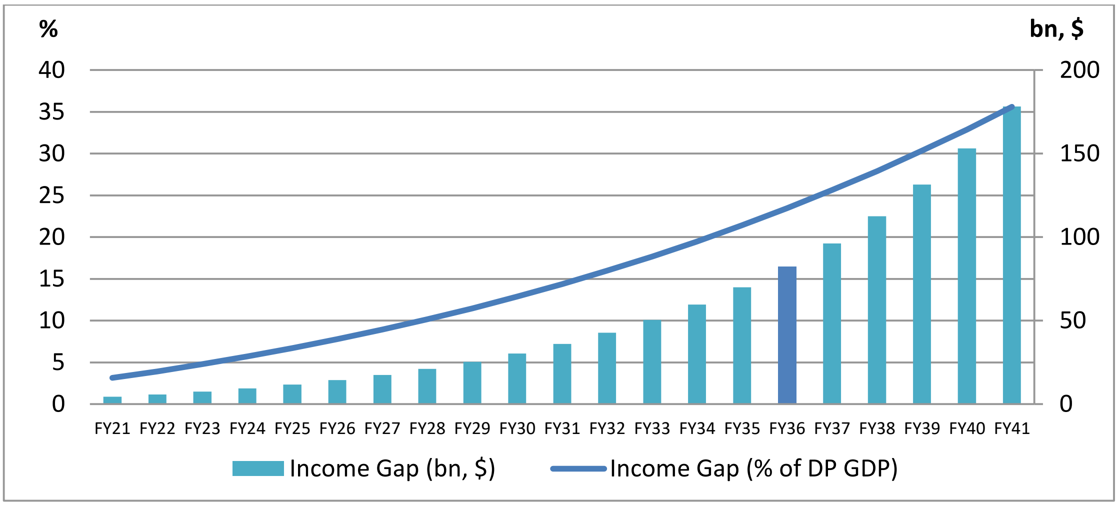


Figure 5.6: Income Gap between BAU Policy Option and the Delta Plan Policy Option

Source: BDP 2100 Projections, GED, 2017

Employment

New job creation depends on economic expansion. In the BAU policy option, because of sliding GDP growth, job creation will slow down. As a result, the level of unemployment would rise at a faster rate.

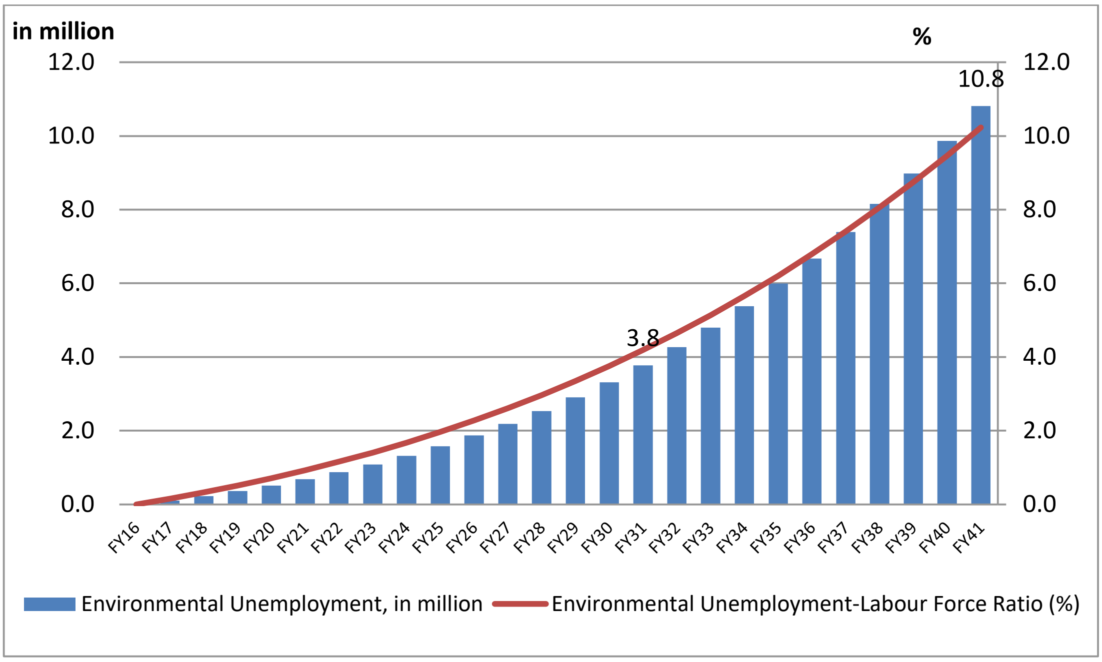


Figure 5.7: Increased Unemployment due to Environmental Degradation in BAU Policy Option

Source: BDP 2100 Projections, GED, 2017

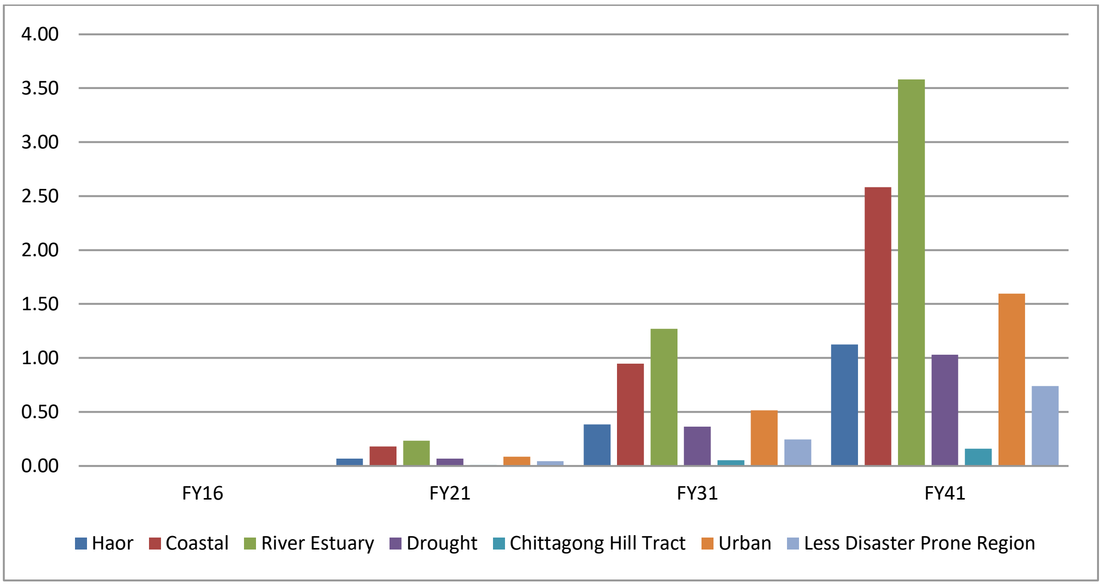


Figure 5.8: Hotspot wise Increase in Unemployment in BAU Policy Option (in millions)

Source: BDP 2100 Projections, GED, 2017

In the BAU policy option, with the intensification of climate change and other delta related environmental risks, total loss would be the highest in river estuary, but in terms of magnitude of loss, coastal zone would be affected more relative to its economic size due to the climate change impact. Population and economic size of river estuary is approximately more than double compared to the coastal zone while the estimated loss for river estuary is one and half[15] times bigger than coastal zone. This outlook points to the fact that coastal zone is more vulnerable to climate change. Since unemployment is directly proportional to income loss, the number of additional unemployment would be higher in coastal zone and river systems and estuaries areas. Additional unemployment in the country would increase to 3.8 million by FY2031 and further to 10.8 million in FY2041. Almost one third of this additional unemployment would happen in the coastal zone.

Poverty

In the BAU policy option, despite some reduction, the head count moderate poverty ratio would remain high at about 12.7%. Bangladesh will also miss out on its target to eliminate extreme poverty by FY2031. The key reason behind the higher poverty incidence in the BAU policy option is lower per capita income growth. The slower decrease in the head count poverty implies a corresponding higher number of people above the poverty line. In the BAU policy option the number of poor people would accordingly remain high at 25.1 million. Urban migration would increase more under this policy option, as additional people would become unemployed in disaster prone areas.

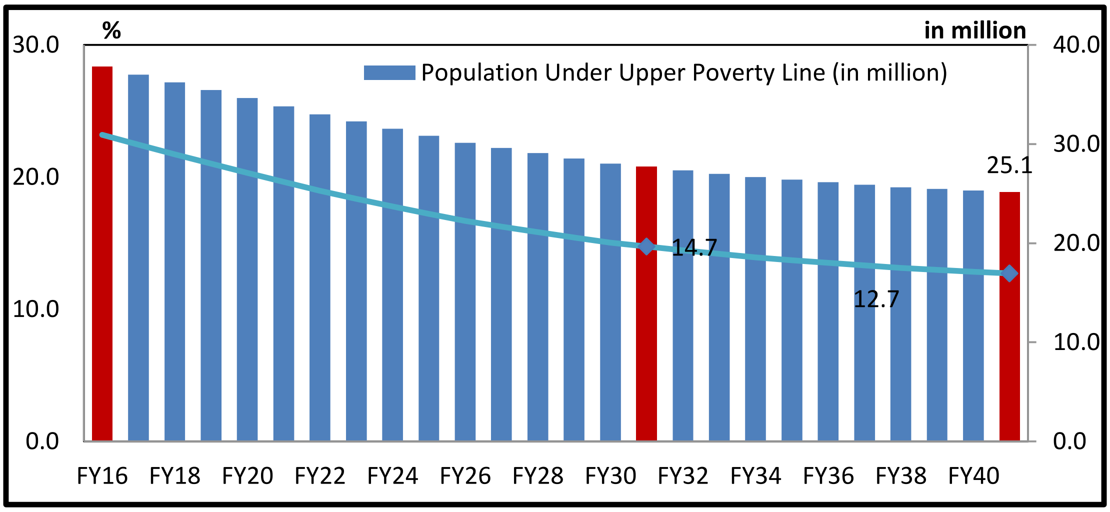


Figure 5.9: Moderate Poverty in BAU Policy Option

Source: BDP 2100 Projections, GED, 2017

[15] Total loss in the coastal zone would be larger relative to its economic size because coastal zone is considered as more disaster prone area compared to the other regions in Bangladesh. This study assumes that this area would be highly impacted from salinity intrusion, cyclones, tidal surges and floods.

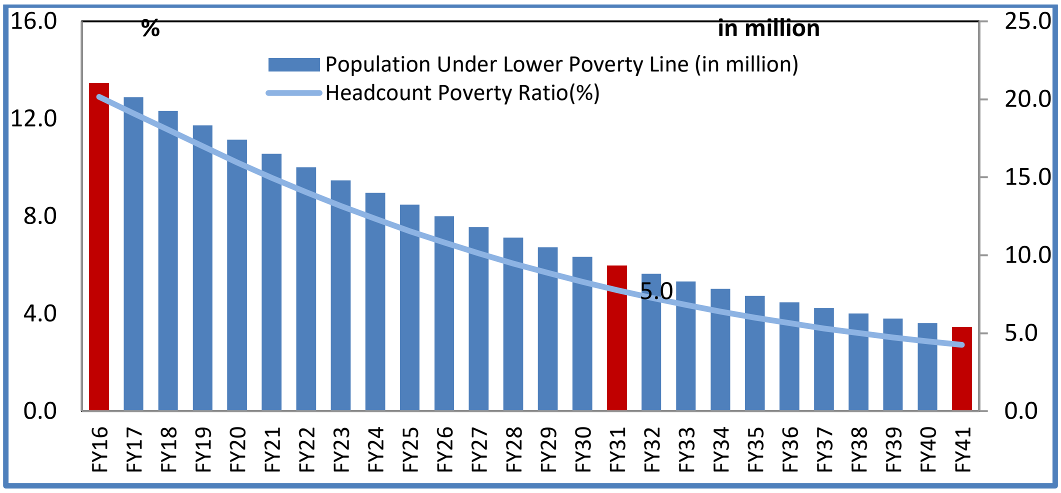


Figure 5.10: Extreme Poverty in BAU Policy Option

Source: BDP 2100 Projections, GED, 2017

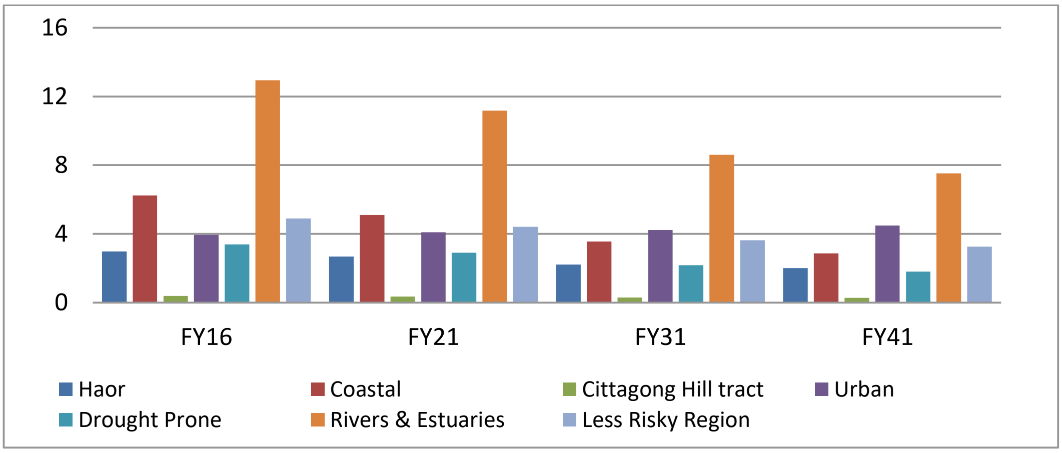


Figure 5.11: Hotspot-wise Moderate Poverty in BAU Policy Option

Source: BDP 2100 Projections, GED, 2017

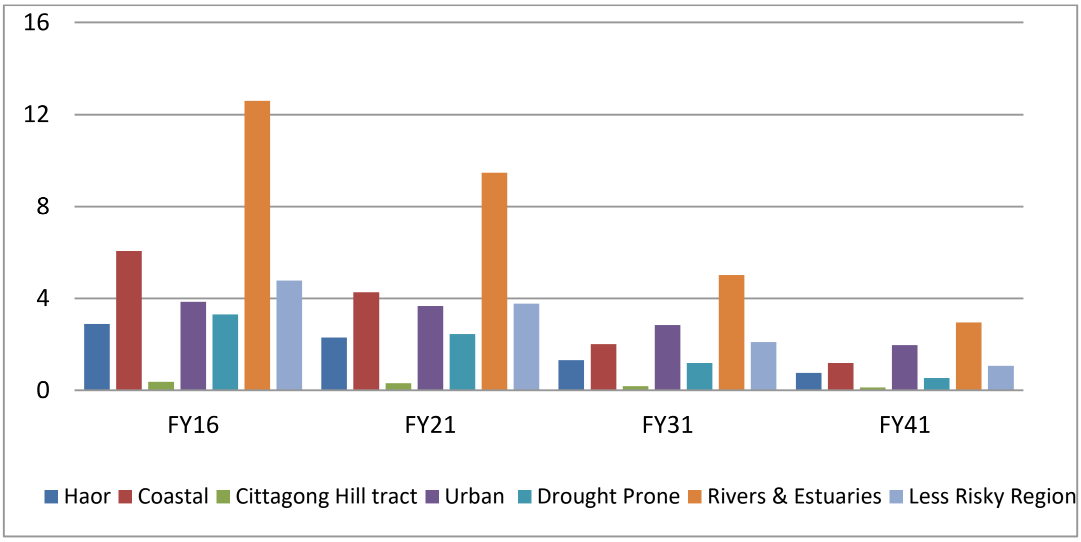


Figure 5.12: Hotspot-wise Extreme Poverty in BAU Policy Option

Source: BDP 2100 Projections, GED, 2017

Migration and Urbanization

Increase in migration and resulting urbanization over time with economic growth is a natural phenomenon due to underlying economic pull and push factors. But in BAU policy option because of intensified degradation of environment; the magnitude of migration would further intensify. As in the past, migration would mostly occur from rural and high environmental degradation prone areas to urban areas, thus further increasing the extent of urbanization.

Table 5.1: Hotspot-wise Migration[16] in BAU Policy Option (in million)

Hotspots	FY2016[17]	FY2021	FY2031	FY2041
Haor and Flash Flood Areas	0.05	0.11	0.22	0.34
Coastal Zone	-0.50	-2.29	-6.33	-10.72
Chattogram Hill Tracts	0.02	0.04	0.08	0.12
Urban Areas	0.69	3.97	11.38	19.43
Barind and Drought Prone Areas	-0.16	-0.73	-2.02	-3.42
River Systems& Estuaries	-0.34	-1.55	-4.30	-7.29
RHF	0.24	0.46	0.95	1.47

** Negative values denote the number of emigrants.*
Source: BDP 2100 Projections, GED, 2017

As indicated in **Table 5.1**, the number of emigrants from coastal zone and river systems and estuaries will be relatively higher than all other regions. And from these emigrants, most would immigrate to the urban regions of the country. This would intensify the increase of population in urban regions; leading to concentration in the slums with further unemployment/underemployment and serious health issues. These adverse effects might deteriorate the law and order condition in urban areas.

The Delta Plan Policy Option

A key consideration in this policy option is the implementation of focused climate adaptation related public investment and strategies. This would in turn crowd in private sector investment (both domestic and foreign). Along with higher investment, productivity would also increase as adverse effects of climate change and natural disasters are averted owing to the implementation of BDP 2100 investments and policies, leading to higher growth under the Delta Plan (DP) policy option.

Under the DP policy option, Bangladesh is able achieve its GDP growth target of 8% by FY2020 and maintain an average growth rate of 9% or more until FY2041. As a result, a key outcome of the DP

[16]To calculate number of emigrants for BAU, at first the shares of population for this region from 2001 to 2011 were considered and using their average shift the shares of population for the year 2016 were calculated. A forecast of population until 2041was created keeping the shares of 2016 constant. Finally due to lack of data, to incorporate migration both for economic and environmental reasons; the intensities were doubled for emigrants and were halved for immigrants.

[17]Only considers economic migration.

policy option is that Bangladesh would become an UMIC by FY2030-31 and solidify this position in FY2041, notwithstanding the climate change and other environmental shocks. This policy option envisages that Bangladesh's per capita income would be around US$ 4,376 in FY2031 and climb to US$ 16,422 in FY2041, while maintaining 9.0% growth rate on an average from FY2016 to FY2041. These per capita income figures exceed the corresponding thresholds for UMIC as defined under the WB guidelines. Indeed, projections show that Bangladesh will cross the UMIC threshold by the target year FY2030-31. For this sustained economic growth to materialize, Bangladesh will need to pursue an export oriented, manufacturing led growth strategy coupled with increased workers' participation rate and much higher average productivity of labor. Moreover, public investment would primarily concentrate on infrastructure development and mitigating environmental impacts, and thereby crowd in private domestic and foreign direct investment to accelerate and sustain growth over the entire time span.

Table 5.2: Years Required Transforming to Upper Middle Income Country

Economy	Economy turned into LMI(year)	Economy turned into UMI(year)	Period as LMI Country(year)	Average per capita GDP Growth(from LMI to UMI)
China	1992	2009	17	7.5
Malaysia	1969	1996	27	5.1
South Korea	1969	1988	19	7.2
Taipei, China	1967	1986	19	7.0
Thailand	1976	2004	28	4.7
Bulgaria	1953	2006	53	2.5
Turkey	1955	2005	50	2.6
Costa Rica	1952	2006	54	2.4
Oman	1968	2001	33	2.7

LMY and UMI denote lower middle income and upper middle income country, respectively.

Source: Jesus Felipe, ADB Working Paper, WP: 306, March, 2012

Table 5.2 highlights the years required by selected countries to become an UMIC from a LMIC status. China was the fastest among all countries to achieve the status of an UMIC by taking only 17 years. Over these 17 years, China had maintained an annual average economic growth rate of 7.5%. South Korea and Taipei were little bit slower; they spent 19 years as LMICs. In their path towards becoming UMIC, China and some other East Asian countries emphasized more on boosting savings, private and public investment and export oriented growth[18]. From 1992 to 2009 China maintained an investment to GDP ratio of 36.3% on average, while Malaysia kept the ratio at around 29.1% from 1969 to 1996 (WEO, IMF) but required much longer time period to become an UMIC. Thus, acceleration in investment was considered to be a key driver to fostering sustained long run economic growth in the East Asian economies.

Major Features of the Delta Plan Policy Option

The main highlights of the Delta Plan policy option are as follows.

[18]Schuman (2009) provides a fascinating account of how East Asian countries became rich during the second half of the 20th century. Rapid growth including increasing investment and export orientation were the top priorities of policy makers.

- In this policy option, average economic growth is projected to be 9% during FY2016-41. The sectoral share in GDP would undergo major changes with a rapid decline in the share of agriculture and a corresponding increase in the share of industrial sector; whereas the share of the service sector would remain almost same, although the composition will change with a growing share of formal services as against informal services. It is envisaged that the share of agriculture would decline to less than 7% while that of industry (including manufacturing, energy and construction) would rise to more than 40%. In recent years, the industrial sector of Bangladesh is highly dominated by lower capital intensive industry (especially readymade garment), but it is expected to change over this period by being more capital intensive. The capital intensity increase happens from the adoption of better technology and skilled labor in both manufacturing and construction.
- Though the share of agriculture is expected to continue to decline, productivity (both of labour and land/capital) in this sector is expected to rise through invoking appropriate technology and higher value-added production for both domestic market and for exports. Employment in the sector will also go down, thereby releasing labour for the modern industrial sector and services sector.
- Population growth is expected to follow a declining trend during FY2016 to FY2041. On the basis of the UN population projection, population growth is assumed to fall to 0.39% in FY2041 from around 1.02% at present. Lower population growth will contribute to higher per capita GDP growth.
- Investment-GDP ratio (I/Y ratio) would increase to 46.9% (including additional delta investment) in FY2041 from 30.1% in FY2016. Therefore, over the period, I/Y ratio is required to increase by more than 16.8 percentage points. It is important to note that, Bangladesh has just achieved 7.11% GDP growth in FY2016 for the first time and investment in the economy has remained below 31% of GDP. Even though the GDP growth and investment target might be viewed as ambitious, realization of these targets will be a key prerequisite for Bangladesh to become an upper middle income country by FY2031 and a high income country by 2041.
- Investments in both public and private sector would need to grow at a faster rate to provide adequate infrastructure support and second to enhance and sustain output growth based on better technology and more skilled labor. Public sector would play a pivotal role in creating conducive environment for investment through bringing visible improvements particularly in transport, primary energy and power sectors. Thus, it is assumed that Bangladesh would focus more on increasing domestic resource mobilization, strengthening Public Private Partnership (PPP) framework especially to implement mega projects in order to reduce infrastructure gap.
- Past experience in Bangladesh reveals that private sector would play prime role in mobilizing investment resources. It is assumed that investment climate as well as the confidence of investors (both local and external) would be enhanced through appropriate policies that reduce the cost of doing business and improve incentives for investment in manufacturing. Therefore, domestic private investment is expected to increases by more than 11.8 percentage points of GDP during FY2016-41. In addition, inflow FDI is assumed to rise to be more than 3.0% in 2041 from the current level of about 1.2% of GDP.
- Growth in the general price level (inflation) is expected to be stable at around 4.3 to 4.5%, supported by prudent monetary policy and continued sound macroeconomic management. Growth of broad money (M2) would be around 17% on an average during FY2016-41.

- Tax revenue effort would need to increase from 9.0 percent in FY2016 to 21.9 percent in FY2041. ADP is expected to grow steadily and then stabilize at around 10% of GDP, while revenue expenditure is assumed to increase to 20.6% in FY2041 from 9.4% in FY2016. Total expenditure is set to almost double to 29.0% of GDP in FY2041 from 15.3% of GDP in FY2016.
- Fiscal deficit including grant is expected to remain stable at a sustainable level of around 4.7 to 5.0% of GDP. Financing of the deficit is assumed to be dominated by domestic sources, but external financing is expected to increase in absolute terms primarily through non-concessional borrowing from multilateral and official bilateral sources and market borrowing through issuance of sovereign bonds.

Per Capita GDP

Figure 5.13 shows the path of per capita GDP in the BAU and BDP 2100 policy options. The per capita GDP in dollar terms widens progressively between the two policy options as the GDP growth gap widens between them. As a result, while Bangladesh comfortably reaches UMIC by FY2031 under the BDP 2100, it significantly under-performs in the BAU. As the gap between the two growth paths widens, per capita income outcomes also widen. Under the BDP 2100, Bangladesh reaches a per capita GNI of US$ 16,422 in FY 2041; whereas under the BAU the GNI per capita climbs only to US$ 9,537 at the same year. This cumulative loss of US$6,885 in FY2041 is entirely due to the losses from climate change, natural disasters and inefficient water resources management. Clearly, the neglect of climate change and natural disasters will cost Bangladesh quite severely over time.

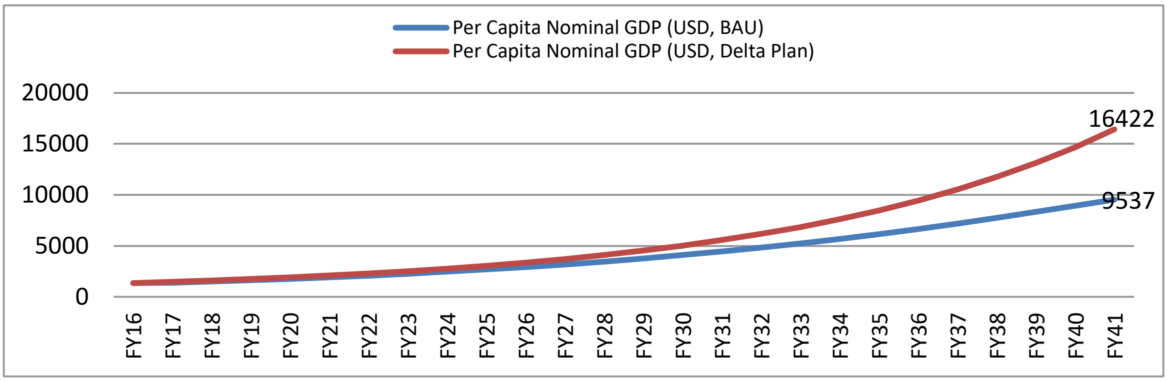


Figure 5.13: Per Capita Nominal GDP (US$)

Source: BDP 2100 Projections, GED, 2017

The projections also indicate that Bangladesh may fall into the middle income trap in the absence of higher levels of investment on adaptation, requiring much longer time to become a higher middle income country if environmental risks become more severe. It is also conceivable that without the BDP 2100 implementation and in the event of the worst case climate change scenario, Bangladesh may not attain UMIC status for a long period of time.

Employment

The BDP 2100 policy option projects a better employment situation with the unemployment rate decreasing to 4.4% in FY2041. This outcome is contingent upon higher investment and a faster expansion of the manufacturing sector creating additional job opportunities. For comparison, in the BAU policy option, the unemployment rate would be above 15% in FY2041 because of slower economic expansion with accelerated depreciation of capital due to environmental hazards.

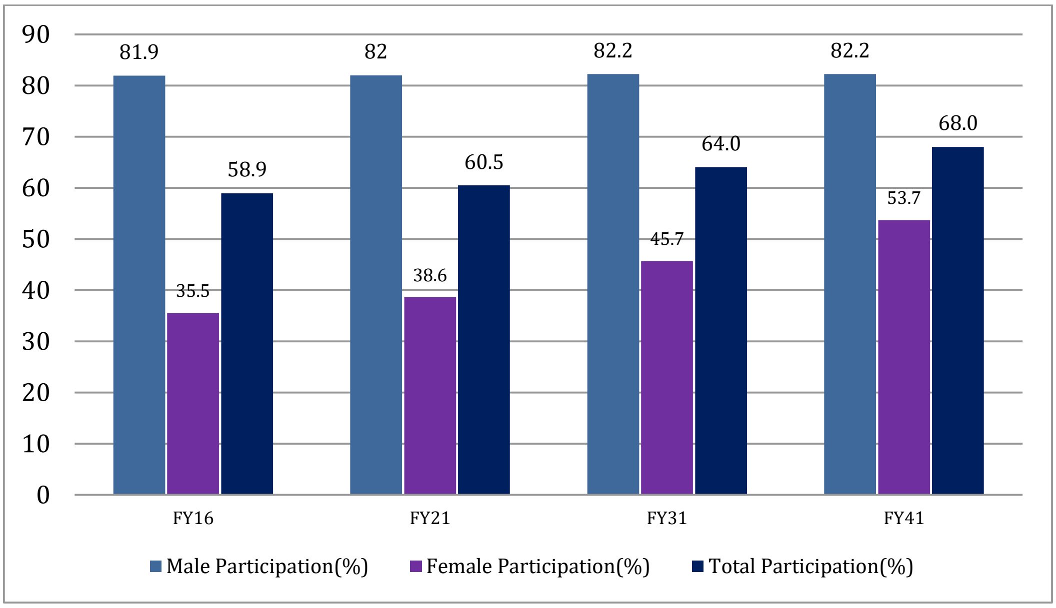


Figure 5.14: Labour Force Participation in Delta Plan Policy Option

Source: BDP 2100 Projections, GED, 2017

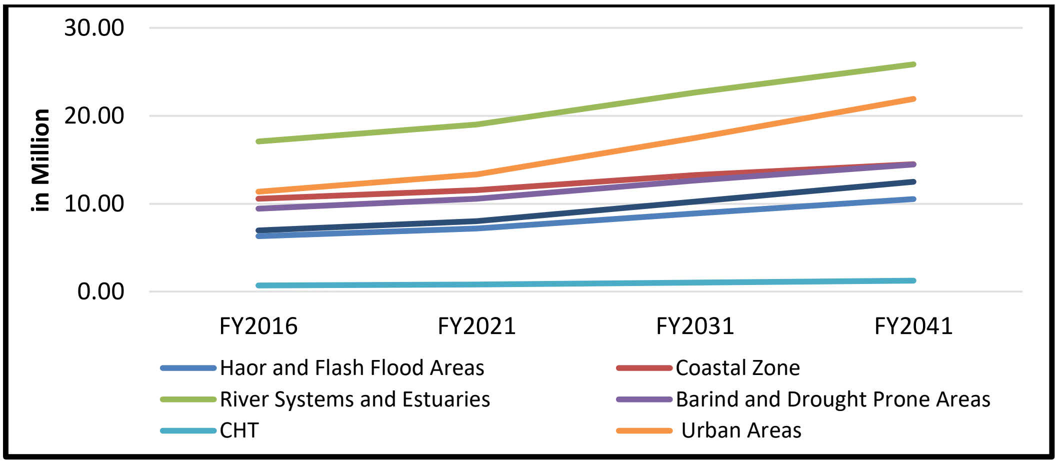


Figure 5.15: Employment in Delta Plan Policy Option

Source: BDP 2100Projections, GED, 2017

As shown in Figure 5.14, total labour force participation rate would increase to 68% at the end of FY2041 from 58.9% in FY2016. Although male labour force participation is projected to increase slightly to 82.2% in FY2041, a dramatic change is expected to happen in the female labour force participation rate. Over the period, it is expected to be 18.2 percentage points higher compared to the starting period of FY2016.

The BDP 2100 policy option also projects hotspot wise employment over the period. Employment in the urban areas would grow faster while employment in coastal zone is estimated to follow a declining trend as both push and pull factors which would intensify migration from environmentally hazardous coastal zone to the urban or relatively safe areas. In the Haor and flash flood area, the baseline estimates show that employment would significantly increase over time because of higher female participation rate and increase in the intensity of agricultural production due to better land management particularly during dry season.

Capital Accumulation

Historically, the rate of growth is highly dependent on capital accumulation, particularly in lower and middle income countries. In the case of Bangladesh, growth has also been capital intensive with the Incremental Capital Output Ratio (ICOR) rising over time, which indicates that an increase in the investment ratio over time would be required for long term sustainable growth (estimates of capital stock are provided in **Annex Table B5.1**).

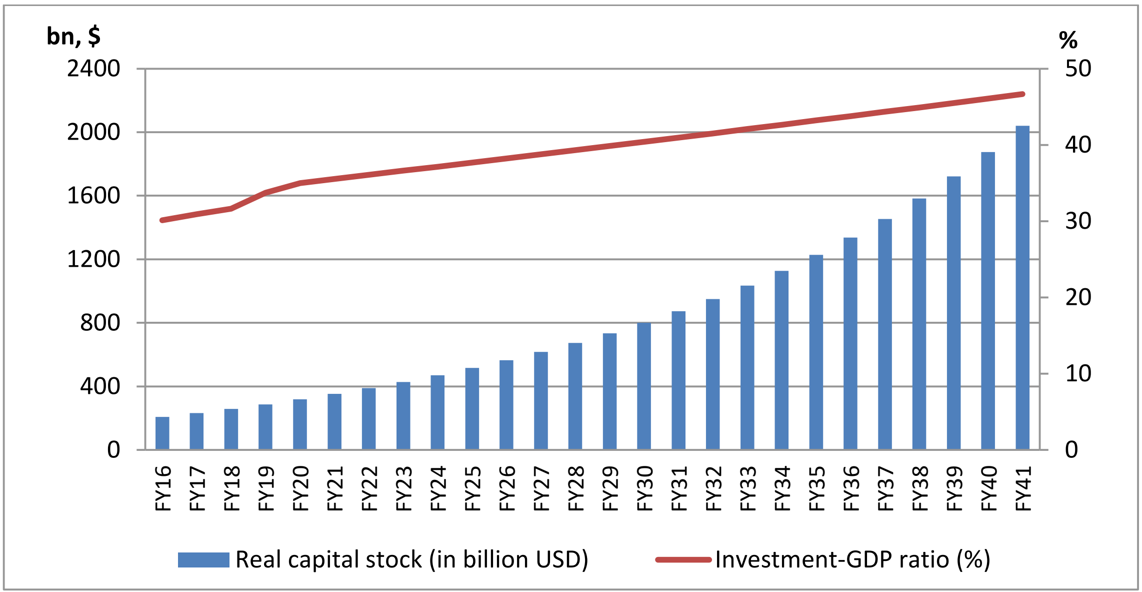


Figure 5.16: Capital Accumulation in Delta Plan Policy Option

Source: BDP 2100 Projections, GED 2017

In the 7thFYP period it is envisaged that the investment to GDP ratio would need to increase by 5.6 percentage points in the 5-year period to achieve 7.4% average growth rate . Net capital accumulation over the period (FY2016-FY2041) would follow an increasing pattern which indicates output share of capital would contribute more to the growth of real per capita income.

5.4.3 Poverty

Employment generation and increase in real per capita income are key fundamentals to reduce poverty. Moreover, real wage is determined by the average labor productivity. Historically, labor productivity in agriculture is lower than the labor productivity in manufacturing and service sectors in Bangladesh[19]. Thus to scale up real income growth, increasing employment generation in the industrial and service sectors will be most important. The 7thFYP accordingly emphasizes the

[19]Using the estimated employment figures of 7thFYP, there is a noticeable increase in average labour productivity during 7thFYP period. During FY2015-FY2020, overall labour productivity would grow by a healthy 3.5% per year, while average labour productivity in agriculture would increase by 3.6% per year. Average agriculture productivity increases relatively at a faster rate due to technological progress and migration of farm workers to nonfarm activities. Nevertheless, the migration to nonfarm activities (including industrial) would be sustained because the average output per worker is BDT 127,000 in others sectors while it is only BDT 49,000 in the agriculture sector.

structural transformation of the economy so that the GDP share of industry increases rapidly and the relative share of agriculture falls correspondingly.

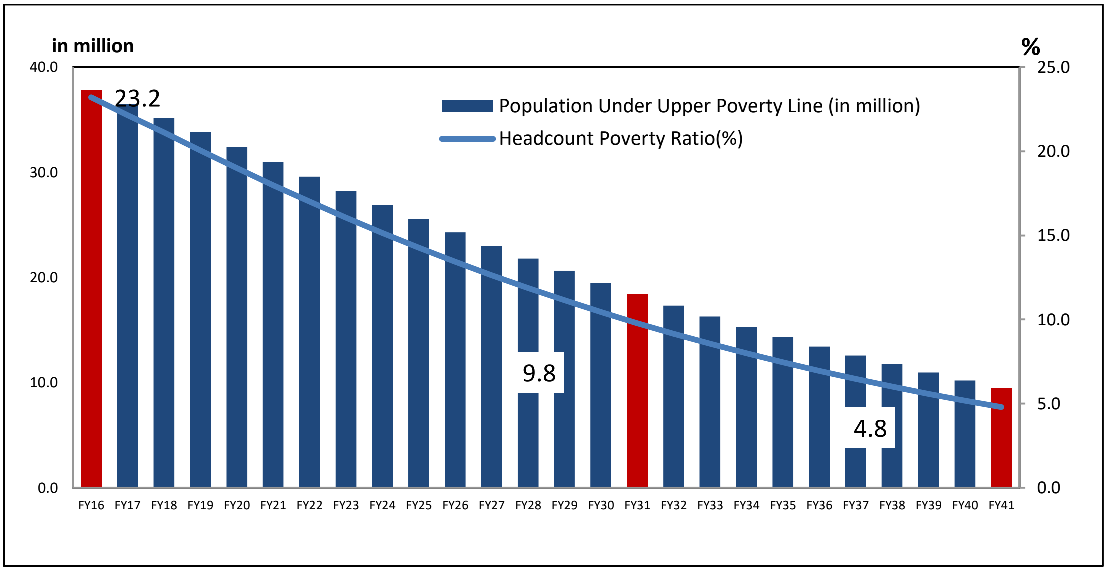


Figure 5.17: Moderate Poverty in Delta Plan Policy Option

Source: BDP 2100 Projections, GED, 2017

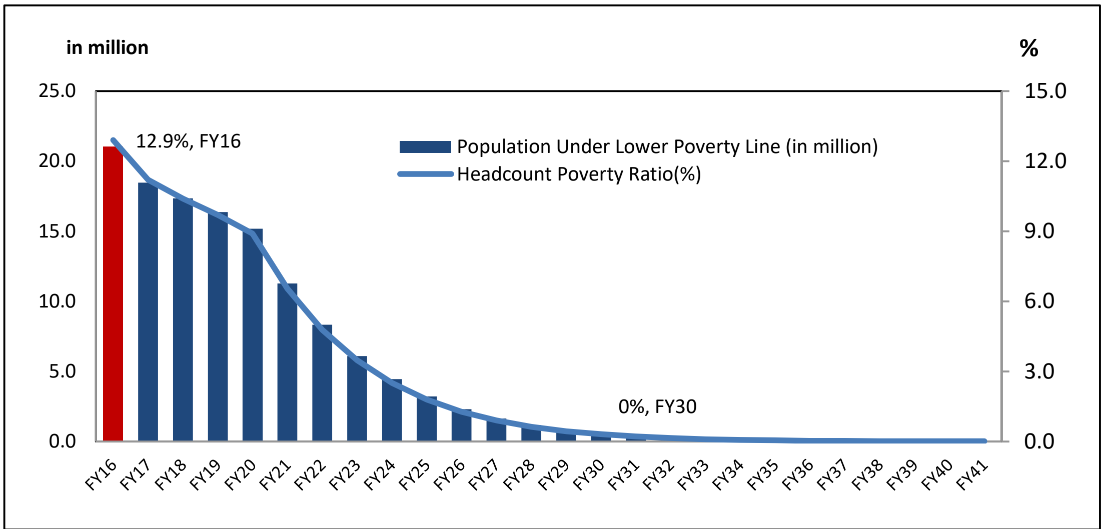


Figure 5.18: Extreme Poverty in Delta Plan Policy Option

Source: BDP 2100 Projections, GED, 2015

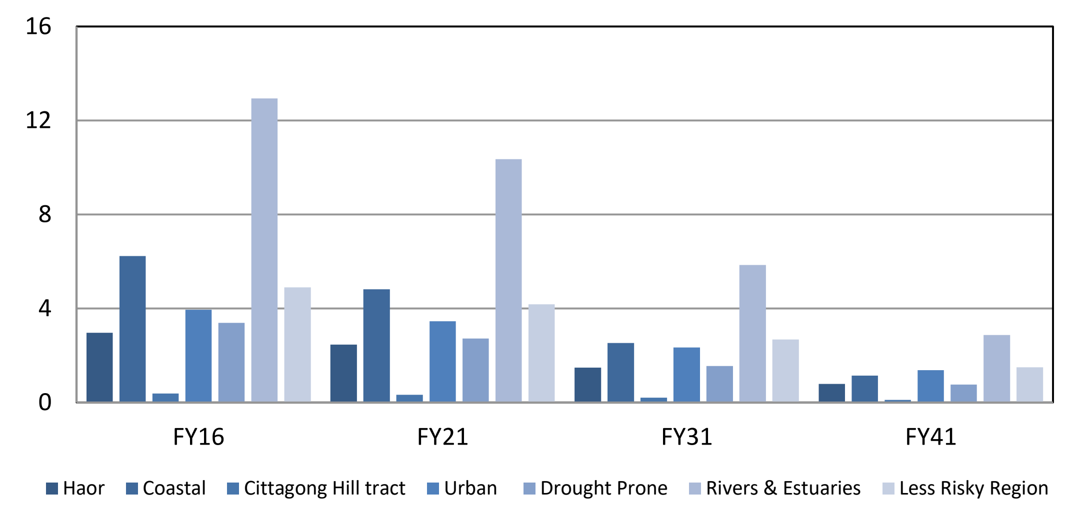


Figure 5.19: Region wise Moderate Poverty in Delta Plan Policy Option

Source: BDP 2100 Projections, GED, 2017

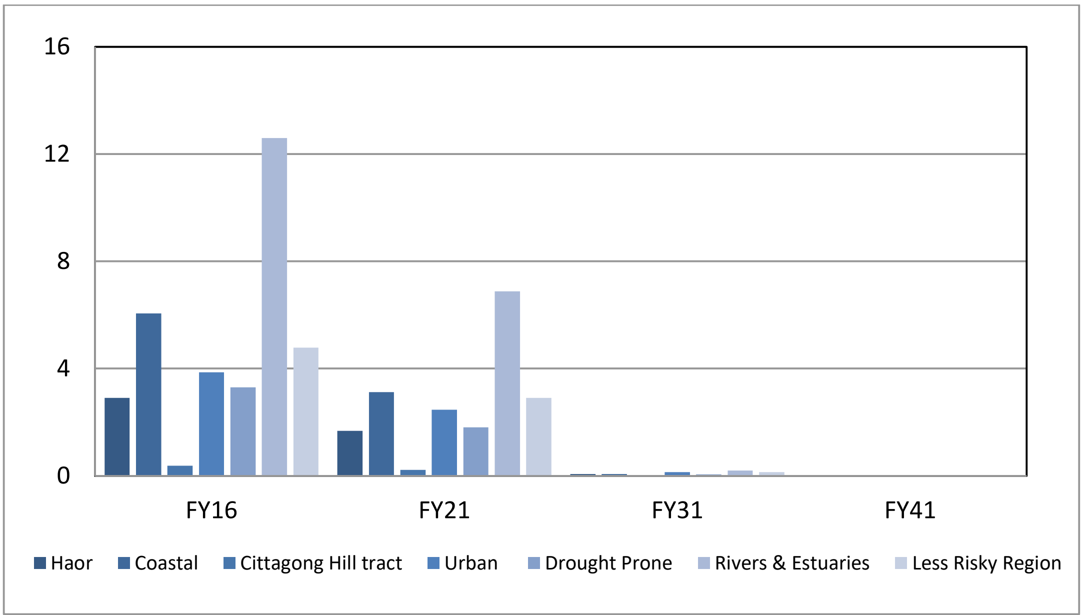


Figure 5.20: Region wise Extreme Poverty in Delta Plan Policy Option

Source: BDP 2100 Projections, GED, 2017

Over the last decade, the rate of poverty reduction has been impressive in Bangladesh. Growth in real per capita income has been the main driver of poverty reduction. In 2016, the head count poverty ratio is estimated to have declined to 23.2%, entailing an 8.3 percentage point reduction in poverty from 31.5% in 2010. Increased industrial sector share and higher agricultural productivity, would significantly reduce Bangladesh's moderate head count poverty ratio to 4.8% by 2041.

As experienced in the last five years, extreme poverty has decreased from 17.6% in 2010 to 12.9% in 2016 and in the 7thFYP it is projected that extreme poverty would fall below 9% by FY2020. The DP policy option projections show that Bangladesh would be able to completely eradicate extreme poverty by FY2031. Faster growth and increase in labor productivity creates job and increases real wages economy wide, but especially in the rural economy and informal services where the bulk of the extreme poor are engaged for livelihood. The observed high elasticity of extreme poverty reduction to growth (1.16 for 2000-2010) illustrates this growth extreme poverty linkage.

Although, the head count poverty ratio declines nation-wide, the pattern of decline in poverty reduction varies across the regions. According to HIES data, river estuary region has recorded the highest rank in terms of head count poverty ratio and urban region the lowest. However, in recent years urban poverty reduction has suffered due to excessive migration of the ultra-poor from other vulnerable regions. An interesting phenomenon is seen here: the head count poverty ratio is second highest in less disaster prone region relative to more disaster prone areas - coastal, drought, etc. This might happen because of large poverty concentration in Mymensingh and Sherpur that have a large population dependent upon low-productivity agriculture and low inflow of foreign remittances, limiting the growth of non-farm rural economy. The projected figures suggest that the overall poverty would follow a declining trend across all regions, but compared to other regions, the head count poverty ratio would decrease at a slower pace in less disaster prone region owing to the weak initial conditions in Mymensingh and Sherpur.

Migration and Urbanization

In BDP 2100 policy option, compared to BAU policy option, less number of people migrates to urban regions of the country, which is a common experience seen with economic growth and development. Though the number of migrants is higher from coastal and river estuary region to urban regions.

Table 5.3: Hotspot-wise Migration[20] in Delta Plan Policy Option (in million)

Hotspots	FY2016	FY2021	FY2031	FY2041
Haor and Flash Flood Areas	0.05	0.15	0.38	0.62
Coastal zone	-0.50	-1.41	-3.45	-5.67
Chattogram Hill Tracts	0.02	0.05	0.13	0.22
Urban areas	0.69	1.94	4.76	7.78
Barind & Drought Prone Areas	-0.16	-0.45	-1.10	-1.81
River Systems& Estuaries	-0.34	-0.96	-2.34	-3.86
RHF	0.24	0.66	1.63	2.66

Negative values denote the number of emigrants.

Source: BDP 2100 Projections, GED, 2017

Additional Resource Requirements

Aggressive investment policy is required to counter the negative impact of environmental hazards. To combat natural disasters, Bangladesh needs to prepare a bolstered and unified investment plan with additional investment in various sectors across all the regions. It is estimated that on average,

[20]First the shares of population for this region from 2001 to 2011 were considered and using their average shift the shares of population for the year 2016 were calculated. Then a forecast of population until 2041was created keeping the shares of 2016 constant. Finally, due to lack of data, to incorporate migration both for economic reasons; the average shifts were taken into consideration to capture population dynamics.

an additional investment of 2.0-2.5% of GDP each year will be required for the purpose of mitigation and adaptation of environmental degradation.

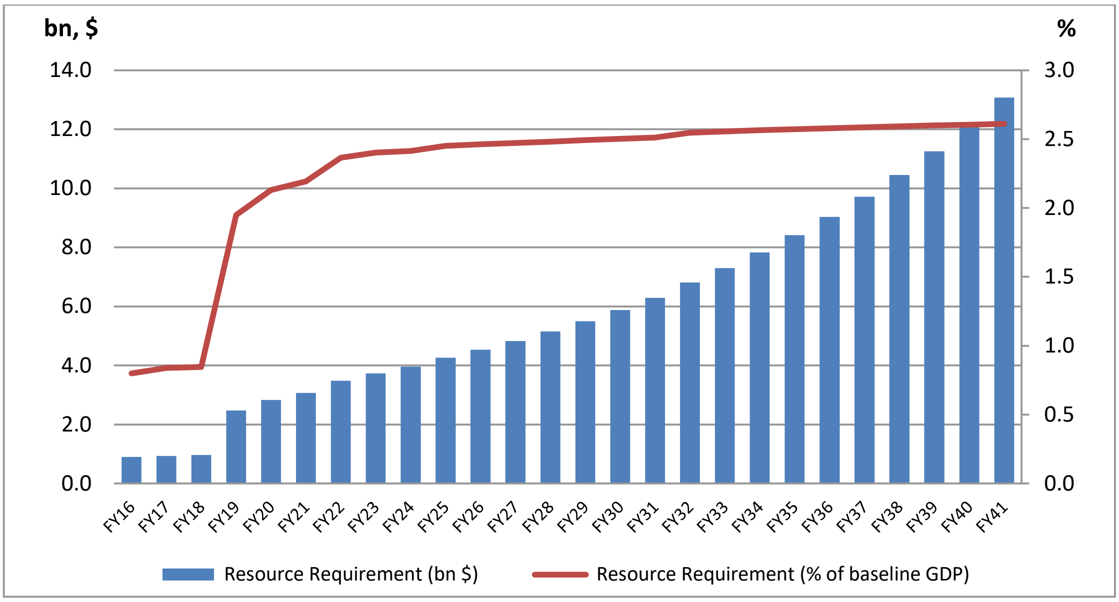


Figure 5.21: Requirements for Mitigation and Adaptation (FY2016-41)

Source: BDP 2100 Projections, GED, 2017

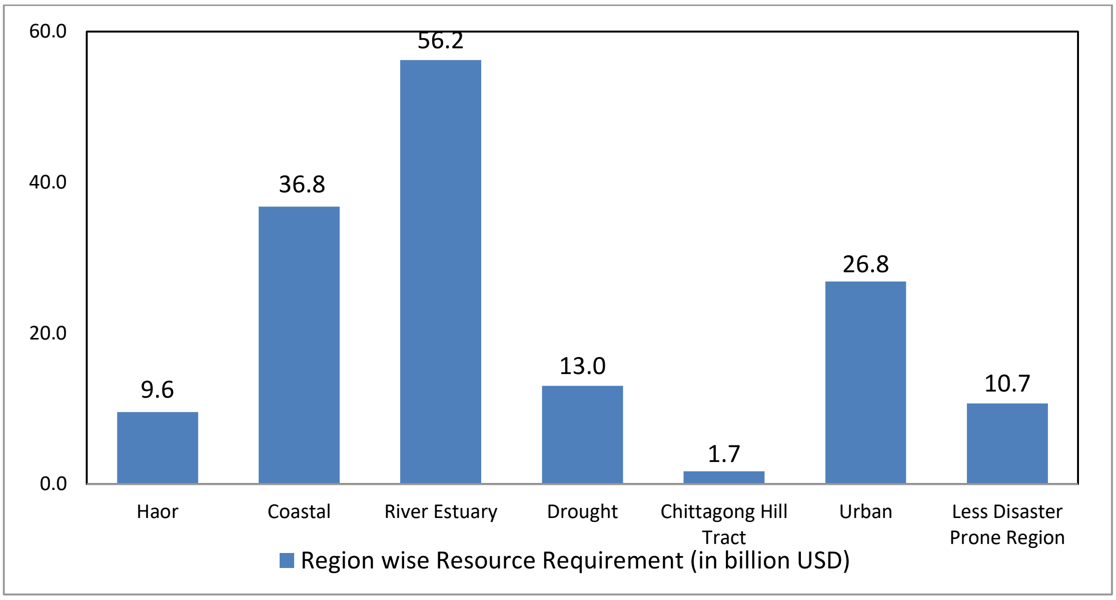


Figure 5.22: Hotspot-wise Additional Resource Requirement (FY2016-41)

Source: BDP 2100 Projections, GED, 2017

More investment is required in river estuary region as in terms of magnitude it is the most severely affected region. A total of US$ 56.2 billion in constant prices in additional investment will be required for adaptation purpose. Coastal and urban regions rank second and third with approximately US$ 36.8 billion and US$ 26.8 billion of additional investment requirements, To mitigate and adapt adverse impacts of natural hazards, Bangladesh would require 2.3 percentage of GDP on average as delta specific investment. Some portion of this investment would however be generated from FDI and private investment. Initially the share of public investment would be higher, but it would decline over time as higher public investment would catalyze additional private investment.

5.4.4 Sectoral Results

Growth rates generated under the two policy options by major sectors are discussed here. Growth rates, underlying structure and investment requirements are also provided. More specifically, sectoral results are provided for: real GDP growth; sectoral GDP share; employment and sectoral employment share.

Sectoral Growth Rates

GDP growth rates by selected sectors are shown in Table 5.4. As envisaged in the growth strategies of 6thFYP and 7thFYP, in order to boost employment the manufacturing sector along with construction and organized services would be the engines of high growth. Among the manufacturing activities, sectors such as 'food processing'; 'leather and footwear,' 'textile and clothing', 'pharmaceutical', 'ship building' are envisaged as the main growth generators. These activities / sub-sectors are projected to experience double digit growth rates toward the end of the Seventh Plan period. 'Machinery' and 'other-industries' sectors are also projected to become more buoyant due to the expansion of the economy and gradual diversification of exports. Removal of critical infrastructure bottlenecks in the power and transport sectors through massive new investments is critical for the planned acceleration of the manufacturing sector expansion. Along with manufacturing, in the Seventh Plan the construction sector is projected to continue to be a strong driver of growth due to demographic developments and strong demand for housing and infrastructure.

The service sector has grown at a respectable pace of 6% per year in the preceding 5-year period. Experience with other economies suggests that growth in service sector usually follow the growth patterns of the manufacturing and primary activities. Accordingly, the Seventh Plan targeted a further improvement in the performance of this sector, with emphasis on the expansion of modern services.

Both policy options of BDP2100 assume a continuation of the growth strategy of the Seventh Plan. The growth outcomes are different because of the impact of natural disasters and climate change that is not tackled in the BAU. Thus, in the BAU policy option, growth performances of almost all sectors will suffer, with agriculture experiencing the major loss. Growth rate of agriculture will fall to 1.5% in FY2041 compared to rates of around 2.8% under the Delta Plan policy option. In the BAU policy option, the adverse effects of natural disasters and climate change on capital stock, construction and infrastructure especially in urban areas along with the output losses in agriculture will also slow down the growth of manufacturing sector. The growth of new investments in industrial activities will slow down that will have cumulative effects on slowing down the expansion of industrial activities. The slowdown in both agriculture and industry will reduce the growth of the demand-driven services sector, In contrast, in the BDP 2100 policy option the implementation of the BDP 2100 will offset the negative effects of climate change and natural disasters on output and capital stock and allow the successful implementation of the government's growth strategy. Accordingly, all sectoral growth performances will be better under the BDP 2100 policy option.

Table 5.4: Sectoral Growth Rates (BAU Policy Option)

Sl	Sectors	Growth rates (%)				
		FY2016	FY2020	FY2021	FY2031	FY2041
	Agriculture	**2.37**	**2.52**	**2.52**	**2.32**	**1.87**
1	Cereal Crop	0.50	0.50	0.50	0.46	0.37
2	Commercial crop	0.50	0.47	0.47	0.43	0.35
3	Livestock-poultry-fisheries	5.24	5.72	5.72	5.28	4.26
4	Forestry	5.13	5.38	5.38	4.96	4.00
5	Other Agriculture	0.50	0.53	0.53	0.48	0.39
	Manufacturing	**10.43**	**10.65**	**10.65**	**10.04**	**8.27**
6	Other Food	10.43	10.82	10.82	10.19	8.31
7	Leather	10.43	10.70	10.70	10.13	8.35
8	Textile-clothing	10.43	10.93	10.93	10.30	8.49
9	Chemical Fertilizer	10.43	10.34	10.34	9.75	8.03
10	Machinery	10.43	10.75	10.75	10.12	8.34
11	Petroleum	10.43	10.40	10.40	9.79	8.07
12	Other industry	10.43	10.63	10.63	10.02	8.26
13	**Construction**	8.87	7.60	7.60	7.15	5.89
14	**Services**	6.82	6.75	6.75	6.30	5.14
	Overall GDP Growth	***7.1***	***7.3***	***7.3***	**6.8**	**5.6**

Source: BDP 2100 Projections, GED, 2017

Table 5.5: Sectoral Growth Rates (Delta Plan Policy Option)

Sl	Sectors	Growth rates (%)				
		FY2016	FY2020	FY2021	FY2031	FY2041
	Agriculture	**2.37**	**2.66**	**2.66**	**2.77**	**2.77**
1	Cereal Crop	0.50	0.54	0.54	0.56	0.56
2	Commercial crop	0.50	0.54	0.54	0.56	0.56
3	Livestock-poultry-fishing	5.24	6.37	6.37	6.88	6.88
4	Forestry	5.13	5.31	5.31	5.31	5.31
5	Other Agriculture	0.50	0.55	0.55	0.55	0.55
	Manufacturing	**10.43**	**11.63**	**11.63**	**12.05**	**12.29**
6	Other Food	10.43	12.00	12.00	12.99	13.25
7	Leather	10.43	11.77	11.77	12.06	12.31
8	Textile-clothing	10.43	11.99	11.99	12.72	12.98
9	Chemical Fertilizer	10.43	11.59	11.59	11.82	12.05
10	Machinery	10.43	11.99	11.99	12.23	12.47
11	Petroleum	10.43	10.86	10.86	11.07	11.30
12	Other industry	10.43	11.21	11.21	11.43	11.66
13	**Construction**	**8.87**	**9.94**	**9.94**	**10.24**	**10.24**
14	**Services**	**6.82**	**7.87**	**7.87**	**8.11**	**8.11**
	Overall GDP Growth	***7.1***	**8.0**	**8.0**	**8.2**	**8.4**

Source: BDP 2100 Projections, GED, 2017

Sectoral Shares

The sectoral composition of GDP will change in both the policy options but the GDP contribution of agriculture will fall less dramatically in the BAU policy option despite the losses to agriculture from natural hazards and climate change (Tables 5.6 and 5.7).

Table 5.6: Sectoral GDP Shares (BAU Policy Option)

Sl	Sectors	Share (%)				
		2016	2020	2021	2031	2041
Agriculture		**15.3**	**13.2**	**12.7**	**8.5**	**6.0**
1	Cereal Crop	5.1	4.0	3.8	1.9	1.0
2	Commercial crop	2.7	2.2	2.0	1.0	0.5
3	Livestock-poultry-fishing	5.3	5.0	5.0	4.1	3.3
4	Forestry	1.7	1.6	1.6	1.3	1.0
5	Other Agriculture	0.5	0.4	0.4	0.2	0.1
Manufacturing		**22.5**	**25.8**	**26.6**	**35.4**	**43.8**
6	Other Food	5.6	6.4	6.6	8.8	10.9
7	Leather	0.4	0.5	0.5	0.6	0.8
8	Textile-clothing	8.9	10.3	10.6	14.3	17.9
9	Chemical-Fertilizer	0.8	0.9	0.9	1.2	1.4
10	Machinery	2.7	3.1	3.2	4.3	5.3
11	Petroleum	1.0	1.2	1.2	1.6	1.9
12	Other industry	3.0	3.4	3.5	4.6	5.6
13	**Construction**	**7.3**	**7.4**	**7.4**	**7.4**	**7.0**
14	**Services**	**54.9**	**53.6**	**53.3**	**48.7**	**43.1**
Total		***100.0***	***100.0***	***100.0***	***100.0***	***100.0***

Source: BDP 2100 Projections, GED, 2017

Along with the decline in agriculture growth, the growth of manufacturing and construction will also fall in the BAU policy option. As such the pace of structural transformation will be less dramatic. These sectoral results of the BAU policy option will be reversed in the policy option that assumes the adoption and implementation of the BDP 2100. While the losses to agriculture from the natural hazards and climate change factors are reversed in the policy option, the manufacturing and construction sectors are to secure more robust growth.

Table 5.7: Sectoral GDP Shares (Delta Plan Policy Option Scenario)

Sl	Sectors	Share (%)				
		2016	2020	2021	2031	2041
Agriculture		**15.3**	**12.8**	**12.2**	**7.6**	**4.7**
1	Cereal Crop	5.1	3.9	3.6	1.6	0.7
2	Commercial crop	2.7	2.1	1.9	0.9	0.4
3	Livestock-poultry-fisheries	5.3	4.9	4.8	3.9	3.0
4	Forestry	1.7	1.5	1.5	1.1	0.7
5	Other Agriculture	0.5	0.4	0.3	0.2	0.1
Manufacturing		**22.5**	**25.3**	**26.1**	**34.6**	**44.3**
6	Other Food	5.6	6.3	6.5	8.9	12.0
7	Leather	0.4	0.5	0.5	0.6	0.8
8	Textile-clothing	8.9	10.1	10.4	14.0	18.3
9	Chemical Fertilizer	0.8	0.9	0.9	1.2	1.4
10	Machinery	2.7	3.1	3.2	4.2	5.3
11	Petroleum	1.0	1.2	1.2	1.4	1.6
12	Other industry	3.0	3.3	3.4	4.2	5.0
13	**Construction**	**7.3**	**7.7**	**7.8**	**8.6**	**9.0**
14	**Services**	**54.9**	**54.2**	**53.9**	**49.2**	**42.0**
Total		***100.0***	***100.0***	***100.0***	***100.0***	***100.0***

Source: BDP 2100 Projections, GED, 2017

Sectoral Investment Shares

Total investment is projected to be slightly lower under BAU as compared with the BDP 2100 policy option. But the important point is the productivity of investment in BAU is much lower than in BDP 2100. Thus, with nearly similar investment rates, GDP growth is much lower under BAU as compared with BDP 2100. This is a major policy message. The reason for lower efficiency of capital in BAU is firstly because of loss of output from natural disasters and climate change; and secondly the loss of capital stock that needs to be rebuilt to support the growth momentum.

Sectoral Investment shares are reported in Tables 5.8 and 5.9 . The sectoral investment shares are broadly similar as the underlying growth strategies are the same. What is different is that the sectoral productivity is lower in the BAU and importantly, the absolute levels of investment are higher under BDP 2100 for all sectors because of much larger GDP value. In line with falling share of agricultural activities, the sector as a whole will experience decline in its share of investment in both policy options. Similarly, the manufacturing sector will continue to attract large investment from private sector since the underlying growth strategies are similar. However, a major difference is that the construction sector attracts more investment as compared to BAU. This reflects large public investments in countering sea-level rise, river erosion, flood control and large scale irrigation.

Table 5.8: Sectoral Investment Shares (BAU Policy Option)

Sl	Sectors	Share (%)				
		2016	2020	2021	2031	2041
	Agriculture	**5.26**	**5.28**	**5.13**	**3.78**	**2.82**
1	Cereal Crop	0.28	0.21	0.20	0.09	0.05
2	Commercial crop	0.17	0.12	0.12	0.06	0.03
3	Livestock-poultry-fishing	3.99	4.01	3.93	2.99	2.27
4	Forestry	0.80	0.92	0.86	0.63	0.47
5	Other Agriculture	0.03	0.02	0.02	0.01	0.00
	Manufacturing	**32.06**	**40.38**	**36.88**	**45.77**	**53.82**
6	Other Food	6.73	8.30	7.87	9.80	11.46
7	Leather	0.50	0.63	0.56	0.70	0.83
8	Textile-clothing	11.77	14.70	13.17	16.57	19.78
9	Chemical-Fertilizer	2.03	2.53	2.25	2.69	3.07
10	Machinery	5.74	7.50	7.04	8.71	10.25
11	Petroleum	1.84	2.32	2.06	2.48	2.83
12	Other industry	3.46	4.40	3.93	4.82	5.62
13	**Construction**	**18.51**	**15.91**	**16.59**	**15.44**	**14.09**
14	**Services**	**44.16**	**38.43**	**41.40**	**35.00**	**29.27**
	Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*
	Investment-GDP Ratio (%) revised	**30.1**	**34.4**	**34.5**	**35.3**	**36.2**

Source: BDP 2100 Projections, GED, 2017

Table 5.9: Sectoral Investment Shares (Delta Plan Policy Option Scenario)

Sl	Sectors	Share (%)				
		2016	2020	2021	2031	2041
	Agriculture	**5.26**	**4.83**	**5.42**	**3.97**	**2.84**
1	Cereal Crop	0.28	0.19	0.20	0.08	0.04
2	Commercial crop	0.17	0.12	0.12	0.05	0.02
3	Livestock-poultry-fishing	3.99	3.76	4.24	3.29	2.43
4	Forestry	0.80	0.75	0.84	0.54	0.35
5	Other Agriculture	0.03	0.02	0.01	0.01	0.00
	Manufacturing	**32.06**	**32.63**	**32.63**	**40.49**	**48.52**
6	Other Food	6.73	7.26	7.26	9.63	12.06
7	Leather	0.50	0.50	0.50	0.59	0.69
8	Textile-clothing	11.77	11.54	11.54	14.70	18.02
9	Chemical-Fertilizer	2.03	2.02	2.02	2.36	2.68
10	Machinery	5.74	6.28	6.28	7.59	8.94
11	Petroleum	1.84	1.70	1.70	1.86	1.99
12	Other industry	3.46	3.32	3.32	3.75	4.14
13	**Construction**	**18.51**	**20.45**	**20.45**	**20.71**	**20.17**
14	**Services**	**44.16**	**41.50**	**41.50**	**34.83**	**28.47**
	Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*
	Investment-GDP Ratio (%) revised	***30.1***	***35.5***	***35.5***	***36.5***	***37.7***

Source: BDP 2100 Projections, GED, 2017

Sectoral Employment Share

With labour force growing by more than 3% per year and low-income employment in the farm and informal services sectors, creation of new jobs in the productive formal sectors of the economy is a major challenge. The growth strategy pursued in Bangladesh aims to address the employment issue by creating new jobs in the nonfarm sector and by a rebalancing of the composition of employment away from agriculture and into more productive sectors of the economy. This trend has been already visible in the latest Labor force Survey 2013 by BBS that shows the employment share of manufacturing continues to rise and that of services fall. Importantly, non-farm jobs are also being created in rural services sector. The consequent increase in the demand for labour in rural areas is causing a tightening of the agriculture labor market and real agriculture wages are increasing. This evidence is an important indication of the robustness of the government's ongoing growth and employment strategy.

The broad pattern of sectoral employment shares is similar for the two policy options because the growth strategies are the same (Tables 5.10 and 5.11). However because of lower growth total job creation is much lower in BAU. Manufacturing is the main driver of growth and employment in both Policy options, but it creates many more jobs under BDP 2100as compared with BAU.

Table 5.10: Sectoral Employment Share (BAU) (%)

Sl	Sectors	2016	2020	2021	2031	2041
	Agriculture	**45.20**	**40.16**	**38.85**	**29.57**	**21.71**
1	Cereal Crop	20.32	16.58	15.56	9.06	5.24
2	Commercial crop	5.10	4.17	3.91	2.27	1.31
3	Livestock-poultry-fishing	18.52	18.18	18.14	17.24	14.42
4	Forestry	0.94	0.95	0.96	0.85	0.66
5	Other Agriculture	0.33	0.28	0.27	0.15	0.08
	Manufacturing	**11.37**	**14.37**	**15.33**	**23.72**	**32.07**
6	Other Food	0.27	0.33	0.35	0.55	0.75
7	Leather	0.93	1.18	1.25	1.93	2.61
8	Textile-clothing	4.64	5.89	6.29	9.90	13.56
9	Chemical-Fertilizer	0.81	1.02	1.09	1.62	2.13
10	Machinery	0.01	0.01	0.02	0.02	0.03
11	Petroleum	0.22	0.28	0.30	0.45	0.59
12	Other industry	4.49	5.65	6.04	9.25	12.40
13	**Construction**	**4.49**	**5.01**	**5.14**	**5.99**	**6.30**
14	**Services**	**38.94**	**40.46**	**40.68**	**40.71**	**39.91**
	Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*
	Total Employment (Million persons)	**62.5**	**68.3**	**69.9**	**83.0**	**92.6**

Source: BDP 2100 Projections, GED, 2017

Table 5.11: Sectoral Employment Share (Delta Plan Policy Option Scenario) (%)

Sl	Sectors	2016	2020	2021	2031	2041
	Agriculture	**45.20**	**39.22**	**37.52**	**27.33**	**19.09**
1	Cereal Crop	20.32	16.04	14.43	7.81	3.74
2	Commercial crop	5.10	4.04	3.63	1.97	0.94
3	Livestock-poultry-fishing	18.52	17.95	18.27	16.68	13.83
4	Forestry	0.94	0.93	0.94	0.74	0.52
5	Other Agriculture	0.33	0.27	0.25	0.13	0.06
	Manufacturing	**11.37**	**14.23**	**16.27**	**23.27**	**30.45**
6	Other Food	0.27	0.33	0.38	0.57	0.86
7	Leather	0.93	1.17	1.32	1.91	2.69
8	Textile-clothing	4.64	5.81	6.69	9.92	13.52
9	Chemical-Fertilizer	0.81	1.01	1.15	1.64	2.07
10	Machinery	0.01	0.01	0.02	0.02	0.03
11	Petroleum	0.22	0.28	0.31	0.41	0.49
12	Other industry	4.49	5.62	6.40	8.80	10.79
13	**Construction**	**4.49**	**5.31**	**5.83**	**7.22**	**7.98**
14	**Services**	**38.94**	**41.24**	**40.37**	**42.18**	**42.48**
	Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*
	Total Employment (Million persons)	**62.5**	**68.8**	**70.5**	**86.2**	**101.0**

Source: BDP 2100 Projections, GED, 2017

The key question analyzed in this chapter is – can Bangladesh counter the adverse impacts of climate change? The answer is Yes, provided it adopts appropriate policies and institutional reforms to tackle climate change and invests an additional 2 percent of GDP every year on water resource management, climate change and disaster management projects. These projects must be carefully designed and implemented on a fast track mode. Calculations show that the benefit from the recovery of GDP growth will more than offset the investment cost of the various Delta Programmes, even without explicitly accounting for the loss of life and limb that would be averted in a Delta policy option. The logic for this result is the inherent strength of the Bangladesh economy. Investments and policies that adapt and mitigate those environmental risks help sustain the trends envisaged under the Seventh Plan and shown under the Delta Plan policy option scenario.

Chapter 6
Managing Water Resources

Chapter 6: Managing Water Resources

6.1 Background

The hydro-morphological dynamics and characteristics of the Ganges- the Brahmaputra- the Meghna basins discussed in **Chapter 1** and **Chapter 4** largely govern the water resources management of Bangladesh. As noted, the management of water resources within the country is very difficult and complex as the flow is generated from 93% area of the Ganges- the Brahmaputra- the Meghna, which lays outside of Bangladesh (BDP 2100 Water Resources Baseline Study). The country is frequently hit by natural disasters such as, flood, river bank erosion, cyclone in the wet season; and drought in dry season. Moreover, the country encounters problems like water logging, salinity intrusion, arsenic contamination, navigation problems, etc. These issues, coupled with adverse climate change variability ultimately hinders the country's socio-economic endeavors, as elaborated in **Chapter 2**.

Water remains an indispensable resource and is used in diversified development, production as well as community sectors such as, agriculture, domestic, industrial, commercial, forestry, fisheries, etc. The nation-wide demand for water is growing every day which is being intensified by several socio-technical drivers such as, high demographic growth, rapid and unplanned urbanization, high sectoral demand (such as agriculture, fisheries, transportation, industries etc.), climate change, etc. On the other hand, essentiality of water for the rich but vulnerable ecosystem of the country and variability of water availability in dry and wet seasons complicates the issue of water resources management in Bangladesh. Moreover, the country is confronted with growing uncertainties in receiving equitable water share from its upper riparian countries. Therefore, it is of high importance for the country to manage this critical natural resource in an integrated and holistic strategic manner.

The country has some 35 central government organizations, affiliated with 13 ministries, which are functioning for water sector planning, development and management, with several large, medium and small water management projects to offer beneficial Irrigation, Flood Control and Drainage (BDP 2100 Institutional Framework and Arrangements Baseline Study). A number of plans have been undertaken in different phases by the Government of Bangladesh during the last few decades for systematic water resources development and management. However, the plans before or during the 1990s had limited emphasis on the interplay between such contemporary challenges, such as climate change, natural disasters, environment, land management, agriculture and inland water management. The plans formulated later on have expanded their domain to cover such aspects, but the temporal extent of such plans is confined within the short to medium term only (20 to 30 years), limiting their prospects to properly address the long term consequences of climate change and other uncertainties (transboundary issues, population growth, land use changes, etc.). Importantly, no previous water plan looked systematically at the interplay of water, climate change and natural disasters and the implications for GDP growth, poverty reduction and employment.

BDP 2100 therefore comes up with an adaptive, holistic and long term integrated plan to steer the opportunities and vulnerabilities created by the interface of water, climate change, natural disasters, poverty, environment, ecological balance, agriculture, land use and inland water management for national development. The sustainable use of water resources and prevention of water-related natural disasters provides the backbone to the BDP 2100. The BDP 2100 offers a long term development perspective, considering the spatial and temporal extents of all the contemporary water related issues giving insight for necessary strategies against plausible climate change uncertainties. These water strategies are aimed at developing the country's capacity to flexibly and productively adapt its water resource management to future climate and socio-economic changes as well as to the cross-boundary developments in the Ganges- the Brahmaputra-the Meghna basins with a view to minimizing vulnerabilities and maximizing development gains in terms of GDP growth, employment creation and poverty reduction.

6.2 Water Management Strategies

Chapter 5 identified 6 Delta specific goals that are directly or indirectly related to the adaptive and efficient management of Bangladesh water resources. The associated water management strategies have two dimensions: cross-boundary and national. The transboundary water management issues and related strategies were discussed in **Chapter 4**. In this chapter, the national strategies for efficient water management are discussed. The strategies suggested here have a direct bearing on the effectiveness with which the 6 Delta-specific goals are secured. In turn, they underpin the ability to secure the longer term socio-economic goals of the BDP 2100 based scenario discussed in **Chapter 5**. The adoption and implementation of national water strategies proposed here will have a determining effect on the ability of Bangladesh to achieve those longer term goals.

Efficient management of water resources in long run for sustainable economic development of the country requires formulation of strategies considering the spatial and temporal extents of all the contemporary water related issues with thorough acknowledgement of institutional capacity and coordination as well as the short and medium term development targets of the country. Therefore, a set of strategies with different kinds of measures have been formulated under the BDP 2100 for the national issues and Hotspots identified based on the detailed analysis of the water related problems and challenges of the hydrological regions with motivations of becoming middle income country as laid in Vision 2021 of the GoB; achieving SDG set by the United Nations by 2030; fulfilling the Vision 2041 of the GoB for becoming a prosporous country. It is to be noted that the strategies with different measures have been formulated on the six specific issues and hotspots as identified in **Chapter 1**. The problems related to institutional capacity and coordination and knowledge gaps have been addressed separately under the strategic measures with heading "Institutional" and "Knowledge" for each of the strategies.

The strategies for managing water resources in wet and dry season have been formulated are flexible in respect of measures and actions with its timeframe and uncertainties. The strategies are adaptive in the sense of i) periodic review and update in Five Year Planning cycle on the basis of situation and development need; and ii) the ability to be modified as exogenous scenario conditions and changes with socio-economic needs. These are 'no regret' strategies in a sense of effectiveness in terms of performance under a wide range of external conditions and offers integrated implementation with innovation, advanced information technology and strengthened institutional capacity. Integration also refers to the multi-sectoral impact and needs of Delta and water resources management.

Two national strategies; i) the Flood Risk Management Strategy; ii) the Fresh Water Strategy and six hotspot strategies have been developed. The strategies are described in the following sections. Annex C provides additional technical supporting materials for these strategies.

6.3 Flood Risk Management Strategy

Flood Risk Management (FRM) is crucial to Bangladesh as more than 60% of the country is prone to flooding (BDP 2100 Water Resources Baseline Study). Of the total cropped area, about 1.32 million ha are severely flood prone and 5.05 million ha are moderately flood prone (FAO Aquastat, 2011). Abnormal flooding can submerge more than 60% of the land area, damaging crops and property, disrupting economic activities and causing loss of life. Normal flooding affects approximately 20% of the country each year, but land use and settlement are well adapted to it (BDP 2100 Water Resources Baseline Study). These floods are both 'a blessing' – through groundwater recharge, soil fertilization and the provision of breeding grounds for fish – 'and a curse' through displacement, disease and loss of life and property.

The most extensive flooding generally occurs in the monsoon period when rainfall and river flooding coincide and the river levels do not allow for the drainage of rainfall floods from the adjacent areas. The most disastrous floods, in terms of lives and livelihoods lost, typically occur in the coastal zone when high tides coincide with the major cyclones.

Flood management plans have been developed in the past and have yielded a rich experience base, particularly through the Flood Action Plan (FAP) that was implemented from 1989 to 1995. This experience and lessons learnt were taken up in the Bangladesh Water and Flood Management Strategy (BWFMS) which was approved by the Government in 1995. The BWFMS represented long and short term strategies for water and flood management in the country. The long term strategy included: i) undertaking integrated water and land use planning, including flood protection, flood plain zoning, protection against drought and storm surge; ii) achieving inter-sectoral balance; iii) managing cross-border flows; iv) basin wise development; v) balancing structural and non-structural approaches to water management; vi) setting environmental priorities; and vii) institutional strategies. This flood risk management strategy of the BDP 2100 is built on these experiences and recommendations.

6.3.1 Types of Flooding

Four types of flood occur frequently in Bangladesh: rainfall floods, river floods; flash floods and coastal floods.

1. Rainfall floods caused by high intensity rainfall during the monsoon result in 'normal' floods. They cause relatively little damage or even are beneficial as they help dilute polluted water bodies, reduce irrigation requirements and enable wetland augmentation. These floods can however be aggravated by inadequate drainage, when water levels in the major rivers are high, or by blockage caused by roads and other infrastructure. In extreme rainfall events, there can be losses of lives, crops as well as damage to critical infrastructures and interruption of transport-economy. A distinction can be made between rural, urban and coastal rainfall floods.

2. River floods are caused by spilling of water over the banks of major rivers due to heavy rains in the upstream catchments. This type of flood is often catastrophic, especially when the major rivers rise simultaneously and when rainfall floods are already leading to a reduced drainage capacity. These floods are beneficial for fisheries habitat connectivity, groundwater recharge, wetland

augmentation, flushing of pollutants and increase in soil fertility. These floods cause loss of lives and damage to crops, fisheries, forests and lands. The loss of critical infrastructure, water supply and sanitation facilities and roads, railways, etc. can also make the flooding situation disastrous.

3. Flash floods occur in the eastern and northern hilly regions. Flash floods have a relatively short duration, but generally have high velocities and a rapid increase in water levels. This makes them very destructive at local levels. Due to this type of flood, silt makes the land fertile and the pollutants are diluted, which are beneficial for the country. On the other hand, loss of lives, crops, soils and infrastructures can make certain areas more vulnerable.

4. Coastal floods refer to cyclone induced tidal surges that occur in the coastal zone consisting of large estuaries and low-lying lands. The surges mainly occur during the pre- and post-monsoon periods. Cyclonic floods are potentially the most disastrous of all, for which the loss of lives, homesteads, critical infrastructures such as water supply are sanitation facilities can be signifiant.

6.3.2 Key Issues 2015

Economic damage, poverty and casualties: Extreme floods can be devastating. About 50% of the flood damage was related to agriculture and nearly 40% to infrastructure (BDP 2100 Water Resources Baseline Study). A comparison between the damage caused by major floods are shown in Table 6.1. The 1998 flood was of high magnitude and flooded 68% of the country with a long duration. The flood flow remained above bank full for nearly 1, 3 and 4 months in the Ganges, the Jamuna and the Padma, respectively. On the other hand, the extent of the 2004 flood was much less, about 38% of the country was flooded . The comparison leads to the conclusion that unexpected floods (such as flash floods) cause much more damage to infrastructure.

Table 6.1: Damages resulting from major floods 1974 - 2007

Year	1974	1987	1988	1998	2004	2007
Affected area ('000 km²)	53	57	90	100	56	62
Affected population (million)	30	30	47	31	33	14
Fatalities	28700	1657	2379	918	285	1110
Houses damaged (million ha)	na	989	2880	2647	895	1000
Roads damaged (km)	na	Na	13000	15927	27970	31533
Crops damaged (million ha)	na	Na	2.12	1.7	1.3	2.1
Asset losses (million US$)	936	1167	1424	2128	1860	1100
GDP current (million US$)	12459	23969	26034	44092	55900	68400
Asset losses (% of GDP)	7.5	4.9	5.5	4.8	3.3	1.6
Estimated return period (years)	9	13	55	90	12	14

Source: BDP 2100 Technical Team Analysis, GED, 2015

The effects of severe flooding on the main monsoon crop: Transplanted Aman rice can be severely affected with up to 45% production loss in areas affected by severe flooding. During severe floods, the affected area may exceed 5.3 million ha or 40% of the country. During extreme events, such as the 1998 flood, 66 % of the country was inundated. Of the total cropped area, 1.32 million ha are severely flood-prone and 5.05 million ha are moderately flood-prone (FAO Aquastat, 2011). An overview of the crop damage in relation to flooded area is presented in **Figure 6.1**.

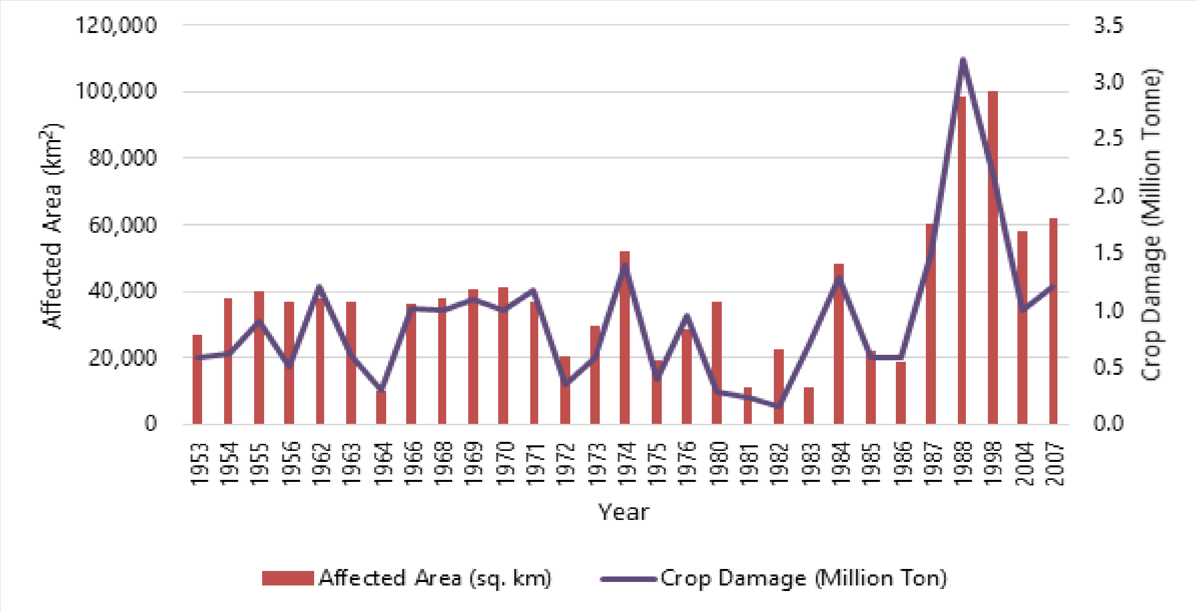


Figure 6.1: Crop Damage in Relation to Flooded area (1953- 2004)

Source: BDP 2100 Technical Team Analysis, GED, 2015

Urban floods are particular phenomenon, with Dhaka being the most affected in terms of population, economic damage and risks to health and livelihoods. Dasgupta et al. (2015) analyzed the specific impacts of urban flooding for Dhaka, focusing on the major flood events of the last 30 years. They reported that the 1988 flood inundated about 85% of Dhaka, isolating the city from the rest of the country for about two weeks. The study also reported that during the 1998 flood, about 56% of Dhaka was inundated for a period of up to 10 weeks. Water supplies were severely affected; and road, rail, air transport, and telecommunications were disrupted. Two thirds of city residents suffered damage to assets, and daily wage earners suffered direct loss of income (Dasgupta et al. 2015). Similar damages were reported for the 2004 and 2007 floods, with varying local impacts in terms of duration, depth and location. A particular case of flood occurred in July 2009, when more than 333 mm of precipitation was recorded within a 12-hour period in Dhaka (Dasgupta et al 2015). Snapped power lines electrified the flood water which caused at least nine deaths and many injuries. In addition to the impacts mentioned above for the major floods, production was suspended at most industrial units in the south eastern area of Dhaka-Narayanganj-Demra (DND), businesses and schools were forced to close, and trading on the stock market was disrupted (Dasgupta et al 2015).

As the country's economy continues developing and diversifying, flood risk in relation to critical infrastructure becomes increasingly important. The functioning of energy lines (power supply, natural gas), major industrial installations, transport and electronic communication and financial sectors as well as their quick recovery after a disaster are critical for development of Bangladesh.

Damage at national level: Although floods may lead to extensive damage locally, the damage at national and year-round level differs. Crop losses during the monsoon are partly compensated for by an increased production of Boro rice in the same area (BDP 2100 Water Resources Baseline Study). Due to significant damage from floods, farmers put more effort in Boro rice production to compensate for the loss and also due to the availability of more (ground) water for irrigation from the additional storage in aquifers and surface water bodies from the preceding large flood event.

Farmers of the areas not affected by floods typically also anticipate higher prices and decide to invest their savings to obtain a higher output.

Increasing flood risk: The recent economic transformation over the past 10 to 20 years has important consequences for flood risk management. A diversified economy, with economic strongholds emerging in the urban areas, connected by critical infrastructure, leads to a large increase of the value at risk and a decrease in the ability to recover from extreme floods quickly.

Vulnerability and poverty: The impact and regular occurrence of floods is an explaining factor for the geographical concentration of poverty in Bangladesh. Floods also impact poor households' ability to escape from poverty by impacting on productive assets, labor productivity, houses, communication, education, health, water and sanitation. People living under the poverty threshold face a higher risk of flooding, as measured by their proximity to rivers and water bodies. Flood limits people's access to public services such as health care, agriculture, treatment for livestock, schooling and reduces their resilience: their ability to recover to their previous level of economic well-being and health. These risks are particularly poignant for female headed poor households, which have even less opportunities for alternative incomes and assets to fall back on. Vulnerable communities face a growing risk due to climate change and transformation of the natural environment.

Casualties: Casualties are caused by the direct impact of the flood (drowning), and impacts during the aftermath of a flood due to polluted water sources and spreading of diseases. The 1998 flood is illustrative in this respect. About 30 million people were affected by the 1998 flood (BDP 2100 Water Resources Baseline Study). Diarrhoea, caused by polluted water or rotten food, accounted for 208 of the 1010 deaths. Other deaths were caused by snakebites, collapsing houses and mudslides. Kuniiemail et al. (2002) conducted interviews among 517 people affected by the flood. Only 1.0% and 6.7% of the respondents treated water before drinking, by boiling and chlorination, respectively. 75% of the respondents, however, believed water collected from tube-wells (93.2%) and rivers (6.0%) to be contaminated (BDP 2100 Water Resources Baseline Study). A substantial number of these casualties can be avoided by improved and robust drinking water and sanitation facilities and hygienic practices.

Operation and Maintenance of FCDI schemes. Inadequate maintenance of FCDI schemes, developed over the last 40 years, as well as a rapidly changing land use is putting the sustainable functioning of FCDI projects at risk (BDP 2100 Water Resources Baseline Study). These schemes provide basic safety and a conducive environment for agriculture and aquaculture and have contributed to reaching the national objective of rice self-sufficiency in recent years, in addition to providing a safe living and working environment. At the same time, FCDI schemes – by excluding flood waters from the flood plain – have contributed to raise flood levels outside the protected areas and interruption of fish migration routes. As a result, frequent public cuts and conflicts have arisen around FCD schemes, illustrating the multitude of interests that exist. These interests include but are not limited to agriculture, fisheries, navigation, safety and environment.

O&M has been a problem on virtually all FCDI schemes, as noted already during the preparation of the NWMP in 1999. Its causes include insufficient public funding, poor cost recovery, lack of beneficiary participation and technical challenges. As reported in the NWMP, 2004 for the period 1994 - 1998, the annual Maintenance BWDB expenditure was in the order of Tk. 1.206 billion, of which some Tk. 1.1 billion allocated for scheme maintenance. The required O&M expenditure was estimated to be in the order of Tk. 4.5 billion or more than three times what was actually spent. **Error! Reference source not found.** below illustrates that this funding gap has greatly increased in he last decade. The notable growth in O&M demand would seem to reflect the building up of deferred maintenance over the years.

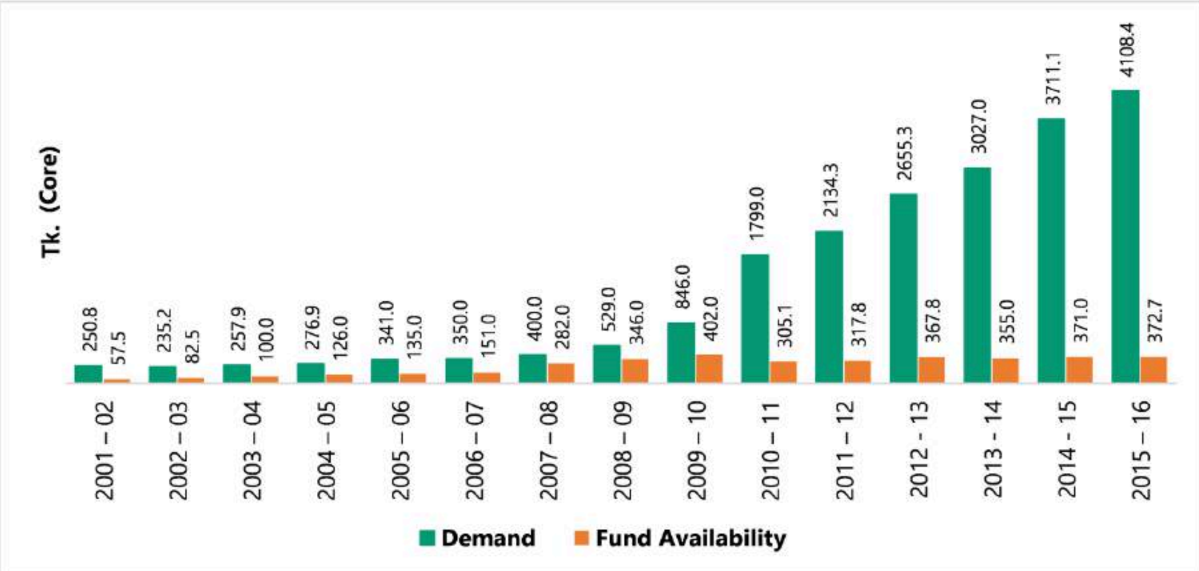


Figure 6.2: O&M Funding Gap of BWDB 2001-2016

Source: BDP 2100 Base Line Study Report: Sixty Years of Water Resources Development

From the figure, it can be seen that about 10% of O&M requirements are actually met. The lack of O&M ultimately leads to greatly increased need for rehabilitation and a prolonged underperforming of FCDI schemes throughout the country.

Drainage Congestion and Waterlogging. Drainage congestion is a key and growing issue in the Bangladesh Delta. Three types of drainage congestion can be distinguished (BDP 2100 Water Resources Baseline Study):

(i) Coastal drainage congestion occurs particularly in the Southwest (SW) in Satkhira, Jashore, Khulna and Bagerhat Districts and Southeastern (SE) Districts of Noakhali and Feni. Their causes are different. In the SW region the causes are twofold: i) reduction of the tidal prism due to the construction of coastal polders from the 1964 onwards. Polder development has limited tidal flooding into the tidal plain, where sediments were naturally deposited. Combined with the reduction of upstream freshwater from the Ganges, a result of the construction of the Farakka barrage and morphological changes around the offtakes leading into the Ganges Dependent Area (GDA), cause a rapid and widespread river siltation. These tidal rivers cannot effectively drain the nearby lands and polders anymore due to the resultant reduced drainage capacity, in turn leading to widespread waterlogging. In the South East zone, the causes are somewhat different. As a result of land reclamation and (natural) accretion in the Meghna estuary, the drainage path has increased, lowering the drainage gradient and, as a consequence, drainage capacity.

(ii) Urban drainage congestion is caused by the combined effect of: i) decreased infiltration and increased run-off due to increased built up areas; ii) inadequate maintenance of urban drainage networks; iii) siltation and waste accumulation; and iv) insufficient drainage capacity, either in the open water bodies (khals, lakes) or in the closed drainage network. In addition to economic disruption, health and environmental hazards are key impacts of urban waterlogging.

(iii) Rural drainage congestion. Occurs as a natural process during high rainfall events and high water levels of the surrounding rivers, hampering drainage; also called rainfall floods. However, prolonged congestion occurs as a result of i) construction of roads, embankments and other infrastructure on the floodplains without adequate provision for drainage; ii) encroachment of drainage waterways; and iii) siltation of drainage khals and regional rivers.

6.3.3 Key Issues 2050

In this section, for each of the key issues, first the main drivers and pressures are identified. Thereafter, based on the analysis carried out in the BDP 2100 Baseline Studies, Hotspot Strategies and the National FRM Strategy, an assessment – using primarily expert judgement - is made of the direction and magnitude of the key issues in 2050. The analysis below is based on the assumption of Business As Usual conditions in which the present implementation of policies is continued and current climate conditions prevail.

Economic damage, poverty and casualties: Key drivers regarding economic damage and threatened livelihoods include economic development, industrialization, climate change and population increase. The flood hazard increases with increasing climate change, key features of the active and resilient scenarios. Impacts of floods increase with increasing average economic value in flood-prone areas, a key feature of the productive and resilient scenarios or with increasing non-flood-resilient population, characteristic of the active and moderate scenarios. The hazard of river bank erosion increases with increasing climate variability (active and resilient scenarios) because bank-full flow which is the condition when risk for bank erosion is largest - is then likely to occur more frequently.

Uncertainty in *climate change* projections makes any computed impacts on peak flows uncertain. Nevertheless, the majority of studies indicate that the total annual flow as well as the peak flow of the Ganges and the Brahmaputra will increase (CSIRO, 2014). Increased surface water inflows and greater monsoonal precipitation will increase flooding. Along the coastal zone flooding is also likely to occur more frequently due to sea level rise and increased storm surges. To obtain an indication of possible changes in climate on peak flows of the major rivers in Bangladesh, IWM (2014) assessed the modelled impact on rainfall and temperature for several locations in the Ganges, the Brahmaputra and the Meghna basins. The changes in climate were averaged for all global circulation models. The average change of the remaining models was used to derive input data for Mike-Basin models of the three rivers. The results indicate increased river discharge, especially during peak flows. The peak flow of the Ganges at Hardinge Bridge during the 1998 flood was about 72,000 m^3/s (CSIRO, 2014). According to CSIRO, this could increase to more than 90,000 m^3/s in 2050. In the Brahmaputra/Jamuna River, climate change could increase peak flows by about 15%, from 103,000 m^3/s to 116,000 m^3/s (CSIRO, 2014).

The projected growth until 2050 suggests an increase in GDP by a factor 15. Much of this growth will be brought about by industrialization and development of the services sector. In the BDP 2100 Delta scenarios, a slowing population growth is foreseen, with extremes occurring in the Moderate scenario (210 million) and Resilient scenario (170 million). If no additional measures are taken (the

BAU conditions), the number of people affected by floods will also increase by between 10 and 30%. The same may also apply to the expected number of casualties. Although not all of the economic growth results in increased economic value of the flooded land, together with the growing population, this will result in an enormous increase of the annual flood risk.

Urban floods: A particular case is Dhaka, the main urban centre of the country, Dasgupta et al (2015) expect a 16% increase in extreme 24-hour precipitation by 2050, compared to the 2004 baseline. As input to the hydrological modelling (carried out by IWM), use was made of the A1FI scenario, which is most comparable with the climate scenario selected for the BDP 2100 Resilient and Active Delta Scenarios.

The cost of implementation of flood adaptation measures were assessed, divided into i) additional investments required to cope with the flood events, labelled 'adaptation deficit', and without climate change; and ii) further measures required to meet the 2050 climatic conditions as anticipated in the IPCC A1FI emission scenario. Dasgupta labelled this as the 'climate change deficit'. The cost of upgrading Dhaka's infrastructure, would amount to Tk. 2.7 billion, equivalent to 0.35% of the annual development budget expenditure (2014–15). Dasgupta indicates that this investment would generate notable returns, given the current and anticipated future levels of flood damage. For example, if an extreme rainfall event like that of 2004 were to occur in 2050, without the investment to address the current 'adaptation deficit', the increased damage caused by climate change would amount to Tk. 2.0 billion, As a result of the investment, the damage would be reduced significantly, to Tk. 0.9 billion (Dasgupta et al 2015). The anticipated damage would be even higher if one would factor in socio-economic developments in 2050, as described in the Delta scenarios. As discussed before, at the current annual GDP growth rate of 7%, the value of assets at risk – and damages - will double every 15 years, assuming simple linear increase of asset value with GDP. A similar line of reasoning is applicable for the vulnerability of communities in the Dhaka Metropolitan Area. Population growth scenarios for 2050, applying the Delta scenarios for Dhaka zila, making use of shift-share analysis are indicated in **Table 6.2**.

Table 6.2: Population Dhaka of District Applying Population Projections Delta Scenarios

Population (million)	BDP 2100 Delta Scenario			
	Productive	Moderate	Resilient	Active
2030	21.2	22.0	20.4	23.3
2050	27.8	29.6	24.0	34.6

Source: BDP 2100 Analysis

The hydrological modelling carried out in the World Bank study (Dasgupta et al, 2015) assumed that pipes, khals, and box-culverts will perform according to design capacity and that storm water will reach them without undue difficulty. These assumptions are optimistic, as indicated by Dasgupta et al (2015).

O&M of FCDI schemes: Key drivers regarding the Operation & Maintenance of FCDI schemes include the financial and technical capacity of public sector agencies, economic development and governance in general. In the continued high growth (resilient) scenario, strong public sector organizations is in place – through decentralized management. In the high growth (productive) scenario, on-going rapid economic development is coupled with a dominant reliance on the private sector. In the two low growth scenarios, public sector agencies remain relatively weak and under-funded, with little capacity to plan for (preventive) maintenance. Under these scenario conditions, several impacts can be envisaged (Table 6.3).

Table 6.3: Impacts on O&M in Different Scenarios

Issues	BDP 2100 Delta Scenario 2050			
	Productive	Resilient	Moderate	Active
Adequacy of public funding	+	++	-	--
Effectiveness of O&M	+	++	-	-
Conflicting interests FCD schemes	--	0/+	--	--

++ = highly positive impact; + = moderately positive impact; 0 = neutral impact; - = moderately negative impact;-- = highly negative impact

Source: BDP 2100 Analysis

Drainage congestion: The three identified types of drainage congestion, will, when remedial measures are not put in place, further increase in extent and duration under future climate and sea-level rise. According to Sarkar (CEGIS, BDP 2100 presentation, 2015) and Brammer (2004), the direct coastal zone may be expected to adjust to the rising sea level due to additional sedimentation and accretion. It is in the inland areas however, where additional accretion cannot take place that increased drainage congestion, especially in terms of duration, is most expected. The most affected areas are the Khulna-Jashore and Noakhali Districts. Urbanization and population growth will lead to greater more river encroachment, inadequate drainage provisions in infrastructure will further aggravate the situation. Under climate change, the frequency and intensity of extreme precipitation events are expected to increase. In urban areas, an increased frequency of drainage congestion becomes more and more unacceptable, as it directly influences people's living conditions (health, discomfort) as well as economic activities and foreign investment.

6.3.4 Detailed Strategies

By focusing on both the short and the long term, the BDP 2100 aims to overcome the well known pitfall that 'the solutions of today become the problems of tomorrow'. The key word is control. International experience indicates that the path to long term development for countries with complex and highly variable water and climate regimes, such as Bangladesh, leads through controlling their water systems. Control entails enhancing productive potential on the one hand and ensuring protection against destructive impacts on the other. Enhancing Productive Use entails investing in the water system in direct support of economic growth and social well-being. Growth enables investment in institutions, information systems, innovation and infrastructure.

Protection Against Destructive Impacts entails focusing on protecting people and assets that are threatened as water-related risks (such as scarcity, floods, access, and resource degradation) grow due to population and economic growth. These two aspects: Enhancing Productive Use, and Protection Against Destructive Impacts, form the core of Water Security, as defined by the Global Water Partnership.

It was mentioned before that the Flood Risk Management Strategy contributes directly to Delta Goal 1: Ensure safety from floods and climate change related disasters. Key elements of this goal, as elaborated in the 7th FYP, are:

"… to facilitate: i) a safe living environment for all, in urban and rural environments; ii) reliable water system conditions for long term economic development; and iii) the performance of key societal and economic functions."

Principles for flood risk management

To address the above goal, and do justice to the lessons learnt in Bangladesh, following three principles for FRM form the basis of its strtaegies:

1. Supporting the economic development, without endangering the environment;
2. Creating a climate-proof Bangladesh, making optimal use if its natural conditions; and
3. Leaving no one behind, building on resilience.

To operationalize the Delta Goal in the 7th FYP and guided by the principles elaborated above, the FRM Strategy consists of three separate but closely linked operational strategies. Each of these strategies is elaborated here below, including linkages to the main proposed investment projects included in the BDP 2100 Investment Plan. As part of each strategy, indicative safety levels are proposed, with further research required, based on nationally consistent societal cost-benefit analysis, to come up with actual desired and realistic standards.

Strategy FR 1: Protecting Economic Strongholds and Critical Infrastructure

Supporting economic development implies that those areas that are essential for the economic growth of Bangladesh require a high flood protection standard. This is required to attract the investments that allow the economy to grow. Typical measures that can provide this level of protection include embankments, barriers, erosion control (e.g. by integrating the measures proposed by this BDP 2100 and the FRERMIP[21] project), and efficient drainage systems. Most of these measures are already in place, albeit at a basic level. In addition, adapted flood proof building is needed for key facilities such as hospitals, power stations, industrial plants and major communication networks between these facilities. Flood control measures will need to ensure that projects do not create inundation problem elsewhere by creating room for rivers that allow them to follow their natural courses and their pathways to the sea.

The following indicative flood protection levels for these economic strongholds and vital infrastructure are proposed: 1/100 and 1/250 up to 2030; 1/250 - 1/1000 up to 2050, and 1/1000 - 1/2500 by 2100;

There are five sub-strategies. They are:

Sub-strategy FR 1.1: Develop and improve embankments, barriers and water control structures: Bangladesh setup a national target to achieve prosporous country status by 2041, for which lots of economic activities is going on and will further go on. But due to the climate change extreme flood may occur for which the economic strongholds, major urban cities need higher level of protection. Therefore, construction of new embankments and other water control infrastructures as well as strengthening and/or maintenance of the existing structures is needed at economic priority zones,

[21] Flood and Riverbank Erosion Risk Management Investment Program (ADB funded)

major urban cities etc. Moreover, building and maintainance of fish passes and fish friendly structures to ensure fish movement to facilitate seasonal migration of fish for breeding and grazing are to be emphasized.

Sub-strategy FR 1.2: Construct adaptive and flood-storm-surge proof building: The buildings and infrastructures like hospitals, power stations, communication networks etc. in the flood prone area needs to flood and storm surge proof by elevating the plinth level of the buildings.

Sub-strategy FR 1.3: Adopt spatial planning and flood hazard zoning: The spatial planning and flood hazard zoning is needed to categorize the critical area. By category, the flood safety level need to setup and implement the needed protective measures.

Sub-strategy FR 1.4: Extension of the flood warning lead time: The flood early warning system need to be updated and the lead time needs to improve. The dissemination system also need to improve for delivering the warning to the local people with a good lead time.

Sub-strategy FR 1.5: Improvement of Drainage: The drainage system need to improve all over the country with special emphasis to major urban centers by better operation and maintenance and enhanced capacity.

These sub-strategies, including measures are visualized in **Figure 6.3**.

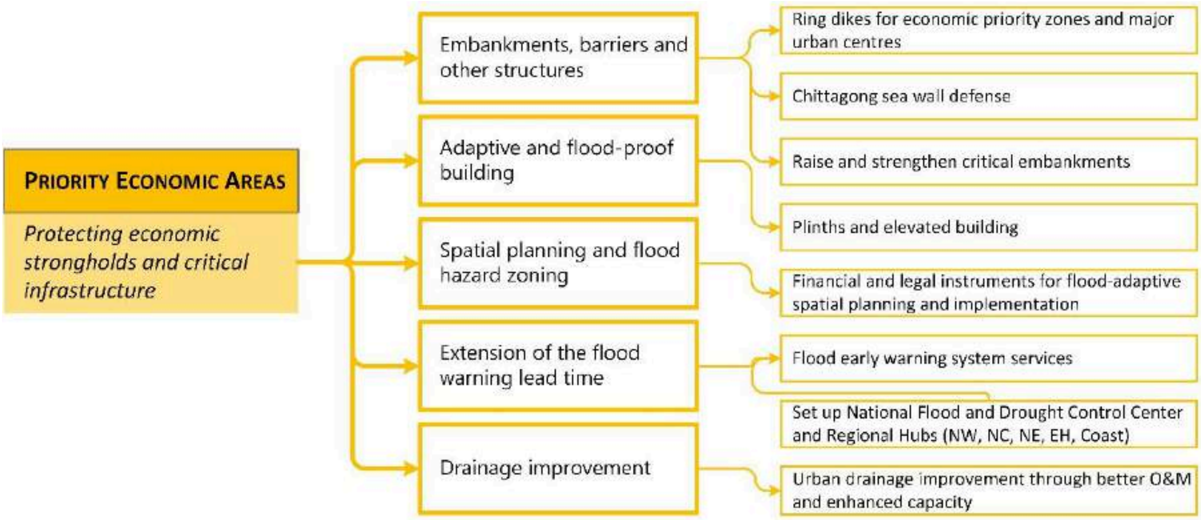


Figure 6.3: Strategy FR 1: Protecting Economic Strongholds and Critical Infrastructure

The following short term measures and projects are included in the BDP 2100 Investment Plan (IP):

1) Strengthen and raise flood protection infrastructure for major economic zones and urban centers
2) Flood proof building and critical infrastructure ,including transport, energy, communication and hospitals
3) Development of effective financial and legal instruments for spatial planning, zoning and implementation, including capacity building
4) Development of the knowledge base : flood hazard mapping and modelling
5) Flood early warning services, supported by public sector flood and drought information centers, providing public and private services to the public and enterprises. A strong

cooperation will be developed between institutions responsible for hydrology (BWDB), meteorology (BMD), modelling (Institutes and Centers), dissemination and early action.
6) O&M enhancement, through institutional building and strengthening the financial base
7) Urban drainage improvement through on-going projects.

Strategy FR 2: Equipping the FCD Schemes for the Future

Creating a climate proof Bangladesh implies that the measures are designed to meet current physical and socio-economic conditions, as well as future developments. The country has invested heavily in FCD development over the past 60 years[22], FCD schemes are in urgent need of maintenance and, in selected areas, remodeling to equip them for the future. Future designs need to take into account projections of climate and hydrological change, sea level rise, as well changed land use and, infrastructure and urbanization. Considering present climate change projections, up to 2030, the rapidly changing socio economic conditions are more important. Beyond 2030, however, and depending on which scenario actually unfolds, climate change may have a notable impact. How the future unfolds is inherently uncertain and investing in measures that could be rapidly outdated due to changing conditions needs to be avoided. At the same time, over-dimensioning of structures- which later turn out to be unnecessary lead to a waste of scarce resources. Flexible measures that are efficient under a range of boundary conditions are therefore most attractive. These are no-regret measures. This is where the Delta scenarios including climate change, sea level rise and socio-economic development, come into play to assess the robustness of different strategies and measures.

Regarding flood protection standards, this strategy includes differentiation which is foreseen between highly productive and diversified FCD schemes, that could develop into economic strongholds, and the agriculture based FCD schemes that are aimed primarily at securing food production and alleviating rural poverty. Cost-benefit analysis lies at the heart of such differentiation, detailed here after:

(a) Diversified FCD schemes, with high value infrastructure, industry and high value agriculture: flood protection level of 1/100 up to 2030, 1/250 up to 2050; and 1/1000 by 2100. Where these areas develop into economic strongholds that are vital for the National/regional economy, then the standards under 'Priority Economic Areas' would apply. This will depend on the unfolding scenario and level of development in the country. A proactive policy of spatial zoning would apply to these areas.
(b) Agriculture based FCD schemes, where O&M and design modification of existing infrastructure is the primary strategy to equip the schemes for the future. Typically, raising the flood protection level beyond the current 1/10 and 1/25 would not be economically viable (BDP 2100 Water Resources Baseline Study). Key productivity improvements lie in better O&M, remodelling of infrastructure to allow for multiple use and interests (agriculture, fisheries, transport, ecology), inside and outside the FCD scheme area, river management and introduction of ICT technologies in (agricultural) water management.

[22] The BDP 2100 Baseline Study on "Water Resources" and "Sixty Years of Water Resource Development in Bangladesh".

Critical infrastructure inside these FCD areas would have a higher level of flood protection, e.g by raising plinth levels, road levels (with adequate drainage) and the like.

Equipping FCD schemes for the future is also about improving operational and long term management. Participatory Water Management (PWM) and enhanced private sector involvement, as well as equipping the users and managers of these FCD schemes with the skills and tools to effectively manage FCD schemes, are part and parcel of this strategy. There are five sub-strategies. They are:

Sub-strategy FR 2.1: Drainage improvement: The drainage system need to improve all over the country with special emphasis to major urban centers by better operation and maintenance and enhanced capacity.

Sub-strategy FR 2.2: Restoration, redesign and modification of embankments and structures: There are lots of FCDI schemes in Bangladesh by BWDB. But due to lack of O&M, most of those schemes are not fully functional which increases the vulnerability of flood. So the embankments and structures need to restore, redesign and modification. Any flood management and flow maintenance measures has to take into account the prevalent submerged chars that become more prominent during the dry seasons. Restoration, redesign and modification of embankments and other such FCD/I structures has to absolutely take into consideration and accordingly be able to fully accommodate the quick and timely drainage of the excess water from upstream catchments, especially when subsequent peak flows converge.

Sub-strategy FR 2.3: Restoration of water bodies and connectivity: Sedimentation and human interventions have made the rivers and khals congested for flowing water. The connectivity of the rivers, khals and other waterbodies need to restore.

Sub-strategy FR 2.4: Improve operation & maintenance: The operation and maintenance of projects is a major problem due to lack of timely funding. And for that the structures are becoming non-functional. So, improvement of the operation and maintenance system is a must for increasing the functionality of the schemes.

Sub-strategy FR 2.5: River management, excavation and smart dredging: The rivers are silting up which reduces the /efficient flow of the rivers. So excavation and smart dredging is needed for the management of the river system maintaining efficient flow. Smart dredging has to adopt not only capital dredging but also maintenance dredging and has to be applied extensively for the major reivers such as Padma, Jamuna, Brahmaputra as well as their tributaries and distributaries such as Dharala, Arial Khan, Kushiyara, Gorai etc. In addition to this, maintenance dredging has to be done to clear out submerged chars developed through years of siltation and decreasing conveyance capacity of flow as well as obstruct navigation routes of major rivers. Navigation routes have to be kept running perennially through regular dredging. Dredging dump locations or "Balumohol" locations have to be circulated that they do not get struck in one location and management of this silt has to be well accounted for and proper management schemes have to be devised.

These sub-strategies, including measures are visualized in **Figure 6.4**. A distinction is made between measures that can or should be taken up by FCD managers and beneficiaries themselves (FCD Schemes- internal management) and for which capacity building and training are key ingredients; and measures that lie in the external environment and for which Government agencies are primarily responsible. Many legal and financial aspects are part of this group of measures.

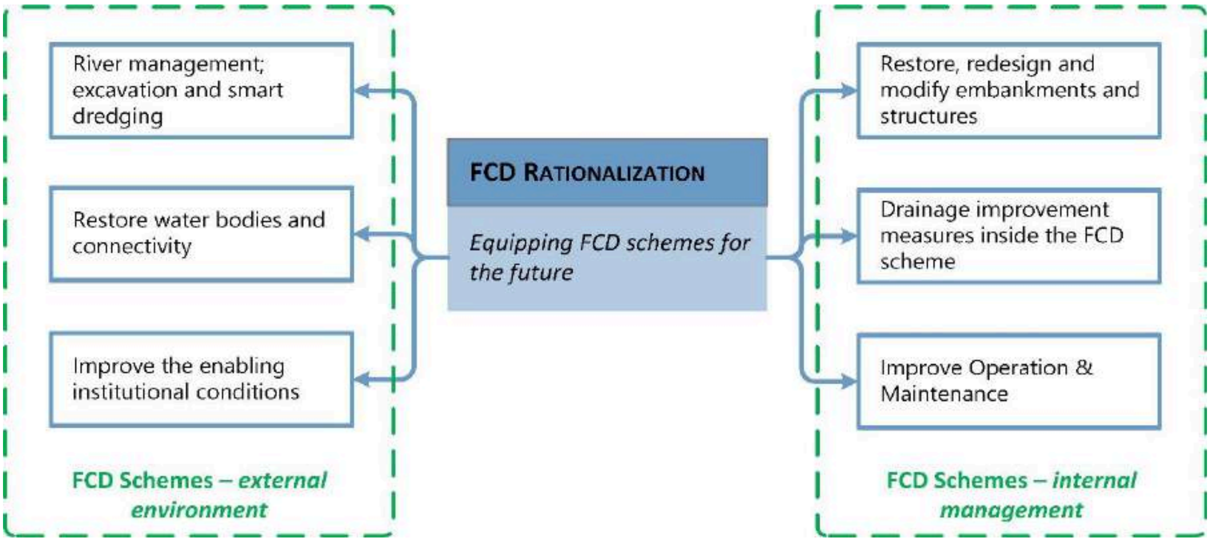


Figure 6.4: Strategy FR2: Equipping FCD Schemes for the Future

The following short term measures and projects are included in the BDP 2100 Investment Plan:

1. *Nation-wide FCD Rationalization program,* including rehabilitation and design modification based on an integrated analysis of needs and conditions, taking into account interests inside and outside the FCD projects, as well as future O&M needs and mechanisms. Institutional strengthening and capacity building are an important part of the program.
2. *River management, excavation and smart dredging,* taking into account the larger sub-basin in which FCD schemes are located and the interest of both protected and non-protected areas. In the coastal zone, this will include tidal river management.
3. *Restoration of water bodies and connectivity,* whilst enhancing the FCD projects, opportunities for river and water body restoration are included, to improve connectivity between floodplains, wetlands and rivers
4. *Capacity building for O&M,* as part of the Governance program of the BDP 2100, a comprehensive capacity building program is foreseen to enhance O&M, in line with the principles of PWM and building on recent experience with Public-Private management models for irrigation schemes.

Strategy FR 3: Safeguarding Livelihoods of Vulnerable Communities

In addition to protecting economic strongholds, there is an obligation to provide safety and to support economic resilience of vulnerable regions and communities in the country. This is in line with the principle of 'leaving no-one behind'. This type of 'protection' is not aimed at avoiding floods and creating a flood free Bangladesh for all. Given the current level of economic development, this is not feasible within the coming decades. Considering the extreme natural and socio-economic boundary conditions and inability to ensure adequate O&M of flood protection infrastructure in remote and poor areas, it is not a desirable goal in the medium term. Leaving no one behind merely means: i) mitigating the most undesired effects of large and extreme floods; and ii) enabling those who are affected by floods to recover quickly in the aftermath of the flood events.

Here the vulnerable communities primarily need attention. The flood management measures are a combination of reducing the impact of floods and developing economic measures that are relatively easy to implement, with low O&M requirements. Examples are forecasting and warning systems that penetrate deeply into the communities e.g. via mobile and digital social networks; adaptive buildings, shelters, drainage and submersible embankments. There are six sub-strategies shown in Figure 6.5 are as follows.

Sub-strategy FR 3.1: Extension of early warning services into the communities: Flood early warning system is an important tool for the vulnerable communities. This service needs to extend with a large lead time, so people should move to safe place before the flood hits. A strong cooperation between local governments and NGOs is fostered, as well as tailoring of early warning services provided by the national and regional flood and drought information centers.

Sub-strategy FR 3.2: Extension and improvement of cyclone shelters: There are lots of cyclone shelter at the coastal zones in Bangladesh. This shelter needs to improve and the numbers should be extended.

Sub-strategy FR 3.3: Flood and storm surge proofing of housing and critical services: The housing and critical services like hospital, road networks etc. should be flood and cyclone proof. These service buildings need to elevated location wise.

Sub-strategy FR 3.4: Social safety net and recovery: Rapid economic recovery needs through vital inputs and financial services after the flood and cyclone.

Sub-strategy FR 3.5: Pilots for nature based flood defenses: The flood defense could be built up using nature like afforestation at some locations on pilot basis.

Sub-strategy FR 3.6: Improving drainage: The drainage system should be improved to accommodate more water which will reduce the effect of flood.

Sub-strategy FR 3.7 : Protection of Chars and its population along with alternative livelihoods.

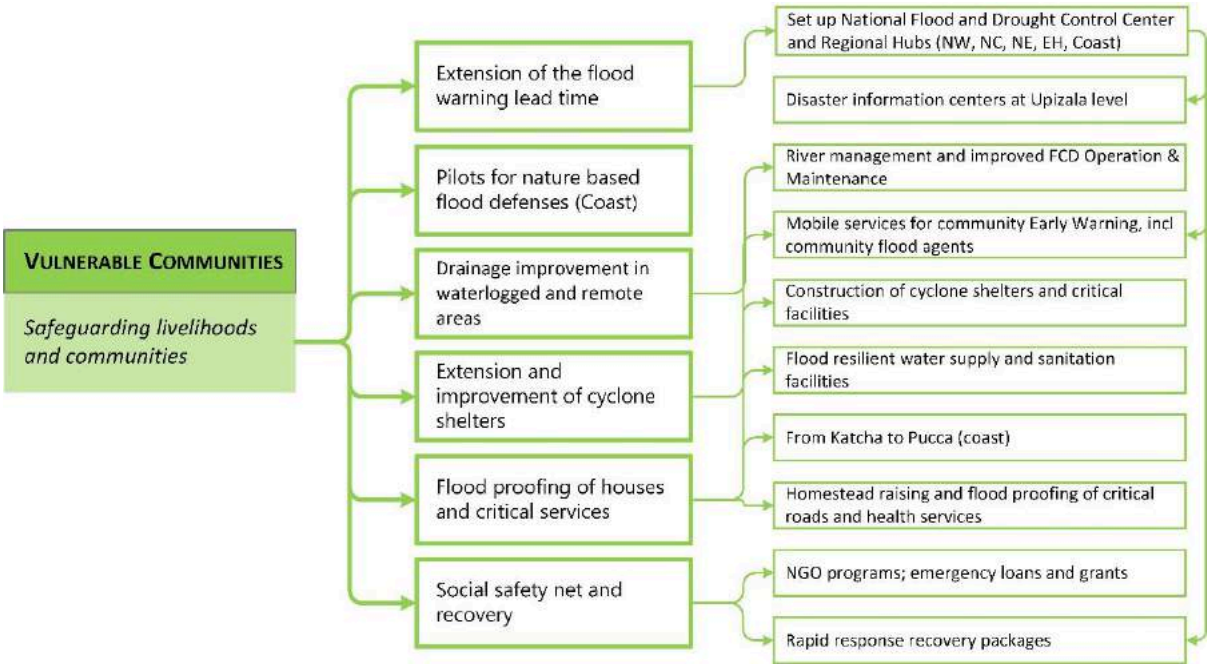


Figure 6.5: Strategy FR3: Safeguarding Livelihoods of Vulnerable Communities

The following short term measures are considered in BDP 2100 Investment Plan:

1. Extension of community based early warning services, including flood agents and networks for communication and action. A strong cooperation between local governments and NGOs is fostered, as well as tailoring of early warning services provided by the national and regional flood and drought information centers
2. Development of flood-resilient cropping systems, supported by innovation
3. Flood and storm surge proofing of housing and critical rural services, in the field of health, communication
4. Strengthening of the social safety net, including rapid economic recovery though vital inputs and financial services

6.3.5 Long term Perspectives

The long term perspective is shaped by elaborating on two potential long term strategies or development philosophies. The two long term potential strategies are: Optimized Water Control and Adaptation by Design. Both visions and associated strategies will never be implemented in their entirety (see Section 5.2 for more detailed discussion). Each region will have a different mix and over time, when the water system has been developed to a sufficient extent, the vision will change, alongwith societal values and economic development. The two philosophies should therefore be seen as cornerstones.

Both end visions have the variable hydrology and climate in mind, and are based on an understanding of the multiple uses and functions of the water system. To gain control, the country needs to ensure the right amount of water at the right time, and of the right quality.

The difference between Adaptation by Design and Optimized Water Control is that a policy according to Adaptation by Design: i) tries to avoid interventions where possible by looking for alternatives, but does not exclude interventions; ii) focuses on local solutions and strengthening of local communities and governance; iii) puts great efforts in cooperation and transboundary negotiations; iv) uses natural processes where possible (Building with Nature); and v) is based on differentiated flood zoning, rather than full embankment of the major rivers.

Whereas, a policy according to Optimized Water Control: i) focuses on interventions as soon as knowledge, institutional capacity and finance permits; ii) provides a basic safety against floods for all, allowing regular floods to enter by controlled gates; and iii) aims for being independent by means of its own barrages and flow diversion projects.

Pathways close to an Adaptation by Design policy are more adaptive than policies that adopt the Optimized Water Control policy. An illustrative example is river bank stabilization and development of flood protection embankment, a measures in line with the policy. Once this set of measures has been implemented and an area is protected against floods, it becomes difficult to remove the protection in favor of resilience or ecological values. People will have invested in economic activity that is not vulnerable to flooding because society relies on the protection or stabilization provided.

Optimized Water Control: In 2100, Bangladesh would have a highly regulated water system and fully developed its water resources. Bangladesh has chosen to master the rivers as much as possible. With the help of domestic and donor funds, large investments have secured the interests of Bangladesh and to optimize conditions for economic development. A strong national government oversees proper and timely implementation and has a central role in the monitoring and the maintenance of all structures. River training works and river bank protection works are implemented in a phased manner, so that the lessons learned from one intervention may be applied in the next. The motto is: 'learning by doing'.

It is this motto of development adaptation that has led Bangladesh to fully grasp and therefore appreciate the fact that the major rivers of the country cannot be fully controlled. That in fact, only by accommodating their innate erosion-accretion process and channel morpho-dynamics and designing water resources insfrastructures accordingly can true development be achieved.Some interventions have had unexpected adverse (downstream) effects, but this was accepted beforehand and the development of knowledge by evaluating these effects has allowed for optimization of the designs. The funds to develop this knowledge base and to mitigate the residual adverse effects by means of new interventions (protection works, dredging works) were secured. A Delta Fund would be available to meet the high cost of maintenance.

A 1/100 maximum flood risk level is secured nation-wide by well-constructed and well-maintained primary embankments along the banks of the major rivers and the char lands, equipped with sluices and culverts for controlled in and outflow of water. The location of this continuous embankment is aligned with river training works and river bank protection; a safety margin is strictly maintained between the embankment and the river bank. A yearly monitoring program identifies critical locations that need additional protection. The flood-prone 'unprotected' area in between the embankment and the river bank is popular with private real estate investors for its magnificent view: high-value and flood-free houses and resorts are developed to explore eco-tourism.

The polders and urban areas in the coastal zone and inland areas are continuously improved and adapted to changing hydrological and economic conditions, driven by agro-economic diversification. Polder water level regulation and control are the norm, through automated gates and pumping systems, where feasible making use of renewable energy sources. High value agriculture, aquaculture and agri-businesses generate sufficient returns to pay the well-established system of water taxes and fees and the policy to retain a large portion of the collected water taxes would be in place. A cycle of improvement and adaptation has thus been put in place. At planned intervals, additional sediment is brought into the polders to improve drainage conditions.

Institutions are well developed and based on a strong centrally organized water management authority with an integrated mandate. A major Rivers Authority has been set up, with far-reaching mandate over the Ganges, the Brahmaputra-Jamuna and the Meghna Rivers. Water management is supported through flood and drought control centers established at sub-catchment level, with most if not all of the information required by users and managers available on-line. At both National and local level, these centers are connected to international water control centers, at global level and within the main river basins of the countries' large rivers. Emergency plans are in place to deal with flood disasters according to coordinated protocols and action plans, water and food shortages or any environmental or health disasters. The general public, through real-time apps available on individual smartphones, has access to (near) real-time information on flood hazards and emergency measures to be taken.

The public and private sector have a strong interest in supporting innovation, with government allocating budgets for research and application of new technologies. Knowledge and proven innovations from comparable deltas, urban and rural areas around the world is readily adopted and adapted to local circumstances. *The following projects in this respect included in BDP 2100 IP:*

1. Construction of a national flood-free infrastructure network, protecting the key economic zones and critical infrastructure and equipped with culverts and drainage provisions, to be able to withstand major floods;
2. Full stabilisation of Jamuna River with two channels, one for waterway transport and one to maintain ecological values, combined with large-scale land reclamation and with continuous embankments alongside both river banks;
3. Fully regulated polder systems and drainage networks in the large urban centers to maintain water levels and based on level of service principles and agreements.

Adaptation by Design: In 2100, the main rivers have been trained in a highly adaptive and innovative manner, where connectivity with the floodplain is a key feature, without impediments to the natural drainage patterns, thus minimizing the need for large infrastructure.

Valuable assets such as industrial or urban areas and infrastructure are well protected or located outside the river's reach. River bank protections in combination with local river training works stabilize the river where this is needed. Flood risk zones have been established that respect the need for large-scale water discharge and retention capacity during the monsoon period. The certainty on the local flood hazard in these zones allows people to make optimal decisions on permanent settlements and investments. The highest protection standards apply to critical infrastructure and assets of high economic value. People living in areas with higher flood hazards are encouraged and supported to take responsibility for their flood resilience. Using sediments from the river bed, new-built properties in high-risk areas are elevated to enhance flood resilience.

Flood control schemes that have been developed in the floodplain have been redesigned to allow for wetland and river restoration and promote connectivity between the local and main rivers and the flourishing wetlands. Ecology is preserved in flood-prone areas in combination with agriculture. Connections between major and medium rivers have been restored by means of local and tailored river training.

By avoiding large investments in large-scale interventions, funds have become available for a national re-settlement program that has brought great social relief. People that previously suffered from river bank erosion are given the possibility to re-settle and to develop other means of income. The national government has delegated many responsibilities to the local districts that have the best information on local economic developments and local maintenance efforts on embankments. Agreements with India on the management of the river catchment areas of the Ganges and the Brahmaputra have improved knowledge and control over floods during the monsoon period.

Large-scale interventions are only implemented when absolutely necessary, because they are generally costly (construction as well as operation and maintenance), they are irrevocable during a long period and they may have an adverse impact that needs to be compensated by another intervention (cascade effect). A knowledge base is developed first before embarking on large-scale interventions. The same counts for institutional capacity as well as economic development: the scale of the intervention is carefully balanced with the country's abilities to manage and to finance interventions as well as maintenance. Mitigating measures to enhance resilience are applied to buy time until conditions are favorable for an intervention.

In the coastal zone, a great diversity of polder systems has emerged, with regular sedimentation taking place in a controlled manner. Based on local prioirities and economic opportunities, mixed aqua-agriculture systems have developed, with a high degree of regional processing and adding value. Critical infrastructure such as roads, storage facilties and energy are well protected and facilitates local level adpatation to climate change and rapid repsonse to the occasional disaster are in place.

Institutions are highly developed, with tailor made local regulations- backed up by national framework laws -allowing for flexible solutions to match local conditions. A major Rivers Authority has been set up, with far-reaching mandate over the Ganges, the Brahmaputra-the Jamuna and the Meghna Rivers.

Water management is supported through flood and drought control centers established at sub-catchment level, with most if not all of the information required by users and managers available electronically. At both national and local level, these centers are connected to international water control centers, at global level and within the main river basins of the countries' large rivers. Emergency plans are in place to deal with flood disasters according to coordinated protocols and action plans. The general public, through real-time apps available on individual smartphones, has access to (near) real-time information on flood hazards and emergency measures to be taken.

The public and private sector have a strong interest in supporting innovation, with government allocating budgets for research and application of new technologies. Knowledge and proven innovations from comparable deltas, urban and rural areas around the world is readily adopted and adapted to local circumstances. *The following mesures are suggested in this respect:*

1. State of the art flood early warning, preparedness and action systems fed by global data and models as well as detailed local level information. These systems are complemented by emergency supplies at community level that support rapid economic recovery.
2. Large scale wetlands restoration and creation so as to restore natural water retention and drainage capacities, combined with strong regulation to avoid and to reverse river bank encroachment.
3. Implementation of the National inland islands project (Jamuna Pearls): development of separate flood-safe areas (string of dike rings) that include villages and key central facilities as well as industries at flood-free elevations, leaving sufficient public space inside the dike ring for water retention and leaving ample space outside the dike ring for regular floods, agriculture and ecology. The Pearls or flood-free polders will be located inside (former chars) or besides the rivers, connected with long bridges. The stability of the river banks that form the contours of the Pearls will be maintained through local river training works in combination with river bank protection. The development of the Pearls will transform the Jamuna River from a hazardous place to live into a popular area in which people will want to live and invest.
4. National Flood Resistant Infrastructure Project: Construction of a main flood-resistant infrastructure network for the major Economic Strongholds of the country, thus eliminating the largest part of economic set-back due to extreme floods.

Governance

The preferred strategy for capacity building and institutional strengthening includes:

- Incorporating flood concerns in all sectoral and spatial development policies, strategies and programs through appropriate revisions in consultation with relevant stakeholders;
- Enhancing the capacity of Government staff for policy, program and project formulation, and implementation;
- Strengthening institutional capacity for flood risk management by setting up of mechanisms for inter-ministerial and inter-institutional coordination at various levels of the Government, and for managing new adaptation and planned mitigation funds, as well as O&M funds;
- Enhancing O&M capacity following the principle of PWM and making use of PPP;
- Strengthening the knowledge base by aligning the activities of hydrological, meteorological and dissemination agencies for effective action.

Knowledge agenda

The preferred strategy for research and knowledge management includes:

- Climate change and flood risk modelling at national and regional levels, including small grids for forecasting and early warning and focused flood hazard maps;
- Preparatory studies for flood adaptation in priority economic zones and vulnerable communities;
- Monitoring of locations of major interventions before and during implementation, paying special attention to ecosystem and biodiversity changes and their impacts;
- Appropriate insurance methods for crop and asset losses.

6.3.6 Flood Risk Management Pathways

FRM Pathways for Priority Economic Areas: To protect economic zones and major urban areas, first actions will be to raise flood defenses to 1:100 levels in priority areas (embankments & seawalls). At the same time, critical infrastructure will be elevated or ground floor plinths raised to 1:100 levels. Both these protections can be further raised (e.g. to 1:250 or 1:1000 levels) in the future as socioeconomic conditions change and demands for greater protection emerge.

Drainage improvements (e.g. channel widening) are also undertaken in the short term, with pump drainage schemes implemented for economic zones in the future in response to changing socioeconomic demands.

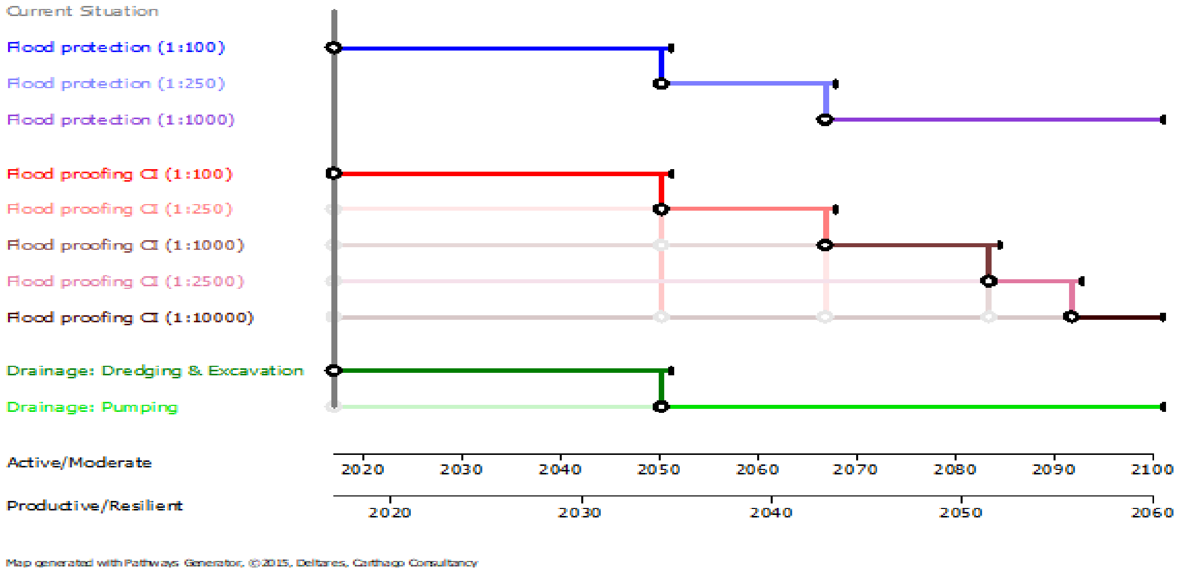
Note this national flood risk pathways map will need to be regionalized and refined for specific priority economic areas.

Key enabling actions will include the following:

- implement financial and legal instruments to establish clear spatial planning rules based on flood hazard zoning (protection levels for different areas)
- improve Flood Control Centre (FFWC) early warning services and set-up regional FFWC hubs
- improve O&M (rationalization): the ability to charge for these services will be socioeconomic scenario-dependent (e.g. public versus public-private versus fully privatized).

*Note use of economic change as the governing condition in this pathway map.

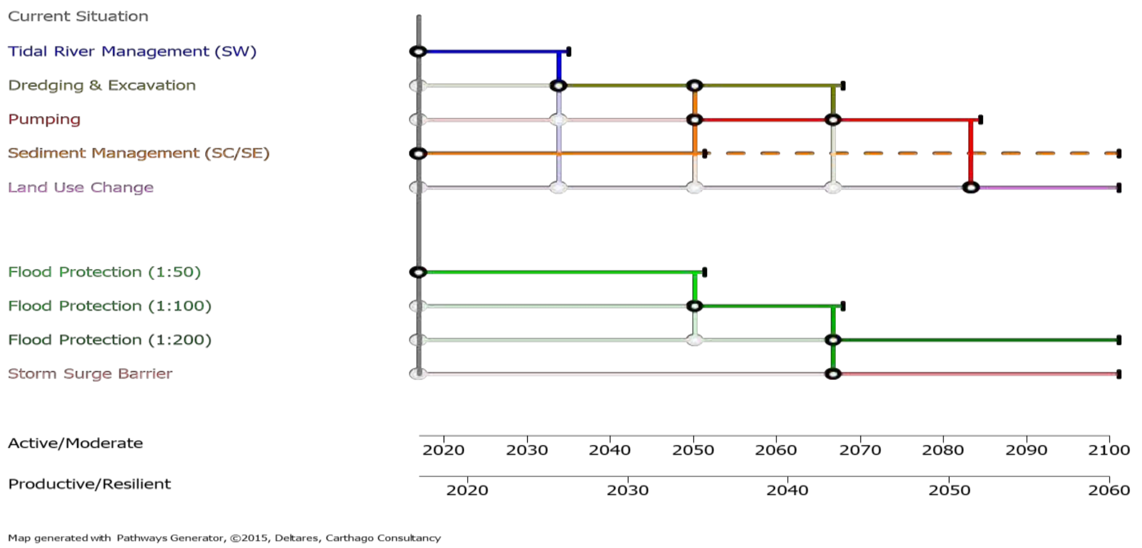
FRM Pathways for Priority Economic Areas



Flood Risk Management Pathways for the Coastal Areas: To protect coastal areas from floods, one first action is to raise existing flood defenses to 1:50 levels (embankments & seawalls). These protections can then be further raised in the future in response to changing socioeconomic demands (e.g. to 1:100 or 1:200 levels). Should societal demands for protection beyond 1:100 levels emerge, storm surge barriers may also be constructed at that time.

Tidal river management (TRM) and sediment management (SM) will also commence in the short-term, with the latter continuing as an enabling 'no-regret' measure over the entire planning horizon (i.e. beyond its tipping point). TRM will be implemented until it reaches its acceptable socioeconomic limits, at which point dredging will be demanded. Pumping is only introduced in the mid-term once the acceptable limits for dredging and SM are exceeded. As the economy continues to grow, land use changes will eventually be implemented in the long-term to modify land use in the vulnerable coastal areas.

Flood Risk Management Pathways for the Coastal Areas

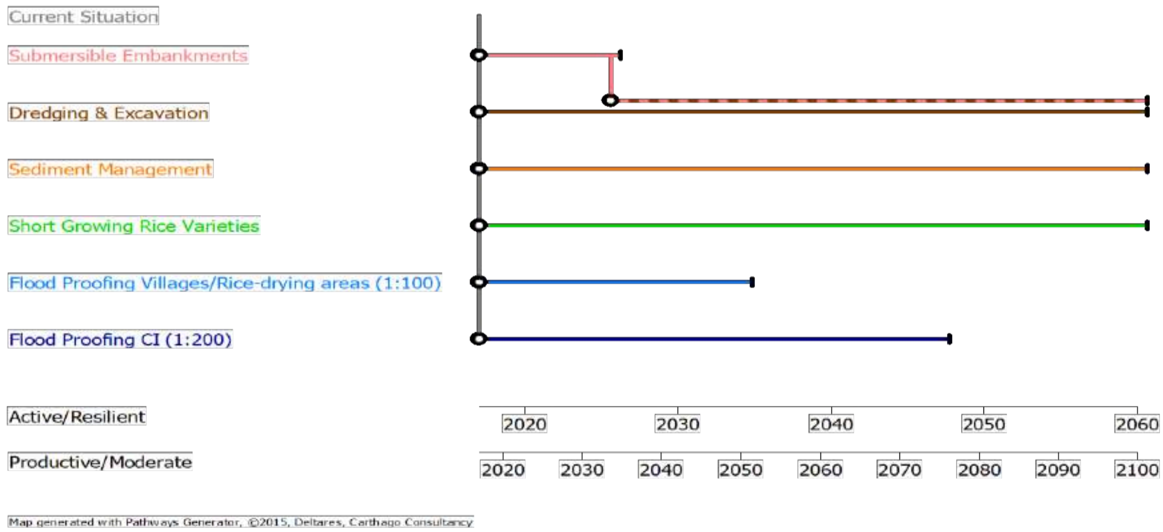


Flood Risk Management Pathways for Flash Floods in Haor Areas for SFCD: A number of simultaneous actions are required to protect Submersible FCDs in the Haor Areas against flash floods. Submersible embankments will be put in place, however these soon reach their natural limits and need to be combined with dredging activities within the coming 10-15 years. Sediment management is also required as a 'no regret' action and will continue throughout the planning horizon.

Also in the short-term, short-growing rice varieties will be introduced, with their cultivation similarly continuing throughout the planning horizon. Likewise, flood proofing of targeted areas is also implemented, however this is expected to reach its acceptable limits in the mid-term. Villages and rice drying areas will be elevated or ground floor plinths raised to 1:100 levels, whilst any critical infrastructure will be raised to 1:200 levels. The latter two protections are anticipated to reach their acceptable limits in terms of rising water levels in the mid- (1:100) to long-term (1:200), after which point other actions will be needed.

*Note use of the climate change as the governing condition in this pathway map. Note this national coastal flood risk pathways map will need to be regionalized and refined for specific coastal areas.

Flood Risk Management Pathways for Flash Floods in Haor Areas for SFCD



6.4 Fresh Water Strategy

The Freshwater Strategy predominantly is built on the hotspot strategies. Of particular importance are the River system and estuaries, Barind and drought prone areas, Coastal zone and Urban areas hotspot strategies where issues of drought, freshwater availability and water quality are a growing concern.

For the Barind and drought prone areas, freshwater shortage is mostly related to water needs for agriculture and water supply, i.e. hydrological and agricultural drought. In other areas, such as the Dhaka Metropolitan Area (DMA) and North Central Region, freshwater shortage is a growing issue for industry, environment and navigation. In the Coastal Zone, salinization of surface and groundwater, as well as aquifer contamination with arsenic are key challenges. Bio-chemical pollution, particularly in the large urban centers is another key area that is addressed in the National Freshwater Strategy.

Key policy principles that form the framework for the strategy include the NWPo (1999). the NWMP (2004), the 6th FYP and 7th FYP and the NWA (2013) and the overall economic and sustainable development vision of the Government of Bangladesh, as laid down in the NSDS (2013) and the Vision 2021.

Freshwater resources are particularly vital for the agriculture sector, which includes the crops, livestock, fisheries and forestry sub-sectors. At national level, agriculture provides employment to approximately 43% of the total labour forces and contributes some 15.33% to the National GDP (BDP 2100 Agriculture and Food Security Baseline Study). Water resources are also important for the Transport sector.

The demand of water resources in the industrial sector, is growing rapidly. Whereas water demand is still low compared to the agriculture sector, industrial use is expected to grow by 440% by 2050 (BDP 2100 Water Supply and Sanitation Baseline Study). Water resources are particularly important for the textile and leather industries, both in terms of consumptive needs and in view of the severe pollution inflicted.

Water quality is a growing concern for the country, with 32 rivers, located predominantly in the urban areas and divisional headquarters, and many of the wetlands at serious environmental risk due to pollution, encroachment, and disconnection between wetlands and the river system. The latter is particularly relevant for the North West and North Central hydrological region. Bio-chemical pollution is a particular issue in the two largest urban agglomerations Dhaka and Chattogram and to a lesser, but growing, extent in many of the district headquarters and industrial areas.

Total Renewable Water Resources (RWR) are 1,211 bcm/year, amounting to a per capita availability of 8.051 m^3 per year (BDP 2100 Water Resources Baseline Study). Of this, 1,189.5 bcm are surface water and 21.1 bcm are groundwater resources. Internal RWR is estimated at 105 bcm of which 84 bcm originate from surface- and 21 bcm from groundwater. External RWR is 1.106 bcm, of which 0.03 bcm is from groundwater (BDP 2100 Water Resources Baseline Study).

The freshwater strategy focuses on both water availability and water quality. The Barind and Drought Prone Areas Hotspot was selected as representative for the drought or freshwater availability issues. Whereas for the Barind and Drought prone areas and Coastal Zone Hotspots and to a certain extent the CHT, drought is mostly concered to agriculture water needs and for WASH. In other Hotspots, drought is a growing concern for industry, navigation and for environmental consideration. Water quality is a key issue in the Urban Areas and Coastal Zone Hotspots, with respect to both bio-chemical pollution, salinity and arsenic contamination.

6.4.1 Key Issues 2015

Key issues regarding freshwater were discussed in the baseline studies, and were elaborated in the respective hotspot strategies. These key issues are first discussed in the sections below before analyzing the potential impacts of scenario changes in 2030 and 2050. For water availability, key issues at present include: i) drought; ii) groundwater level decline; iii) floodplain connectivity and degradation of wetland ecosystems; and iv) water supply and sanitation.

Regarding water quality, key issues include: i) bio-chemical pollution of surface and groundwater; ii) arsenic contamination of groundwater; iii) ground and surface water salinization.

Drought: The Western part of the country, covering the North and South Western Hydrological regions and parts of the North Central and CHT regions, are considered the Barind and drought prone area of the country. Severe droughts are most common in the High Barind (Natore, Bogura and Thakurgoan districts). Perennial river flows are present in the major regional river systems, but many of the minor rivers lack sufficient environmental flows in the dry period.

Although drought occurs primarily in the winter Rabi season, pre-monsoon (pre-Kharif) and monsoon (Kharif) drought can also be severely damaging to the rice crop. Although the lack of rainfall is a key cause, the low moisture holding capacity of most of the soils is an additional factor in explaining the occurrence of drought. It is worth noting that drought and food security are not always directly linked. The areas in the country where food insecurity tend to occur, for example, Kurigram do not suffer from drought as in the Barind and Drought prone areas. The prevailing poverty, inequality and inadequate road communication in these areas equally affect food security. In case of Kurigram, river erosion is also a key hazard.

Hydrological drought, occurring at the end of the dry season (April - May) is a growing concern for industry. Although not well quantified, sufficient and good quality process water is a constraint for the growing textile and food processing industries in the DMA. The textile sector accounts for more than 80% of all export earnings, accounting for US$ 24 billion in 2015 out of a total export of US$ 34 billion . The textile sector provides employment to approximately 4.2 million people (IFC, 2015). The leather industry directly employs around 0.56 million people and provides some US$ 700 million in export earnings annually. According to the study carried out by the Water Resources Group (WRG) titled 'Consolidation and Analysis of Information on Water Resources Management in Bangladesh', 2015, the textile and leather industries predominantly use groundwater to meet their demand, mostly through unmetered self-supply. The same study predicts that, at anticipated textile growth rates, the demand from that sector will increase to 9.5 million m^3 per day, or the equivalent of the requirements of 15 to 20 million people.

The lack of dry season flows in many of the regional rivers in the North Central region, vital for the provision of freshwater flows for the DMA, is a key issue, with impacts on water quality, navigation and the environment.

Groundwater level decline: Groundwater is an important source of drinking and irrigation water in Bangladesh. Some 80 % of irrigation originates from groundwater, particularly for the cultivation of Boro rice. To protect the population from water-borne diseases, millions of (shallow) tube wells, were been developed in the country from 1980's onwards. Due to arsenic contamination, deeper exploration took place from the early 1990's onwards, resulting in the installation of DTWs with an average depth of 100- 250 m, particularly in the coastal zone. An even more massive development took place since the mid 1980's with the use of groundwater for HYV Boro cultivation in the Rabi (dry) season. This development spurred much of the country's' agricultural production leading to self-sufficiency in food.

The Bangladesh Integrated Water Resources Assessment Project, carried out a countrywide analysis of groundwater status in 2013-2014 (CSIRO, 2015). Two factors were assessed i) the number of wells below the 'critical depth' of 8m; and ii) recovery of groundwater tables during the monsoon season, an indicator of long term groundwater use sustainability. Both pre and post-monsoon levels for a large number of wells in the NW and NC (particularly Dhaka) show a declining trend. Two important factors contribute to this trend: a relatively low rate of recharge and a very high abstraction rate. Recharge in the Barind tract was traditionally low as compared to other areas of the country, along with the Madhupur tract in the Northcentral region. The extensive groundwater development mentioned before, has however led to an increase in the recharge rate.

For Dhaka and Gazipur, a strong declining trend is evident and the hydrograph shown from Dhaka district demonstrates the extreme drawdown. For wells in Dhaka and Gazipur districts, these trends are driven mostly by urbanization and drinking water abstraction.

Floodplain connectivity and degradation of wetland ecosystems: A network of beels, haors, baors, lakes, canals, and ponds exists in the country.Some of them remain under water for the whole year whilst others are submerged in the wet season only. The total area covered by open and closed water bodies is some 43,980 km^2. Of this total, more than 80% are considered 'open water bodies', in which connectivity between rivers, estuaries, wetlands and floodplains are essential for their ecological functioning.

The wetlands and water bodies provide a key source of livelihood for many rural poor in the country. Fish and fishery products are the country's third largest export commodity contributing 5.1% of its exchange earnings (FAO, 2011), 4.91% of GDP and provides 63% of the national animal protein consumption (DoF, 2003). Total fish production the country during the 2007-2008 was about 2,57 million metric tonnes of which 2,065 million metric tonnes were produced from freshwater including culture fisheries and 0.04 million metric tonnes from marine water including shrimp (DoF, 2009).

Decreased floodplain connectivity and related degradation of wetlands is mainly caused by past development of roads and infrastructure, the development of FCD projects and water abstraction for irrigation in the Rabi season. As an example, before FCD development, Chalan Beel, located in the southern part of the NW region, consisted of four large beels, and is now characterized by 97 disconnected and dry-falling ponds (Barind Delta Workshop, 2015). For the North West region, which has the highest number of beels in the country, a reduction in wetland area by 29% has taken place from 1989 to 2010. At national level, of Bangladesh's 260 freshwater fish species, 40% are threatened with extinction (IUCN, 2000), owing to decrease in wetlands

Water supply: Although domestic/municipal water demand only represents a small portion of total demand , freshwater availability is key to an effective, affordable water supply service to the population of Bangladesh. Relative to Freshwater Strategy the key issues for water supply include:

- Co-ordinated allocation of (scarce) water resources, where municipal demand takes priority over other sectors (as per GoB legislation);
- In relation to this: pricing principles on water abstraction, to ensure suitable incentives on water savings practice where required, and to accommodate for capital and O&M expenditure relative to water resources development;
- A shift is required from groundwater to surface water in major urban conglomerations where groundwater abstraction exceeds sustainable recharge. In this regard further understanding is to be gained on hydrogeology to better assess sustainable safe yields;
- A shift would be required from shallow (arsenic) aquifers, to deep (arsenic free) aquifers. In this regard, suitable allocation between sectors is of paramount importance. Moreover, better understanding is to be developed on potential migration of arsenic from shallow to deep aquifer. The ultimate alternatives are yet to be developed.

- For safe and cost effective water supply, the raw water quality is a key parameter. Measures to protect and improve the water quality of both groundwater and surface water are required.

Bio-chemical pollution of sediments, surface- and groundwater: Pollution of surface water is caused by three major sources of contamination: industry, agriculture and domestic-municipal. About 11% of the rivers in Bangladesh are polluted by industry wastes and 32 rivers are considered as having severe pollution from industry. Most of the industries are located on the banks of the rivers. Key polluting industries include textiles, tanneries, pulp and paper mills, distilleries, fertilizer and chemical industries (Conway et al., 2000).

Hazardous chemicals of both organic and inorganic compositions are discharged into the water bodies from all of these industries, often without adequate treatment. The highest number of industries in the country is located in and around big cities such as Dhaka, Chattogram and Khulna. Some 65% of all chemicals, plastics and petroleum industries, totaling some 7000 industries, are concentrated in and around the Dhaka Watershed, in the Dhaka, Narayanganj and Gazipur districts (Minnatullah, 2010, Environmental Consultation, World Bank, Bangladesh). According to a 2007 World Bank study (IWM, 2007), some 1.3 million m^3 of waste is discharged per day into the rivers of Dhaka watershed (Buriganga, Shitalakhya, Turag, Balu, Bangshi, Dhaleswari & Tongi Khal). Industrial discharge is 60% of the total load while domestic discharge is 40%. In addition, the sewerage system is overloaded and functions at only 30% of demand.

Arsenic contamination in groundwater: Coastal salinity and localized high dissolved iron in the alluvial aquifer was considered the major problem before the problem of arsenic in groundwater began appearing in the 1980's. Some three million tube wells, installed at shallow depths (10 to 50 m), discharge groundwater with arsenic concentrations above the Bangladesh drinking water standard of 50 µg/l. and about 28 to 35 million people have now been exposed to drinking water containing arsenic that exceeded the Bangladesh arsenic standard. Between 46 to 57 million people have been exposed to drinking water containing arsenic that exceeded World Health Organization (WHO, 2008) arsenic standard of 10 µg/L (DPHE-BGS 2001). A recent study (Flanagan et al., 2012) reports that over the next 20 years arsenic-related mortality in Bangladesh (1 of every 18 deaths) could lead to a loss of US$ 12.5 billion assuming a steady economic growth and an unchanged population exposure to arsenic contamination. Cost-effective means of arsenic removal are only slowly emerging, with a range of technologies having been tested and developed.

Salinity- surface and groundwater: Salinity in the coastal zone is a normal hazard, but in the South West it has been accentuated by the reduction in dry-season flows entering the Gorai distributary. A reduction in freshwater inflows from the Ganges River, siltation of the tributaries of the Ganges, and siltation of other rivers following the construction of the coastal polder system has resulted in a significant increase in river salinity during the dry season (World Bank, 2014). Salinity in the coastal zone increases steadily from December to February, reaching a maximum in late March and early April (CEGIS, 2001. Surface water salinity in coastal Bangladesh is also related to salinity of the Bay of Bengal and the circulation pattern of the coastal waters induced by the ocean currents and the tidal currents in the coastal waters. Salinity now reaches as far as Khulna (**Figure 6.6**), and affects the supply of both potable water and fresh water for industrial use, particularly for cooling water use. Salinity is also a problem for Chattogram during low flow conditions of the Karnaphuli River, as the saline front approaches the abstraction point for the city water supply (NWMP, 2004).

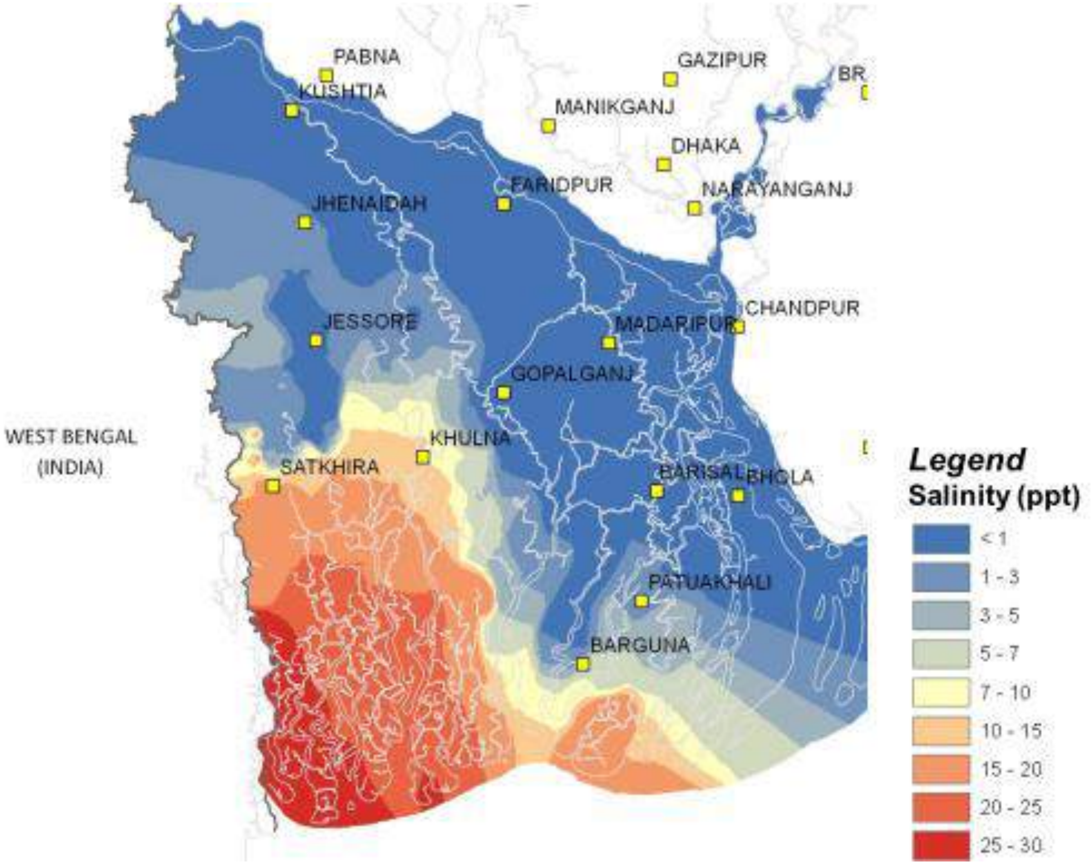


Figure 6.6: Average Maximum salinity - Surface Water During 2011-2012 in the Southwest Region.

Source: BDP 2100 Baseline Study Report: Water Resources, 2015

Saline groundwater in the coastal belt and in the islands of Bangladesh is found up to 100 km inland. A total of 14 districts are affected by salinity in the coastal belt, with an affected population of about 12 million people. The upcoming of saline water due to well over extraction in Bangladesh is still questioned, however several wells in the coastal but also inland areas have been abandoned due to salinization of the groundwater. There is no sharp boundary between fresh and saline groundwater zones, rather a patchy pattern of fresh and saline groundwater lenses distributed irregularly in areas close to the coast (Sanchez, 2015).

According to a World Bank study, (Implication of Climate Change for Fresh Groundwater Resources in Coastal Aquifers in Bangladesh, World Bank, 2010), three main paths of groundwater salinization in the coastal aquifer are: i) intrusion of saline water in the coastal groundwater rom the sea as source of saline water, a process that could be accelerated by sea level rise and a decreasing groundwater level; ii) downward movement of saline surface water to the aquifer. This saline surface water is brought to inland by storm surges or transgression of the coast; and (iii) migration of pre-existing pockets of saline water in the subsurface.

It is expected that groundwater will remain the pre-eminent source of drinking water in future and, given the quality constraints mentioned previously, the exploration of deeper aquifer may be inevitable in the coastal zone. Deep aquifers have already been explored for drinking water purpose in saline prone areas with deep tube wells in the eastern coastal zone which are currently providing fresh potable water. The hydrogeological properties and the characteristics of this aquifer are however not yet well known.

6.4.2 Key Issues 2050

In this section, for each of the key issues, first the main drivers and pressures are identified, in relation to the different scenario directions. Thereafter, based on the analysis carried out in the Baseline studies and Hotspot strategies, an assessment – using primarily expert judgement - is made of the direction and magnitude of the key issues in 2030 and 2050. The analysis below is based on the assumption of a BAU case. The development of a meta-model, foreseen in the second half of 2016, will support quantification of the impacts. The analysis referred to in this section is drawn from the Hotspot strategies and supporting sessions.

At the end of this section, the key issues are summarized in two tables for 2030 and 2050. The tipping pointswhich need further refinement and analysisare visualized on a summary map thereafter.

Drought: Key drivers regarding drought include climate change, agricultural technology development, population increase and industrialization. These drivers have a direct influence on water demand and availability.

The key water consumer in the country is the agriculture sector, accounting for 80% of the total water use (Upali et al, 2015). Based on food demand modelling, largely driven by population increase, IWM estimates the water demand for rice production to increase by 8% in 2020 and 13% in 2030, from the 2010 base. The increase in demand is almost exclusively generated for Boro rice cultivation, which would grow by 27% and 54% respectively (Upali et al, 2015).

The location of the demand will also change, due to the reduction of the agricultural land, of which estimates vary between 0.5% to 1 % per year at the national level (CSIRO, 2015). It is not surprising to note that the North Central region shows the highest level of decline.

Climate change has a much smaller impact on future demand than the increased food demand outlined above. Mainuddin et al. (2013), concluded that due to climate change only, irrigation water demand is projected to increase by less than 1% for the 2030 average condition to the maximum of 3% for the 2050 dry condition. The climate scenarios (2030 average and dry and 2050 average and dry) correspond to a large degree to the two climate scenarios used in the BDP scenarios. The additional irrigation water requirements at country level will be less than 1 bcm for the 2050 dry climate scenario (Mainuddin, 2013).

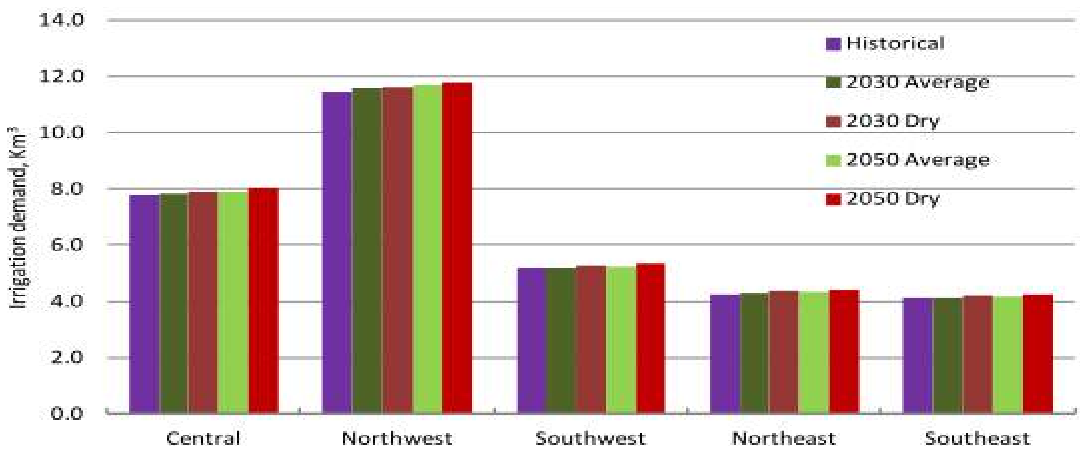


Figure 6.7: Irrigation Demand for Different CC Scenarios

Source: CSIRO, 2015

Domestic and industrial use is expected to grow by 100% and 440% respectively by 2050 (CSIRO, 2015), based on the assumption of industrial demand as fixed percentage (25%) of domestic use. The 2011 domestic water demand was estimated to be 2.7 bcm, which is expected to increase to 4.1 and 5.4 bcm respectively by 2030 and 2050 due to population increase and per capita consumption. The corresponding figures for industry are 0.08, 0.18 and 0.35 bcm. Much of the increased domestic demand will be generated in large cities (see **Table 6.4**).

Table 6.4: Water Demand Projections for Selected Large Cities in Bangladesh (m^3/day)

Name	2010	2015	2020	2025	2030
Dhaka	2,108,000	2,144,000	2,616,000	3,130,000	3,901,000
Khulna	129,564	146,890	169,472	194,676	228,133
Chattogram	712,800	-	1,243,200	-	1,896,000
Rajshahi	104,400	127,132	157,367	194,528	245,283
Rangpur	60,269	77,669	122,476	170,379	224,987

Sources: Dhaka WASA Water Supply Master Plan; Master Plan for Water Supply & Sewerage Improvement for Khulna, Rajshahi and Rangpur (KEITI); Available Water Assessment and Salinity Intrusion Analysis for Karnafuli, Sangu and Feni Rivers (IWM, 2008)

Groundwater level decline: Demands from agriculture, drinking water supply and industry drive the key issue of groundwater level decline. These are, in turn, driven by climate change, population growth and increased industrial demands. Most of these drivers will have a similar impact on groundwater level decline:

- Climate change will lead to increased demands from agriculture – assuming comparable cropping practices and patterns due to longer drier spells and increased temperatures. This, in turn, will drive the occurrence of increased drought (hydrological and agricultural) and demands for further groundwater abstraction;
- Population increase will lead to increased demand for safe water in urban and rural areas;
- Industrial growth, which relies heavily on independent groundwater supplies, will lead to increased abstraction.

Tipping points

Groundwater is a key source of safe water supply for many families and communities in the rural areas. When the static water level in the local well drops below the critical depth of 8m, most of the suction lift pumps can no longer operate. Especially poor communities and families will be affected, having little resources to develop wells equipped with force mode pump sets. Another tipping point relates to drilling depth, at which traditional machinery cannot drill a well and more sophisticated techniques are needed. This is generally considered to be 30 m (Sanchez, 2016).

Floodplain connectivity and degradation of wetland ecosystems: Increased water demand, pollution and on-going urbanization and population growth constitute pressures on the already sensitive wetland ecosystems and floodplain-river system. In the moderate and active scenarios, pressures will be driven mostly by population increase, urban sprawl and increased agricultural demand. As a result, many beels are at risk of further encroachment. Sources of contamination will be dominated by the domestic and agriculture sectors.

In the productive and resilient scenario, pressures will be mostly driven by urban and industrial development with similar impacts on wetlands encroachment. Pollution from industrial and urban sources will increase.

Tipping points are not straightforward to determine and would seem to have been passed already for many wetlands and river systems. Environmental flows of rivers and wetlands constitute minimum conditions as tipping point. Various methods to determine environmental flows exist, most of which are related to the hydrological regime and water quality required for the survival of key species.

Salinity- surface and groundwater: Drivers and pressures include sea level rise, reduced dry season rainfall, reduced upstream freshwater flow from the Ganges, Padma and Meghna distributaries and storm surges. These processes are compounded by subsidence. Groundwater salinization is further affected by increased pumping, to accommodate water supply and irrigation demands, resulting from population and land use changes, leading to a higher flux of saline intrusion. The fresh water lenses that occur in the coastal area, fed by fresh rainwater in the monsoon season, may be threatened by upward pressure from saline groundwater. Due to pumping from deep aquifers, saline contamination of freshwater aquifers is another risk.

Sectors that will be negatively affected include i) agriculture; caused by the decreasing productivity of rice growing in the Rabi but also Kharif season; ii) water supply in urban and rural areas; due to increased salinity of both surface and groundwater; iii) industry; due to increased corrosion; and iv) ecology; particularly on key tree species in the Sundarbans. A positive impact may be expected for shrimp, crab and fisheries production.

Model computations by IWM, comparing the present situation (2012) and 2050, and assuming 52 cm SLR (**Figure 6.8**), show the salinity front advancing particularly in the South Central part of the coast. These scenarios correspond to the high climate change Resilient and Active Delta scenarios. According to the model, the salinity front spreads across the districts of Barguna, Patuakhali, Bhola and Jhalokati and to a lesser extent Pirojpur and Barishal districts. As a result, 'traditional' rice cultivation will be endangered towards 2050 in the high Climate Change scenarios.

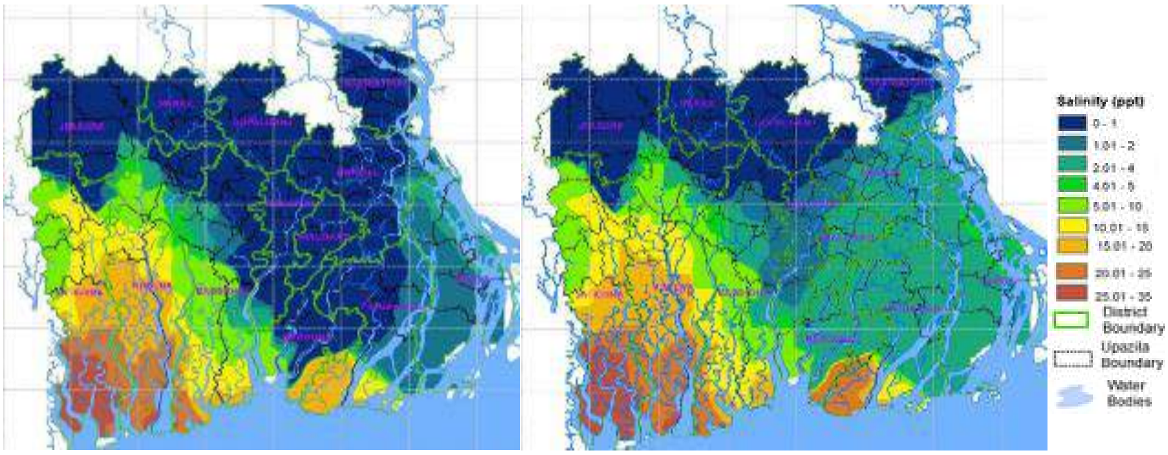


Figure 6.8: Model Computations Surface Water Salinity, 2012 (L) and 2050 assuming 52 cm SLR (R)

Source: BDP 2100 Baseline Study Report: Water Resources, 2015

Tipping points

A value of 3 dS/m (as measure of Electro-conductivity, or EC) is assumed by FAO as upper limit for rice cultivation. In Bangladesh, in many salinity studies, ppt is often used (or Parts Per Thousand (ppt) is often used as a measure of Total Dissolved Solids (TDS) with 2-3 ppt considered the upper limit for salt tolerant rice varieties. Above this level, (salt water) shrimp becomes the most viable alternative. In even more saline conditions, of 8 ppt and higher, shrimp culture becomes less viable, giving way to crab production (BDP 2100 Fisheries Baseline Study).

Regarding saline intrusion through surface water, the tipping points indicate the need for a change from one type of land/ water use or economic activity to another. This does however not only depend on one indicator. Soil salinity, crop variety type and tolerance, taste preferences and socio-economic factors such as land ownership and market conditions also play a role in switching from one type of cropping pattern to another or from agriculture to aquaculture. Regarding drinking water, the presence of an alternative freshwater source and the level of poverty play a key part in defining the tipping point in ‘real life’.

Regarding the use of groundwater for drinking purpose, local consumer tolerance to salinity is high, and generally considered to reach up 600 mg/l in Bangladesh (0.6 ppt), as compared to the WHO ‘standard’ (2008) of 200 mg/l (0.2 ppt), above which, depending on the overall consumption, risks to increase hypertension.

For groundwater, it is not simple to define a tipping point. When water of a high salinity level intrudes into a specific well, the process might be irreversible or take hundreds of years before the well can be used again. Extraction should therefore cease before such irreversible intrusion takes place. As a thumb rule, and depending on the local aquifer characteristics, a tipping point can be defined as the point in time when the distance between the well and the undesired concentration becomes 1/3 of the original distance between the two.

Bio-chemical pollution of sediments, surface- and groundwater: Industrial growth, urbanization and population increase are key drivers leading to increased bio-chemical pollution. Especially in the active and moderate scenarios, investment in treatment will need to be taken care of by the public sector, which, if past trends are continued, will most probably not keep up with the increased pollution loads.

Tipping points

Dissolved Oxygen (DO) is a key indicator for the environmental health of surface water bodies. Below a value of 4 mg/l, most fish life can no longer survive, leading to a breakdown of the aquatic ecosystem. Restoration of these rivers entails large investments, whilst the original biodiversity will not recover even after these investments have been carried out.

Regarding groundwater, threshold values have been determined for hazardous chemicals and nutrients. Once the aquifer is contaminated remediation is highly costly and typically requires a sustained intervention over a long period due to the slow groundwater movement processes. One tipping point cannot be determined for groundwater, rather a mix of indicators is needed.

A similar approach should be adopted for the pollution of sediments, the remediation of which is very costly. A tipping point would be the concentration level at which the sediments no longer absorb contaminants in the water bodies.

Arsenic contamination: The availability of arsenic free groundwater in the coastal zone is only indirectly influenced by climate change. Arsenic is typically found in iron sulphides and oxides, and when redox conditions change, i.e. as a result of increased pumping during the dry season and heavier rains (recharge) during the rainy season, arsenic can mobilize and contaminate groundwater. Climate change may influence the pumping regime due to higher evaporation rates and higher water demands, exacerbated by longer and more severe droughts. A potentially greater influence can be expected from population increase, leading to a greater demand on the scarce fresh, but arsenic contaminated, groundwater. A change in the regional groundwater flow patterns caused by changes in rainfall distribution in time and space may also increase the mobilization of arsenic.

Tipping points

Rather than calling this a tipping point, the standards applied by the MoHFW are applied to define whether a well is arsenic safe or not.

6.4.3 Detailed Strategy

The Freshwater Strategy not only focuses on solving the issues of today, projected into the future, but also with an end vision in mind and back casting towards the present. These are amalgamated into the preferred strategy. By focusing on both the short and the long term, the BDP 2100 aims to overcome the well known pitfall that 'the solutions of today become the problems of tomorrow'.

The key word is control. International experience indicates that the path to long term development for countries with complex and highly variable water and climate regimes, leads though controlling their water systems.

Control entails enhancing productive potential on the one hand and ensuring protection against destructive impacts on the other. Enhancing Productive Use entails developing water resources and investing in the water system in direct support of economic growth and social well-being. Growth enables investment in institutions, information systems, innovation and infrastructure.

Protection against Destructive Impacts entails focusing on protecting people and assets that are threatened as water-related risks (such as scarcity, floods, access, and resource degradation) grow due to population and economic growth. These two aspects: Enhancing Productive Use, and Protection against Destructive Impacts, form the core of Water Security, as defined by the Global Water Partnership.

The freshwater strategies consist of two distinct but related strategies: for Water Availability and for Water Quality. Thereafter, a dedicated strategy is presented on water supply and sanitation. For each strategy, attention is paid to three aspects: Infrastructure, Institutions and Innovation.

There are two objective of this Fresh Water Strategy named a) Water availability and b) Water quality. These two objectives are detailed into sub-strategies and measures. In line with the principles of IWRM, water availability and water quality are closely linked. Most of the sub-strategies therefore contribute to both objectives. For the purpose of this strategy, the terms measure and project are used interchangeably, to indicate an intervention as part of a sub-strategy.

Strategy FW 1: Ensure Water Availability by Balancing Supply and Demand for Sustainable and Inclusive Growth

The freshwater strategy is aimed to ensure water availability by balancing supply and demand for sustainable and inclusive growth. As described above, increased droughts and water shortages for different socio-economic sectors are expected in the future and, if one continues with the 'business as usual' strategy, these constraints will hamper the sustainable growth as envisaged by GoB in NSDS, (2013). The cross-boundary issues are important here. In the sections below, first a short description is provided of the sub-strategy. Thereafter, the main measures or interventions are presented.

Sub-strategy FW 1.1: Supply management and additional irrigation including strong dialogue and prospects for river basin development for cross-bounday rivers: Where adequate water resources exist or can be developed, this sub-strategy is geared towards providing additional irrigation water for sustainable growth. The key beneficiary of this sub-strategy is the agriculture sector and, where valuable groundwater supplies can be substituted by surface water resources in the other sectors. Sustainable O&M of irrigation systems is particularly an essential feature of this strategy. Capturing of monsoon and post-monsoon season resources in water retention bodies and rubber dams (where feasible) should be pursued. The main elements of this sub-strategy are depicted in Figure 6.9.

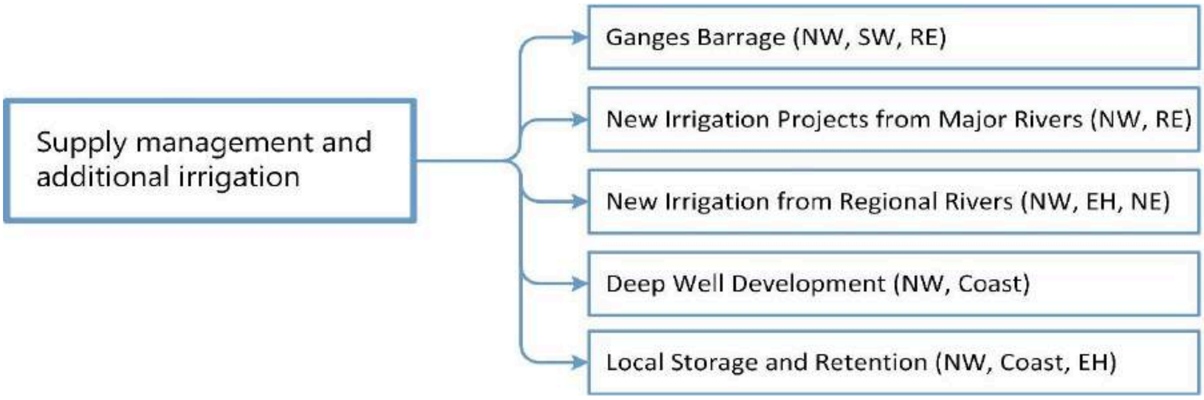


Figure 6.9: Sub-strategy FW 1.1 (Supply Management and Additional Irrigation)

Sub-strategy FW 1.2: Demand management and efficient water use: This sub-strategy is aimed at reducing the demand for freshwater, for those areas where additional water resources cannot be (economically) developed or where more urgent socio-economic priorities such as safe water supply, industry, ecology or navigation receive a higher priority. Again, a mix of interventions is included, consisting of less water consuming crops to more efficient irrigation and more effective management and pricing (Figure 6.10).

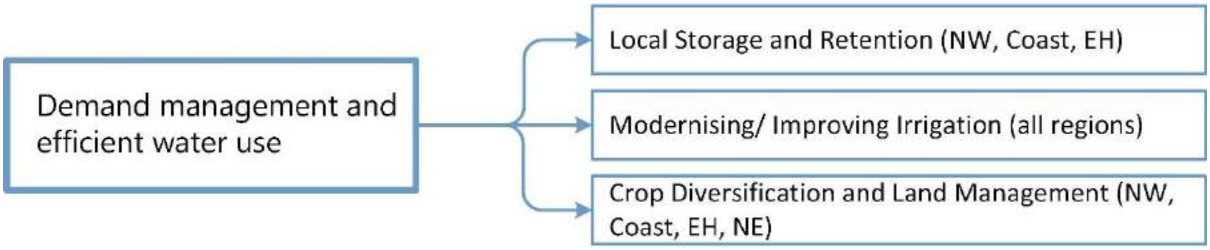


Figure 6.10: Sub-strategy FW 1.2 (Demand Management and Efficient Water Use)

Sub-strategy FW 1.3: Enhancement of freshwater flows in urban and rural rivers: The sub-strategy to enhance freshwater flows in the regional river system is closely related to the River Systems and Estuaries Strategy (Figure 6.11). Key issues that the sub-strategy addresses include water quality in the (peri-) urban areas and saline intrusion in the coastal zone. Climate change, through SLR and increasing dry spells potentially has a strong negative impact on these issues. The sub-strategy involves both water quantity and water quality aspects.

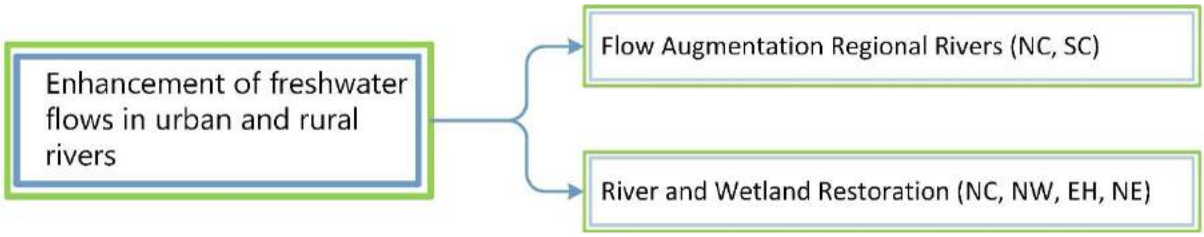


Figure 6.11: Sub-strategy FW 1.3 (Enhancement of Freshwater Flows in Rivers)

Sub-strategy FW 1.4: Resource planning and environment: restoring water and ecosystem: Resource planning to restore and protect water and ecosystems lies at the basis of all sub-strategies (Figure 6.12). This sub-strategy does not include major infrastructural works and is focussed primarily on Institutional development (capacity building, appropriate protection and management arrangements) and knowledge/innovation in support of long term sustainable water resource planning.

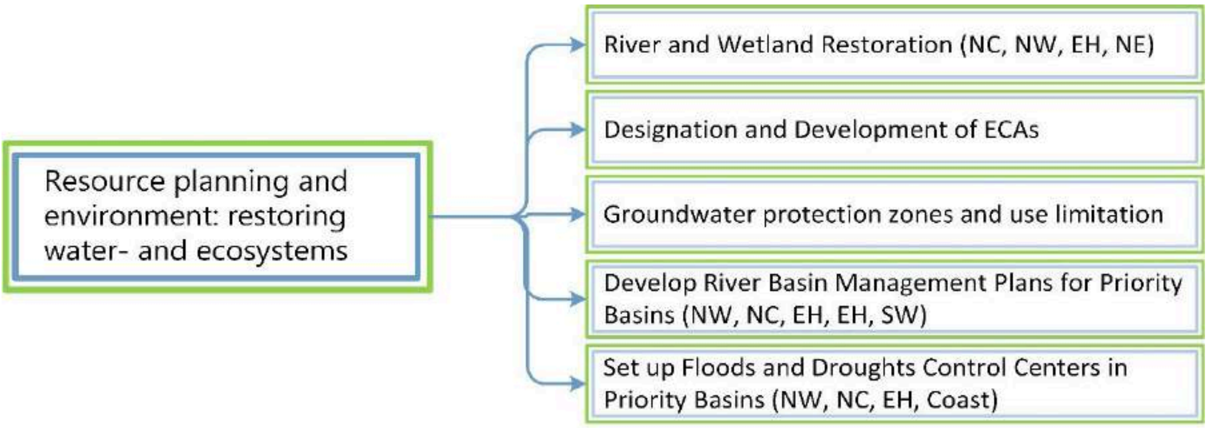


Figure 6.12: Sub-strategy FW 1.4 (Resource Planning and Environment)

Sub-strategy FW 1.5: Ensuring safe water to sustainable drinking water and sanitation: Sustainable use and availability of safe water for drinking and sanitation purpose should be ensured. Encourage rainwater harvesting where feasible. Also, increasing storage in existing water retention bodies should be promoted.

Strategy FW 2: Maintaining Water Quality for Health, Livelihoods and Ecosystems

This strategy is based on the second objective "water quality" of the freshwater strategy. Water quality is a growing concern for the country, with many rivers and wetlands at serious environmental risk. To ensure healthy lives, livelihood and ecosystem of Bangladesh, the quality of water needs to maintain according to rules and regulation.

Sub-strategy FW 2.1: Pollution control and treatment: This sub-strategy involves both protection of environmentally valuable and sensitive areas and the prevention of pollution by enhanced treatment (Figure 6.13). The DoE authorities as well as the urban drinking water and sanitation authorities are key actors in implementing these interventions, many of which have already been elaborated in master plans and investment projects. The main aim of the BDP 2100 is to ensure synergy between these highly necessary investments and other interventions. Developing a sound knowledge base is a key component of this sub-strategy.

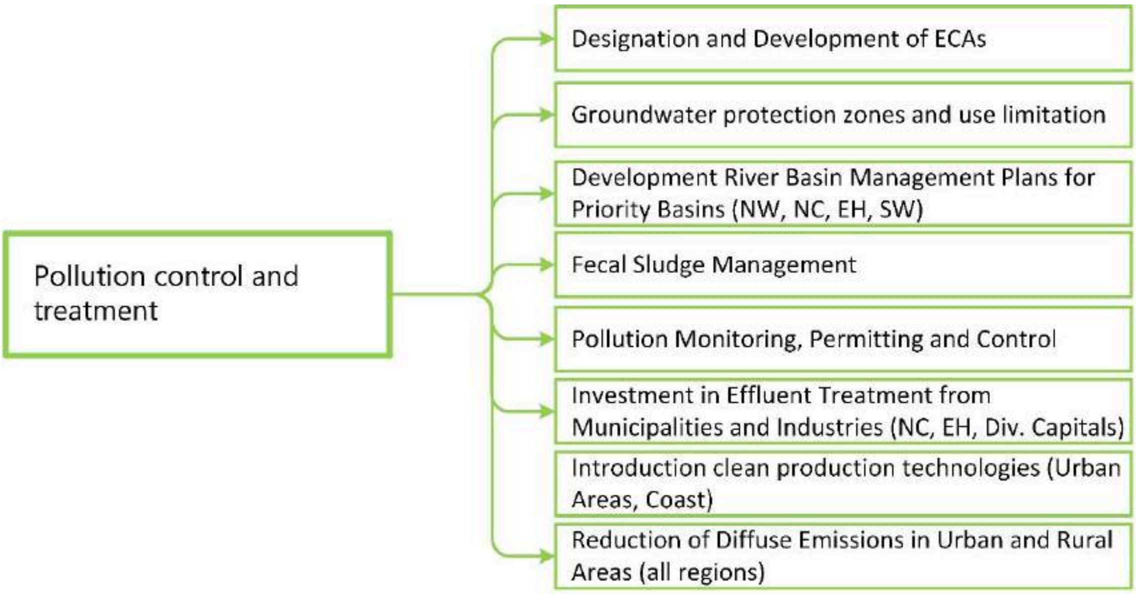


Figure 6.13: Sub-strategy FW 2.1 (Pollution Control and Treatment)

6.4.4 Long term measures and perspectives - 2050 and beyond

The long term perspective is shaped by elaborating on two potential strategies or development philosophies: Optimized Water Control and Adaptation by Design. Both visions and associated strategies will never be implemented in their entirety. Each region will have a different mix and over time, when the water system has been developed to a sufficient extent, the vision will change, along with societal values and economic development. The two philosophies should therefore be seen as cornerstones.

Both end visions have the variable hydrology and climate in mind, and are based on an understanding of the multiple uses and functions of the water system. To gain control, the country needs to ensure the right amount of water at the right time, and of the right quality.

Optimized Water Control

In 2100, Bangladesh has a highly regulated water system and has fully developed its water resources. By building on the principles of IWRM and thoroughly understanding its water system, the water managers have managed to develop the required infrastructure to allocate and distribute scarce water in a rational manner, and built up the scientific and adaptive capacity required for such complex management.

Key infrastructure includes a network of large barrages on the main rivers of the Padma and the Brahmaputra, with the aim to utilize its flows year round. These large interventions were however postponed until sufficient knowledge of their impacts was available, until the investment could be justified and underpinned by sufficient economic growth, and until institutional capacity in the public and private sector was developed to manage construction, operation and maintenance properly. Regional irrigation schemes have been developed to alleviate the increasing drought in the northwestern part of the country. The Padma barrage was constructed to augment water supplies to the Gorai and other Rivers in the South West to mitigate the impacts of SLR and salinization. In addition, as a result, surface water irrigation schemes could be developed by direct pumping from the Ganges.

Off takes and regulators have been developed on the two main rivers, which are generally fully trained and embanked. These allowed for a degree of connectivity between the river system and its floodplain, as well as minimizing impediments to drainage, thus fulfilling a long term aim of the national water policy and early integrated water resource management plans. Offtake stabilization in the Jamuna River, has enabled flow regulation into the regional rivers of the North Central region, allowing for year-round freshwater flows to the DMA area and sufficient water depths for a highly developed inland water transport system.

The polders in the coastal zone and inland areas are continuously improved and adapted to changing hydrological and economic conditions, driven by agro-economic diversification. Polder water level regulation and control are the norm, through automated gates and pumping systems, where feasible making use of renewable energy sources. Freshwater needs inside the polders are met through coordinated inlets of freshwater and releases of freshwater from upstream. High value agriculture, aquaculture and agri-businesses generate sufficient returns to pay the well-established system of water taxes and fees and it is government policy to retain a large portion of the collected water taxes at local level for direct investment in local water management. A cycle of improvement and adaptation has thus been put in place.

Together with much needed investment in faecal sludge management, urban wastewater treatment and reuse, combined with environmental control of industries, water quality has improved to international standards and health risks have been eliminated. All-important surface and groundwater sources are monitored and regulations are strictly enforced. Transition mechanisms for polluting industries have been successful in stimulating the adoption of clean environment technologies. The wastewater can be reused for irrigation. 100% of the urban population has access to safe and reliable water, through a piped and metered water system. Urban areas, including the smaller urban centers all avail of faecal sludge management systems and the larger cities have wastewater treatment, with a range of technologies in place, from constructed wetlands to advanced biological treatment, to meet local needs. Modular systems are in place to be able to expand to growing populations. Recycling of water and nutrients, at the most economic level, takes place in all divisional capitals. As a number of towns have developed surface water based drinking water supply systems, hand tube wells can be used again and in many cases industries have followed the shift to surface water. The network developed at a later stage includes the Brahmaputra Barrage, feeding both the Northwest with irrigation supplies and supporting the revitalization of the Old Brahmaputra channel and dependent areas in the North-Central Hydrological Region.

Institutions are well developed and based on a strong centrally organized water management authority with an integrated mandate. All abstractions are licensed, with preferential allocation to drinking water, and based on detailed water budgets, monitored and regulated through automated and state of the art ICT, globally available data and models. At city level, water corporations have developed their mandate and financial position to operate as public-private companies, with approaching full cost recovery and investment capabilities to provide water to all sectors of society.

Water management is supported through flood and drought control centers established at catchment level, with most if not all of the information required by users and managers available on-line. At both national and local levels, these centers are connected to international water control and information centers, with intensive data and information sharing within the main river basins of the countries' large rivers. Water resources are allocated according to accepted and science-based allocation priorities, as laid down in national policy documents and the Water Act. These include off- and instream demands, and environmental flows defined according to accepted methods. Emergency plans are in place to deal with water and food shortages. Both the public and private sectors have a strong interest in supporting innovation, with government allocating budgets for research and application of new technologies. Knowledge and proven innovations from comparable deltas, urban and rural areas around the world are readily adopted and adapted to local circumstances. Highly efficient fertigation is the norm in water scarce areas. Water productivity[23] has doubled is comparable to the most water efficient economies of the world.

Large investments take place based on well considered studies andwhere applicable pilot experiences. After testing and refinement of the legal framework, PPP are now in place and capable of managing irrigation schemes in a cost-effective manner. PPPs are put in place based on clear requirements and conditions, and reviewed on a regular basis. Cost-benefit analysis lies at the heart of all investments, with an aim to ensure both economic and financial viability. Cost recovery of all O&M costs is the norm.

Iconic projects in this vision includes:

(1) A network of large barrages on the two main rivers of the country, including a well-developed distribution system, managed as independent hydro-economic units;
(2) Highly water-efficient industries, based on closed water cycles and a minimised environmental footprint;
(3) Public-private partnership for highly efficient irrigation as well as (waste)water treatment and re-use schemes;
(4) Fully regulated polder systems, using renewable energy to maintain water levels and quality according to the needs of the inhabitants and economic sectors.

Adaptation by Design

In 2100, Bangladesh has developed a comprehensive and far reaching water sharing agreement with India on the main and minor rivers. This includes the regional transboundary rivers of the Northwest and to some extent, the North Central, North East regions and as well as the River Systems and Estuaries. River basin plans, in which the water system is taken as the basis, have been developed. Intensive monitoring, modelling and capacity development at decentralized and

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[23] Water productivity is generally defined as crop yield per cubic meter (m^3) of water consumption, including 'green' water (effective rainfall) for rain-fed areas and both 'green' water and 'blue' water (diverted water from water systems) for irrigated areas (www.iwmi.cgiar.org)

central level has led to an in-depth understanding of the surface- and groundwater system, allowing for tailor-made solutions.

Where possible, demand and supply are matched at local level, with an emphasis on developing local water resources such as wetlands, ponds, rainwater harvesting and managed aquifer storage and recharge. Wetlands and river systems are restored in terms of their ecological functioning and retain their function as natural water reservoir, feeding the aquifer. Flood management schemes that have been developed in the floodplain have been redesigned to allow for wetland and river restoration and promote connectivity between the local and main rivers and the flourishing wetlands. Rules and regulations regarding conservation of natural wetlands in the country have to be put to practice.

The main rivers have been trained in a highly adaptive and innovative manner, where connectivity with the floodplain is a key feature, without impediments to the natural drainage patterns, thus minimizing the need for large infrastructure. A string of smaller reservoirs and sub-surface weirs has been developed in the Northwestern part of the country, operating independently but planned and developed with an in-depth understanding of the available water resources and potential uses and only after securing the water supply with upstream users and laid down in firm agreements.

In the coastal zone, a great diversity of polder systems has emerged, with regular sedimentation taking place in a controlled manner. Based on local prioirities and economic opportunities, mixed aqua-agriculture systems have developed, with a high degree of regional processing and adding value. Critical infrastructure such as roads, storage facilties and energy is well protected and failitates locally dirven adpatation to climate change and rapid repsonse to the occasional disaster.

Water demand management is the leading principle. Water pricing, and monitoring and crop insurance and locally developed land and water zoning plans guide the allocation of scarce water between functions and users. The government has strongly stimulated local level innovation in water saving technologies, including a combination of remote sensing applications, real-time water control at farm and local level and the development of highly water-efficient cropping patterns and soil moisture retention. Greenhouses and substrate culture are commonplace, with farmers able to switch quickly between crops to match market demand and available water resources. New water efficient crops and varieties are continuously being developed through a vibrant cooperation between local growers, research institutions and private companies. As a result, water productivity is among the highest in the world. The country has developed niche crops for both the national and international market and has developed the capacity to import its staple food where required.

Together with much needed investment in faecal sludge management, emerging urban wastewater treatment and reuse, combined with environmental control of industries, water quality has improved to international standards and health risks have been eliminated reduced. All-important surface and groundwater sources are monitored, with the emphasis lying on self-regulation and control by the sectors. Transition mechanisms for polluting industries have been successful in stimulating the adoption of clean environment technologies, with much of the required capital being provided through the private sector. The wastewater can be reused for irrigation. 100% of the urban population has access to safe and reliable water, through a piped and metered water system. Urban areas, including the smaller urban centers all avail of faecal sludge management systems and the larger cities have wastewater treatment, with a range of technologies in place, from constructed wetlands to advanced biological treatment, to meet local needs. Wherever possible, natural treatment solutions are preferred, in support of improving ecosystems services provided by the water system. Recycling of water and nutrients, at the most economic level, takes place in all divisional capitals. As a number of towns have developed surface water based drinking water supply systems, hand tube wells can be used again and in many cases industries have followed the shift to surface water.

Water management takes place in a decentralized and participatory manner, with local governments, public-private partnerships and stakeholders taking part in integrated water resources management. Water resources are allocated according to accepted and science-based allocation priorities, as laid down in national policy documents and the Water Act. These include off- and instream demands, and environmental flows defined according to accepted methods. Emergency plans are in place to deal with water and food shortages.

Institutions are highly developed, with tailor made local regulations – backed up by national framework laws – allowing for flexible solutions to match local conditions. Abstractions are licensed and based on detailed water budgets, monitored and regulated through automated and state of the art ICT. A River Basin Authority has been put in place, with extensive powers to plan, allocate and regulate scarce freshwater resources. These authorities, who have close communication with both National and local levels of government, promote environmentally sound water management. At city level, water corporations have developed their mandate and financial position to operate as public-private companies, with full cost recovery and investment capabilities to provide water to all sectors of society. Bangladesh has selected a strategy with continued on-site sanitation solutions with optimized faecal sludge management implementation, and full nutrient and energy recovery. Industries have fiscal incentives towards water use reduction, wastewater treatment and re-use practice.

Water management is supported through flood and drought control centers established at sub-catchment level, with most if not all of the information required by users and managers available on-line. At both National and Local level, these centers are connected to international water control centers, at global level and within the main river basins of the countries' large rivers. Fresh water resources are allocated according to accepted and science-based allocation priorities, with due priority given to human consumption and environmental demands. Water budgets and allocation plans are developed for each (sub-) catchment and Upazilla, and emergency plans are in place to deal with water and food shortages or any environmental disasters. The general public, through real-time apps available on individual smartphones, has access to (near) real-time information on water availability and quality and actively participates in monitoring and inspection. The rural areas experinced successful development of self-sustained water and sanitation local concepts' incorporating improved pond systems, small scale aquifer recharge systems, and eco-based sanitation systems promoting hygiene and enabling nutrient recovery.

The public and private sector have a strong interest in supporting innovation, with government allocating budgets for research and application of new technologies. Knowledge and proven innovations from comparable deltas, urban and rural areas around the world is readily adopted and adapted to local circumstances. Water productivity has increased three to four folds and is comparable to the most water efficient economies of the world.

The following measures are suggested for adapataion by design pathways:

(1) Conjunctive use of surface and groundwater, based on multi-annual groundwater reservoir management, a series of small- and medium sized storage and diversion schemes, productive aquifer storage and recovery techniques and efficient irrigation technology;

(2) A string of small and medium sized reservoirs in barind and drought prone areas of the Western and South Eastern part of the country, managed locally and where needed, making use of renewable energy
(3) A network of highly diversified coastal polder systems, making optimal use of the ample availability of sediment and locally adapted to changing salt levels and agro-economic opportunities;
(4) A string of connected and productive beels providing multiple ecosystem services, with eco-friendly agriculture, fisheries and ecological conservation occurring side by side with productive agriculture and flood management. The multiple users and interests in the area are represented in a multi-level public-private management organisation and mechanisms are in place to weigh the interests and manage conflicts.

6.4.5 Long Term Perspectives

In the medium and long term (2030- 2050) and the very long term (2050 - 2100), uncertainties determine to a large extent which strategy will emerge. The long term strategy therefore does not consist of a list of preferred measures but rather different adaptation opportunities and pathways which are open to development depending on the unfolding of the scenarios.

Measures that are affected strongly in terms of their effectiveness by external conditions (climate, economic development, and technologyinnovation) may require further studies or can be delayed until actual conditions become apparent. No-regret measures, such as improved provision of safe drinking water and wastewater treatment for large urban centers, and increasing water use efficiency, are considered basic measures, which can and should be taken independent of each scenario, and initiated in the short term. Climate change is but one of the uncertainties, with socio-economic and upstream developments playing a significant role as well. The two overall pathways for water availability and water quality are presented in **Figure 6.14** and **Figure 6.15**.

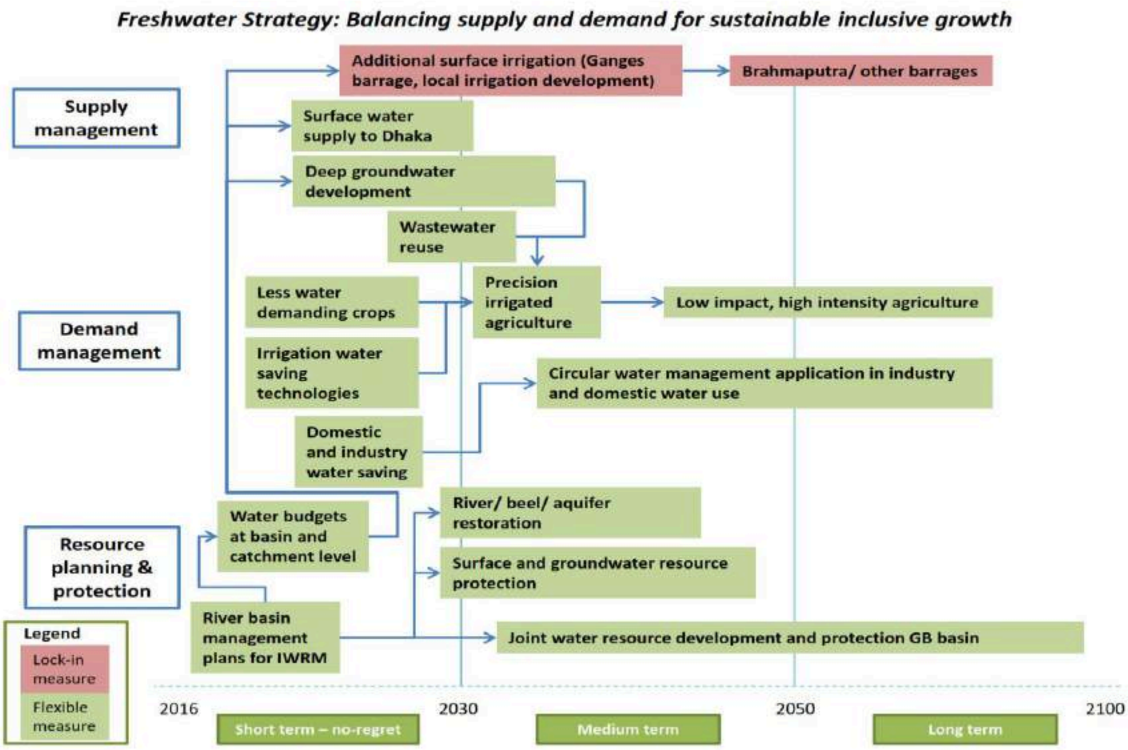


Figure 6.14: Freshwater Strategy FW 1 (Balancing Supply and Demand for Sustainable Inclusive Growth)

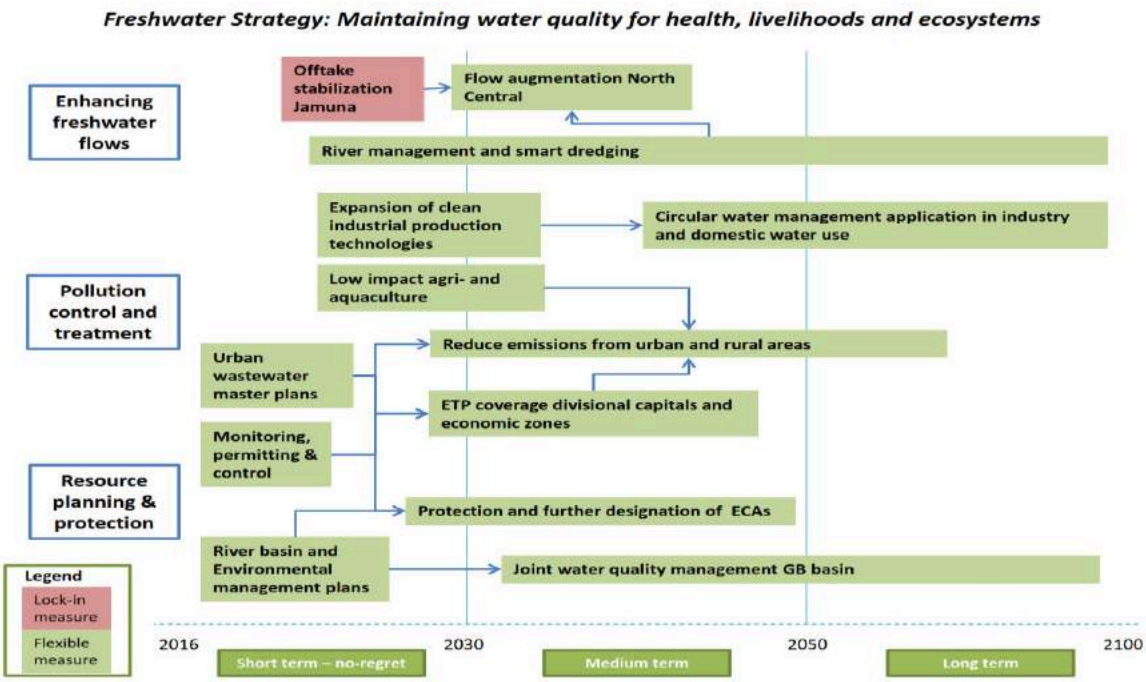


Figure 6.15: Freshwater Strategy FW 2 (Maintaining Water Quality for Health, Livelihoods and Ecosystems)

6.4.6 Adaptation Pathways

The main driver of adaptation pathways for Fresh Water strategies is the percentage decrease in average dry season flows, which varies over the future time horizons for the four different Delta Scenarios (see bottom of **Figure 6.16**). The Tipping Points and Transfer Stations associated for each of the strategies discussed above are also shown in the figure.

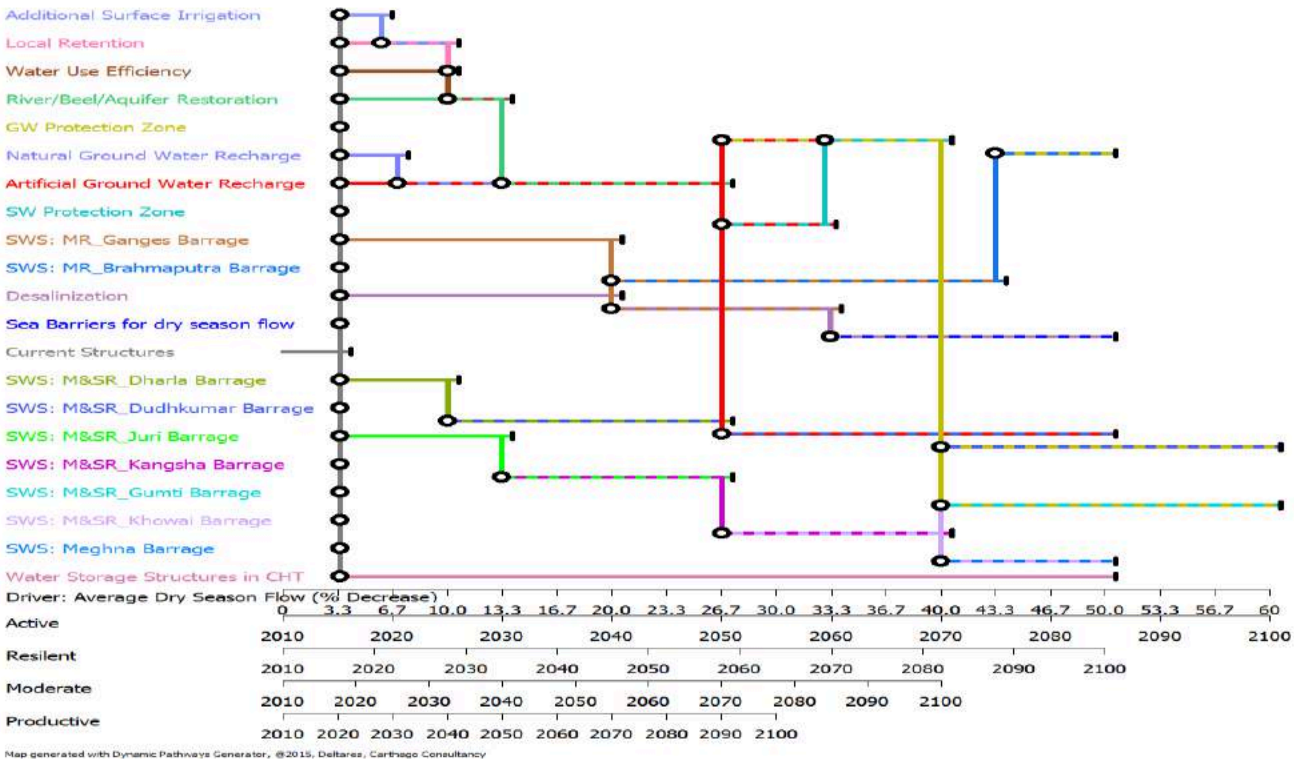


Figure 6.16: Adaptation Pathways for Fresh Water Strategies

6.5 Barind and Drought Prone Areas Strategy

In the Barind, freshwater resources are particularly vital for agriculture sector, which includes the crop sector, livestock, fisheries and forestry sub-sectors. At a national level, agriculture provides employment to approximately 43% of the total labour force and contributes some 15.33% to the National GDP. Fish and fishery products are the country's third largest export commodity contributing 5.1% of its exchange earnings (FAO), 4.1 % of GDP and provide over 60% of the national animal protein consumption (DoF). Water availability and habitat quality, especially in the dry season, and water quality, notably salinity, are key issues for the Agriculture sector.

Water quality is a growing concern for the country, with 32 rivers and many of the wetlands at serious environmental risk due to pollution, encroachment, and disconnection between wetlands and the river system. The latter is particularly relevant for the Barind and Drought prone areas. Bio-chemical pollution is not yet an issue in the Barind, as it is in the urban areas of Dhaka and Chattogram, but may be expected in the medium and longer term, as urbanization and industrialization expand in the region.

Groundwater is an important source of fresh water in the country, both for agriculture (irrigation), water supply and industrial use. Some 80% of irrigation originates from groundwater, particularly for the cultivation of Boro rice. The cultivation of Boro rice during the flood-free Rabi season has been an important driver for attaining food self-sufficiency in the last two decades. The downside of this development has however been the gradual decline of the groundwater table. In these areas, evidence indicates that recharge does not keep up with abstraction.

6.5.1 Key Issues 2015

The Barind and Drought prone areas Hotspot was selected as representative for the drought – or freshwater availability - issue in the country. Water quality is a key issue in the Urban Areas and Coastal Zone Hotspots, with respect to both bio-chemical pollution, salinity and arsenic contamination. Water quality is not a key issue in the Barind and Drought prone areas Hotspot and will not be discussed in detail other than anticipating on potential issues in the near future.

Key issues for the Barind and Drought Prone Areas Hotspot were identified in the Baseline Studies. These key issues are first discussed in the sections below and include: i) Drought; ii) Groundwater decline; iii) Floodplain connectivity and degradation of wetland ecosystems; iv) Floods and drainage congestion; and v) Water supply and sanitation. Thereafter, each key issue is further analyzed in relation to the four Delta scenarios.

Drought

The Barind and Drought prone areas is a drought prone area, with severe drought occurring in the High Barind (Natore, Bogura, Thakurgoan Districts). Perennial river flows are present in the major regional river systems, but many of the minor rivers lack sufficient environmental flows in the dry period. Although drought occurs particularly in the winter Rabi season, pre-monsoon (pre-Kharif) and monsoon (Kharif) drought can be severly damaging to crops. Although the lack of rainfall is a key cause, the low moisture holding capacity of most of the soils is an additional factor in explaining the occurrence of drought in the Barind. It is worth noting that drought and food security are not always directly linked. The areas in the country where famines tend to occur first are Kurigam and the Khulna-Gopalganj beel areas, which do not suffer from drought as in the

Barind. The prevailing poverty and inequality and poor communication (road access) in these areas have impacts on vulnerability to food insecurity. In case of Kurigram, river erosion is a key hazard.

Groundwater decline

Groundwater is an important source of drinking and irrigation water in the Barind and Drought prone areas. Irrigation development, from groundwater, took off in the late 1980's, initially through DTWs, followed by introduction of STW, driven by surface mounted centrifugal pumps. Much of this growth was driven by private, local initiatives, and the publicly managed groundwater based Barind Irrigation Project (BIP). The BIP covers parts of seven northwestern districts namely Bogura, Dinajpur, Joypurhat, Naogaon, Pabna, Rajshahi, and Rangpur. The project was carried out by the Barind Multipurpose Development Authority (BMDA). The significant growth in groundwater irrigated area is shown in **Figure 6.17**. Further details on groundwater declining issue is provided in Annex C.

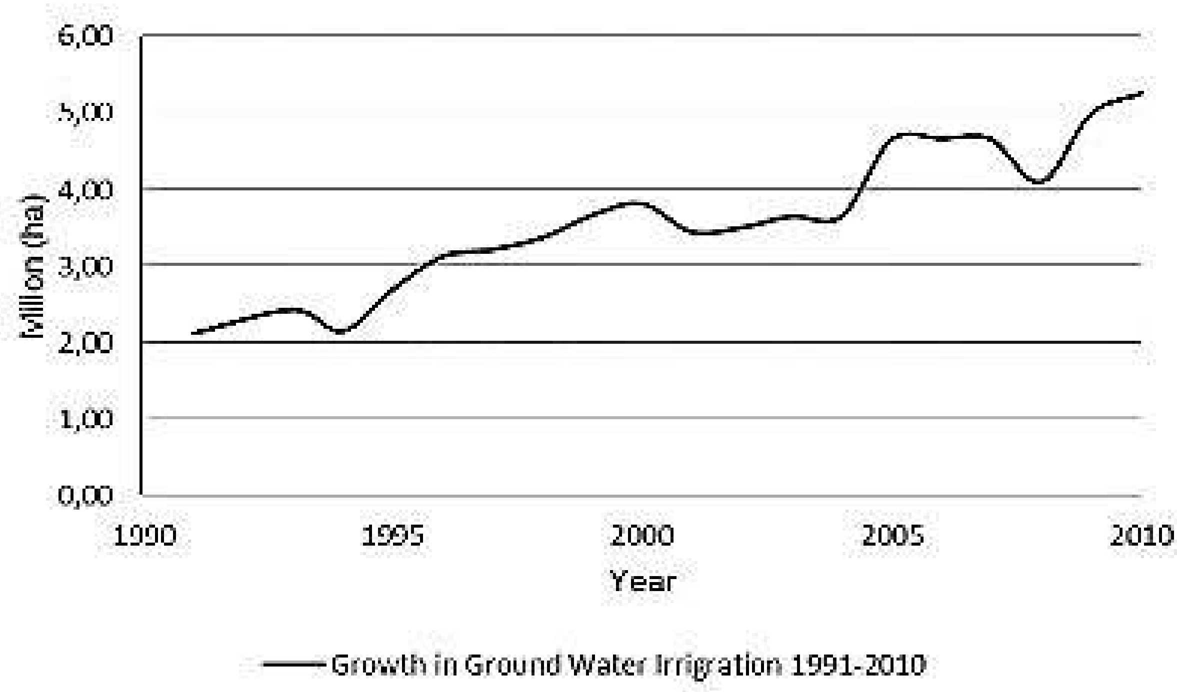


Figure 6.17: Growth in Groundwater Irrigation 1991 - 2010

Source: BDP 2100 Baseline Study Report: Water Resources, 2015

Floodplain connectivity and degradation of wetland ecosystems

A network of beels, ponds and khals (canals), exist in the Barind and Drought prone areas, comprising a rich source of water bodies. Some of them remain under water for the whole year whilst others are submerged in the wet season only. The total area covered by open and closed water bodies in Bangladesh is some 43,980 km^2 (Table 6.5). Of this total, more than 80% are considered 'open water bodies', in which connectivity between rivers, estuaries, wetlands and floodplains are essential for their ecological functioning.

Table 6.5: Total Area of Water Bodies in Bangladesh

Open Water Bodies		Closed Water	
River and Estuaries	10,320 km^2	Ponds	2,150 km^2
Beels and Haors	1,140 km^2	Baors	50 km^2
Kaptai Lake	680 km^2	Coastal Lowlands	1,410 km^2
Flooded Land (average)	28,330 km^2		
Total	***40,470 km^2***	***Total***	***3,510 km^2***

Source: BDP 2100 Water Resources Baseline Study

The wetlands and water bodies provide a key source of livelihood for many rural poor in the country. Over 70% of the rural households in the floodplain catch fish either for income or for food (Thompson et al, 1999). Fish and fishery products are the country's third largest export commodity contributing 5.1% of its exchange earnings (FAO, 2011), 4.91% of GDP and provides 63% of the national animal protein consumption (DoF, 2003). Total fish production the country during the 2007-2008 was about 2.57 million tonnes of which 2,065 million tonnes were produced from freshwater including culture fisheries and 0,04 million tonnes from marine water including shrimp (DoF, 2009).

Before FCD development, Chalan Beel, located in the southern part of the NW region, consisted of four large beels, and is now characterized by 97 disconnected and dry-falling ponds (Barind Delta Workshop, 2015). For the Northwest region, which has the highest number of beels in the country, a reduction in wetland area by 29% has taken place from 1989 to 2010. At national level, of Bangladesh's 260 freshwater fish species, 40% are threatened with extinction (IUCN, 2000).

Floods and drainage congestion

Siltation and drainage congestion, accompanied by regular floods in the Atrai basin, are an additional key issue in the Barind and Drought prone areas. Part of this issue is related to man-made changes to the water system, the most important being the development of FCD and other infrastructure such as roads, bridges and minor embankments as well encroachments of khals and rivers. This infrastructure hampers flood evacuation and drainage. In addition, these interventions have contributed to increased siltation and inadequate excavation exacerbates this issue. Drainage congestion is also related to the soils in the Barind and Drought prone areas which are naturally poorly drained (Brammer, 1997). Puddling for rice cultivation leads to further worsening of the internal drainage conditions.

Key Issue: Water supply and sanitation

Barind and Drought prone areas represents many of the pressing issues on water and sanitation in Bangladesh. As discussed above, the effect of declining groundwater is felt severely and hand-tube well based solutions have needed to be changed to deep abstraction. This situation is expected to worsen and calls for strict water regulation and abstraction allocation. Like in most of Bangladesh, faecal sludge management requires urgent development (technical, institutional and cost recovery) particularly in urban areas. For urban areas water resources assessment is required to decide whether (preferential allocation of) groundwater can be operated sustainably, or whether shifts towards surface water sources, with long distance transport as a future option. These developments will enhance a trend towards piped system solutions. In view of these challenges, effective introduction of cost recovery principles is important. The Barind and Drought prone areas has a relatively high proportion of hard to reach unions, with some typical water and sanitation constraints. These are outlined here below, along with suggested strategies for sustainable solutions.

6.5.2 Key Issues 2050

In this step, two time horizons were applied for the four Delta scenarios, with a focus on the development in the Barind and Drought prone areas. The analysis below is based on the assumption of a BAU strategy in which the government continues the implementation of policies.

Drought

Key drivers regarding drought include climate change, agricultural technology development, population increase and industrialization. These drivers have a direct influence on water demand and availability.

The key water consumer is the agriculture sector, accounting for 80% of the total water use. Based on food demand modelling, largely driven by population increase, IWM estimates the water demand for rice production to increase by 8% in 2020 and 13% in 2030, from the 2010 base. The increase in demand is almost exclusively generated for Boro rice cultivation, which would grow by 27% and 54% respectively between 2020 to 2030.

Climate change has a much smaller impact on future demand than the increased food demand outlined above. Mainuddin et al. (2013), conclude that due to climate change only, irrigation water demand is projected to increase by less than 1% for the 2030 average condition to the maximum of 3% for the 2050 dry condition. The climate scenarios (2030 average and dry and 2050 average and dry) correspond to a large degree to the two climate scenarios used in the BDP scenarios. The additional irrigation water requirements at country level will be less than 1 bcm for the 2050 dry climate scenario (Mainuddin, 2013).

Domestic and industrial use is expected to grow by 100% and 440% respectively by 2050 (CSIRO, 2015), based on the assumption of industrial demand as fixed percentage (25%) of domestic use. The current (2011) domestic water demand is estimated to be 2.7 bcm, which is expected to increase to 4.1 and 5.4 bcm respectively by 2030 and 2050 due to population increase. The corresponding figures for industry are 0.08, 0.18 and 0.35 bcm. Much of the increased domestic demand will be created in the large cities such as Rajshahi and Rangpur, as illustrated in **Table 6.6**.

Table 6.6: Water Demand Projections for Selected Large Cities in Bangladesh, in m^3/day

Name	2010	2015	2020	2025	2030
Dhaka	2,108,000	2,144,000	2,616,000	3,130,000	3,901,000
Khulna	129,564	146,890	169,472	194,676	228,133
Chattogram	712,800	-	1,243,200	-	1,896,000
Rajshahi	104,400	127,132	157,367	194,528	245,283
Rangpur	60,269	77,669	122,476	170,379	224,987

Sources: Dhaka WASA Water Supply Master Plan; Master Plan for Water Supply & Sewerage Improvement for Khulna, Tajshahi and Rangpur (KEITI); Available Water Assessment and Salinity Intrusion Analysis for Karnafuli, Sangu and Feni Rivers (IWM, 2008)

Groundwater level decline

- Climate change will lead to increased demands from agriculture – assuming comparable cropping practices and patterns – due to longer drier spells and increased temperatures. This, in turn, will drive the occurrence of increased drought (hydrological and agricultural) and demands for further groundwater abstraction;
- Population increase will lead to increased demand for safe water in urban and rural areas;
- Industrial growth, which relies heavily on independent groundwater supplies, will lead to increased abstraction.

Tipping points

Groundwater is a key source of safe water supply for many families and communities in the North West region. When the static water level in the local well drops below the critical depth of 8 meter, most of the suction lift pumps can no longer operate. Especially poor communities and families will be affected, having little resources to develop wells equipped with force mode pump sets. Another tipping point relates to drilling depth, at which traditional machinery cannot drill a well and more sophisticated techniques are needed. This is generally considered to be 30m (Sanchez, 2016).

Floodplain connectivity and degradation of wetland ecosystems

Increased water demand, pollution and on-going urbanization and population growth constitute pressures on the already sensitive wetland ecosystems and floodplain-river system. In the moderate and active scenarios, pressures will be driven mostly by population increase, urban sprawl and increased agricultural demand. As a result, many beels are at risk of further encroachment. Sources of contamination will be dominated by the domestic and agriculture sectors.

Tipping points are not straightforward to determine and would seem to have been passed already for this Hotspot, especially for Chalan Beel. Environmental flows of rivers and wetlands constitute minimum conditions as tipping point. Various methods to determine environmental flows exist, most of which are related to the hydrological regime and water quality required for the survival of key species.

6.5.3 Detailed Strategy

To support the Delta goals in the Barind and Drought Prone (DP) areas Hotspot and enhance on-going development activities; the Barind and Drought Prone Areas Hotspot strategy consists of the following three related but independent strategies:

Strategy Barind (DP) 1: Balancing Supply and Demand for Sustainable and Inclusive Growth

Strategy Barind (DP) 2: Minimising losses due to floods and drainage congestion

Strategy Barind (DP) 3: Ensuring water supply and sanitation.

Strategy Barind (DP) 4: Management of cross-boundary water issues including river basin developments.

These strategies and sub-strategies are visualised in the figure below and detailed in the sections thereafter.

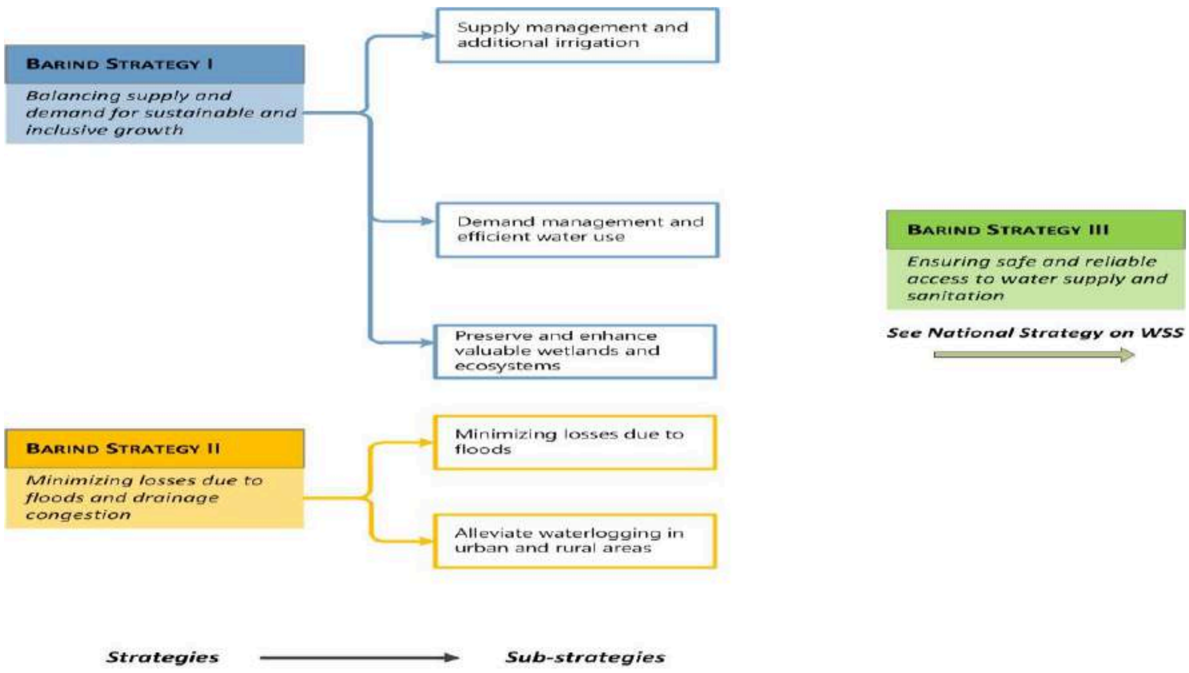


Figure 6.18: Overview Barind and Drought Prone Areas Strategies and Sub-Strategies

Strategy Barind (DP) 1: Balancing Supply and Demand for Sustainable and Inclusive Growth

Ensuring water availability by balancing supply and demand for sustainable and inclusive growth lies at the heart of the first Strategy for the Barind and Drought prone areas. Increased droughts and water shortages for different socio-economic sectors are expected in the future and, if one continues with the 'business as usual' strategy, these constraints will hamper the sustainable growth as envisaged by Government in the National Sustainable Development Strategy (NSDS, 2013, GED). Three sub-strategies form part of the Strategy:

Sub-strategy Barind (DP) 1.1: Supply management and additional irrigation. Where adequate water resources exist or can be developed, from the Ganges and regional rivers, this sub-strategy is geared towards providing additional irrigation water for sustainable and inclusive growth. The key beneficiary of this sub-strategy is the agriculture sector and, where valuable groundwater supplies can be substituted by surface water resources, benefitting the environment, and water supply and industry sectors. Sustainable operation & maintenance of irrigation systems is a particularly essential feature of this sub-strategy.

Sub-strategy Barind (DP) 1.2: Demand management and efficient water use. This sub-strategy is aimed at reducing the demand for freshwater, for those areas where additional water resources cannot be (economically) developed or where more urgent socio-economic priorities such as safe water supply, industry, ecology or navigation receive a higher priority. Again, a mix of interventions is included, consisting of less water consuming crops to more efficient irrigation and more effective management and pricing.

Sub-strategy Barind (DP) 1.3: Preserve and enhance valuable wetlands and ecosystems. The wetlands and water bodies provide a key source of livelihood for many rural poor in the Barind and Drought prone areas Hotspot. Decreased floodplain connectivity and related degradation of wetlands is mainly caused by past development of roads and infrastructure, the development of Flood Control and Drainage (FCD) projects and water abstraction for irrigation in the Rabi season. The Chalan

Beel programme lies at the heart of this sub-strategy, including infrastructure modification and restoration of key beels for fisheries and ecological purposes.

The Preferred Strategy Barind (DP) 1 aims to ensure reliable and adequate provision of freshwater to support equitable and sustainable economic development, environmental sustainability and livelihood security. The core of the strategy is to ensure a sustainable balance between water supply and demand, taking into account all key socio-economic sectors/ livelihoods. Depending on the unfolding of scenarios and the actual impact and performance of implemented measures, the preferred strategy for the medium to long term includes conversion of surface to localised irrigation, efficient irrigation systems, piped system solutions (including effective introduction of cost recovery principles), and increased water storage. Key activities in the preferred strategy include:

- Development of surface irrigation facilities from the Ganges and regional rivers.
- Deep well development in the Northern part of the NW region, in the Teesta floodplain, conditional upon detailed groundwater assessment;
- Designation of groundwater protection zones including use limitation;
- Detailed water budgets and water resource assessments, including surface- and groundwater, feeding into a detailed River Basin Management Plan for the Barind and Atrai basins;
- Set-up of a drought and flood monitoring and control centre;
- Local storage and retention in khals and water bodies -with pilots to assess effectiveness and implementation mechanism;
- Promotion of crop diversification and less water demanding crops and practices;
- Promotion of drip & sprinkler irrigation - including mechanisms for improved O&M and cost recovery;
- Reuse of treated wastewater and recovery of nutrients and energy;
- Modification of FCD infrastructure and improved management (O&M for multiple functions and interests) to support ecological connectivity and wetland quality. The Chalan Beel programme will constitute the main investment in the short and medium term.

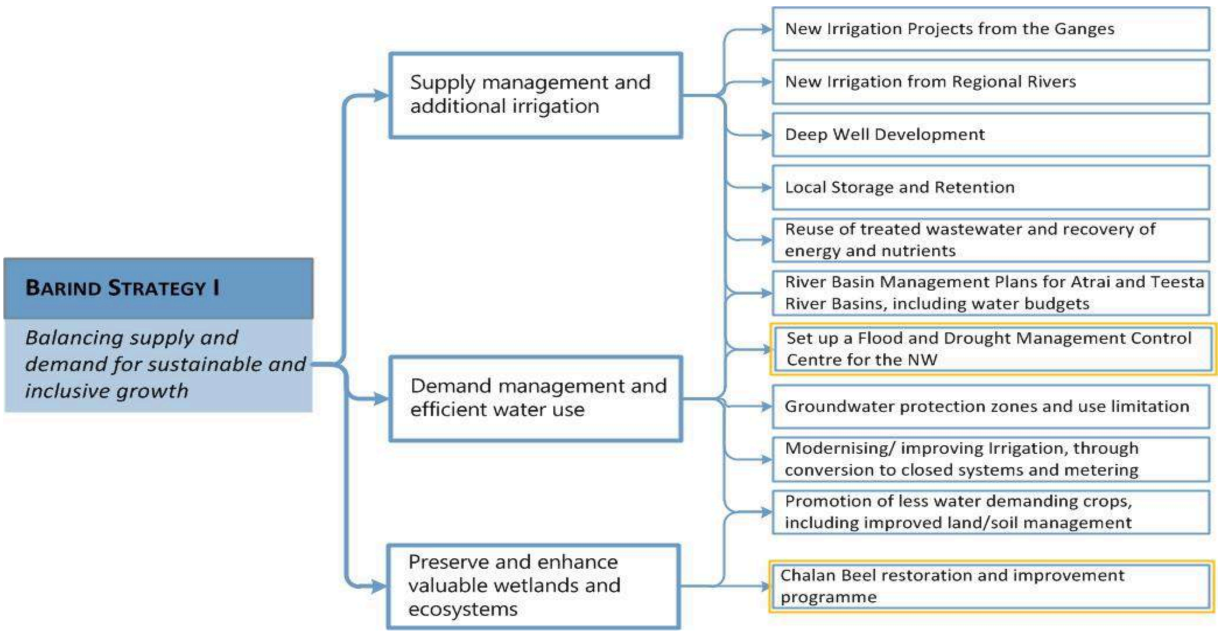


Figure 6.19: Barind and Drought Prone Areas Strategy 1 Sub-strategies and Measures

Strategy Barind (DP) 2: Minimising losses due to floods and drainage congestion

*Sub-strategy Barind (DP) 2.1 Minimizing losses due to floods:*Climate change and the increasing value of assets in the Barind and Drought prone areas Hotspot will lead to an increased Flood Risk in the period up to 2050 and beyond. The lower Barind and drought prone areas and the Atrai basin in particular, are typically affected by floods during the monsoon when prolonged and intense rainfall coincides with high water levels in the main rivers, impeding drainage. Many FCD systems were designed over 25 years ago and are in urgent need of repair and modernisation. A key aspect is taking into account multiple functions and interests and appreciating the positive impacts of flooding in the lower Barind and drought prone areas; including replenishment of beels and wetlands, fish migration and spawning, groundwater recharge and flushing of nutrients and pollutants from the water system.

Sub-strategy Barind (DP) 2.2: Alleviate waterlogging in urban and rural areas.

In the Barind, urban and rural drainage congestion prevails. caused by the combined effect of: i) decreased infiltration and increased run-off due to increased built up areas; ii) inadequate maintenance of urban and rural drainage networks; iii) siltation, waste accumulation and encroachment; and iv) insufficient drainage capacity, due to the construction of roads, embankments and other infrastructure on the floodplains without adequate provision for drainage. In addition to economic disruption, health and environmental hazards are key impacts of waterlogging. Infrastructure modification and river management are key elements of this sub-strategy.

The Preferred Strategy Barind (DP) 2 aims to balance the need for safe and productive living and economic conditions, free from disruptive floods and drainage congestion. This is balanced with a gradual implementation of wetland and beel restoration, with the aim to provide ecosystem services to multiple sectors and interests. In short, the positive impacts of flooding are not jeopardised whilst minimizing the negative impacts. Depending on the unfolding of scenarios and the actual impact and performance of implemented measures, the preferred strategy for the medium to long term includes the following main activities:

- *Excavation of khals and smartdredging of rivers* including capacity building and mechanisms for regular maintenance by LGIs and communities for the minor rivers and water bodies and the BWDB for larger rivers. Dredging will always be as smart as possible, taking into account an enhancing natural flow and sedimentation processes and aimed at minimising the need to large and costly interventions.
- *Infrastructure modification-redesign and flood proofing*. Many infrastructures such as roads, bridges, urban settlements has been developed to fulfil valuable socio-economic needs. These structures also impede drainage and hamper connectivity. The focus lies on the FCD schemes, road and other infrastructure developed. Flood proofing includes developing (critical) infrastructure above anticipated flood levels.
- *Chalan Beel integrated restoration* includes projects for restoration and dredging of Atrai and Hurasagar Rivers. Multiple functions and interests (fishing, agriculture, safety, communication, and environment) will be balanced with a long term perspective, with participatory analysis and modelling approaches. Hydrological and hydraulic modelling, coupled to 2-D morphological models of Atrai and Hurasagar Rivers support the decision-making with participatory modelling approaches

- *Enhanced Flood Early Warning Systems (FEWS)*, ensuring the linkage with the drought and flood monitoring and control centres. The FEWS would have both a technical and a community communication component. This measure entails improvement, up scaling of on-going developments
- *Soil improvement* to enlarge the soil drainage capacity through deep ploughing and other infiltration practices

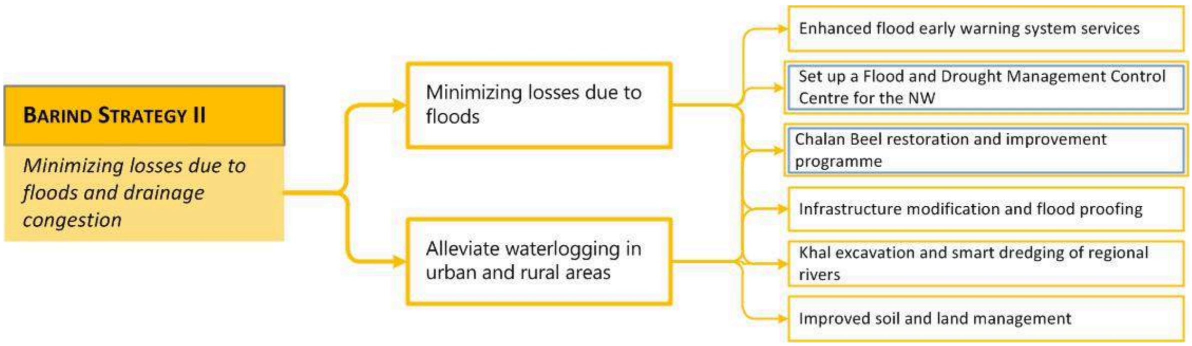


Figure 6.20: Barind and Drought Prone Areas Strategy 2 Sub-Strategies and Measures

Strategy Barind (DP) 3: Ensuring water supply and sanitation

This strategy centres on achieving basic water security and sustainable development goals: ensuring safe and reliable access to water supply and sanitation. There is a strong link with water quality through the development of improved sanitation and wastewater treatment systems in all districts and major settlements, with cost recovery principles advocated for all WSS services. This strategy is elaborated in the National WSS Strategy and so far as water quality is concerned: the Freshwater Strategy of particular relevance for the Barind and Drought Prone Areas Hotspot are:

- Implementation of sewage treatment plants in all district headquarters, including industrial effluent treatment. In anticipation of future agro-industrial development and population expansion, advanced treatment will be necessary, driven also by the desired environmental quality standards of receiving waters;
- Faecal sludge management facilities and practices;
- Conversion of localised systems to piped distribution networks;
- Securing scarce groundwater supplies in areas where an overdraft is taking place.

6.5.4 Adaptation Pathways

Further research is required to identify Tipping Points in relation to key Drivers for each of the four Delta Scenarios. At this stage, for the three strategies, generalized pathways have been drawn up and shown in the figure below. It is expected that as more data collected and knowledge is gained about these issues, more detailed adaptation patheays will be development for these strategies.

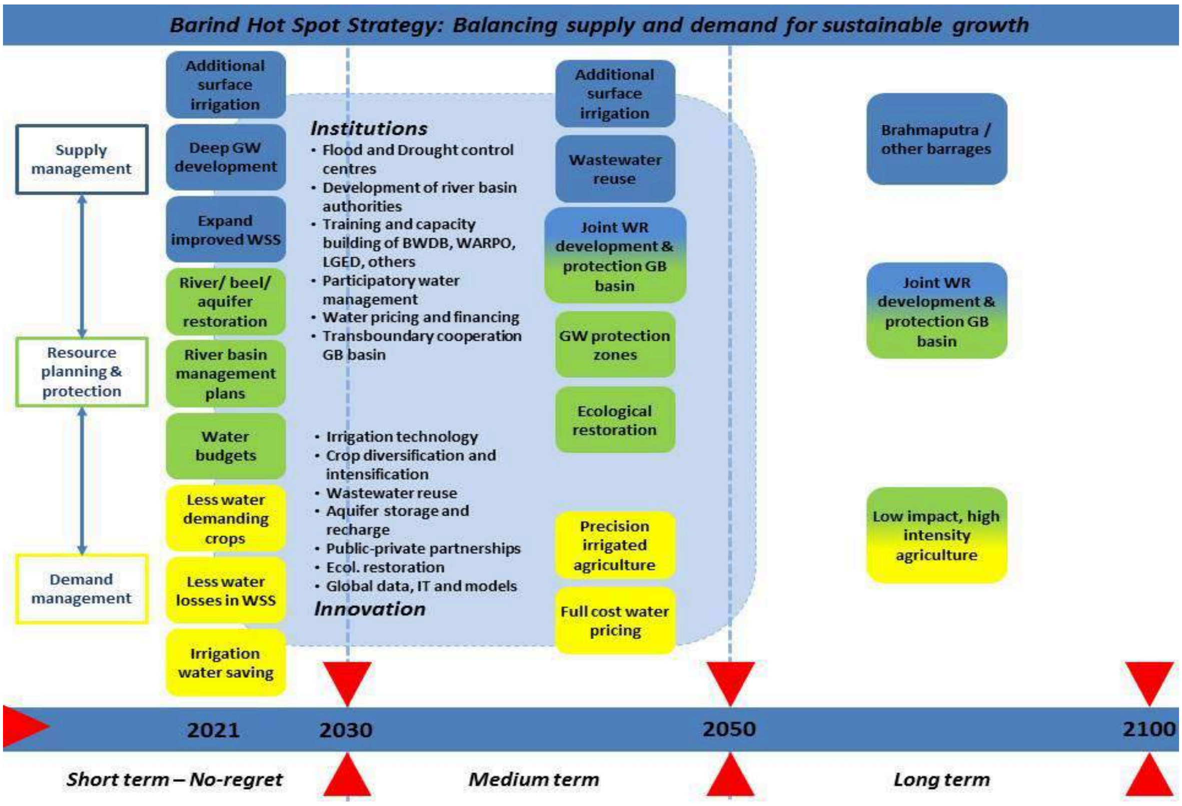


Figure 6.21: Adaptation Pathways for Barind and Drought Prone Areas

6.6 Coastal Zone Strategy

The Coastal Zone of Bangladesh is very heterogeneous and has a tremendous potential to create opportunities of national importance. Examples are intensification of agriculture, aqua-culture and marine fishery, exploration of gas and oil resources, development of the ship building industry, eco-tourism, renewable energy and deep sea port development. The coastal zone of Bangladesh is also a disaster prone area. Cyclones, storm surges, droughts, floods, water-logging and salinity intrusion have a huge impact on people and their livelihood. Poor communication, lack of education and health care facilities, prolonged absence of safe drinking water and insufficient cyclone shelters contribute and multiply the dimension of vulnerability. Furthermore, increasing population pressure increases the competition for limited resources. As a consequence and in order to unlock these potentials, existing and new interventions are required in an integrated and inclusive way. It also calls for a distinct and integrated coastal development strategy.

6.6.1 Key Issues 2015

Floods

One distinguishes flooding (normal rainwater flooding) and floods (tidal, storm surges, riverinefloods) in the coastal zone. Development differs between distinct flood types, as well as that insights in extreme events, and possible policy actions against it need more attention.

Water logging

Several areas in the coastal zone (Western part and Noakhali mainland) suffer from extensive and permanent water logging. Reasons behind water logging are complex and differ between regions, as well as their expected future development. Drainage capacity of the area and Peripheral rivers is a main concern and is expected to be heavily impacted in future conditions.

Riverbank and coastal erosion

In the dynamic morphological environment of Bangladesh, riverbank and coastal erosion will remain as significant issue. Large scale sediment transport in rivers is mainly activated due to higher discharges, which are projected to occur more often in the future into the Meghna Estuary. It is however not very clear that how much sediment load is available in the Ganges- the Brahmaputra- the Meghna basins (e.g. impact of upstream developments) . It is also not clear that ow sediment transport is influenced by SLR and accompanying changes in tidal influence.

Freshwater availability

Large areas (mostly western) in the coastal zone suffer from a deficit of freshwater availability, mainly in the dry season. Drinking water supply (large problem for southwestern regions) and sanitation are treated separately, but shortages are equally felt for agricultural production and the highly vulnerable Sundarbans forest. Projected decreases of transboundary freshwater inflows, sea level rise, as well as possible unprecedented increases in specific demands makes freshwater availability an important key issue for the coastal zone.

Environmental degradation

In addition to problems related to the salinity balance in the Sundarbans and many wetlands in the coastal zone. floodplain connectivity, urbanization pressure and water quality issues (effluents from industry, agriculture and aquaculture), environmental degradation of natural resources in the coastal zone need ample attention and should be assessed for future conditions.

6.6.2 Key Issues 2050

Floods

The coastal zone is prone to different types of floods. It is important to distinguish between the normal rainwater flooding which annually inundates more than 20% of the country. Almost every year cyclone-induced storm surges impacts the coast of Bangladesh in the pre-or post-monsoon period. Only the western part is relatively better protected because of the extensive Mangrove forest 'Sundarbans' naturally reducing wave heights. Tidal floods, for example during spring tide, may cause severe loss on unprotected coastal lands as well as sometimes breach earthen embankments, leading to potentially more harm. The northern and eastern part of the coastal zone is also prone to riverine floods, often aggravated by coincident high tides. The Chattogram coastal floodplain is particularly prone to flash floods, coming from the Hill Tracts.

Considering above flood types, the largest exogenous drivers for future change are:

(1) sea level rise and subsidence;
(2) change in frequency and severity of cyclones and accompanying storm-surges;
(3) increase in peak discharges (and sediment flow) for the main rivers of Bangladesh;
(4) population growth and urbanization; and
(5) (regional) economic development and diversification.

The BDP 2100 delta-scenarios, based on the Climate Change baseline study, referencing Hinkel et al. (2014), states that in general sea level rise in the Bay of Bengal in 2050 is projected to range between 20 to 30 cm in a moderate climate change scenario up to 40-60 cm in a high climate change scenario. These projected numbers are excluding subsidence, which may be identified as a substantial knowledge gap for Bangladesh.[24]

Higher (relative) sea levels will increase surge height and tidal water levels. As the polder levels are expected not to grow naturally, cyclones with comparable frequencies as now, will lead to higher storm surges, higher probabilities of overtopping or polder embankment breaching, as well as larger (salt) water depths in the exposed polder area. A projected higher frequency and severity of land falling cyclones and accompanying storm surges, as a consequence of increased Sea Surface Temperature will further aggravate flood hazards from sea (Ali and Choudhury, 2011). Areas that are now not prone to storm surges (and accompanying winds), will become prone due to climate change.

Unprotected areas outside the polders, influenced by tidal flows and sufficient sediment supply, will naturally grow with sea level rise. Unplanned population growth, land use change and regional economic development, when they are not sufficiently adapted to future flood (and wind) hazards in the coastal zone, will potentially even have a substantially higher impact on coastal flood risk in the future.

In addition to the specific changes in flood risk from cyclones and storm surges, it is suggested that flood hazards locally occurring in the coastal zone related to river floods, flash floods and rainwater floods (leading to drainage congestion) may change, as well. The delta-scenarios only provide figures now on the mean annual maximum discharge changes for the inflow points of the main rivers, but for these flood hazards and risks it is of more significance whether the frequency, timing and duration of more extreme discharges will change. Further, the role of morphological impacts on flood risk should be further investigated. Again, in such a future flood risk analysis, possible socio-economic changes should be included as well, as these in general have proven to be of more impact than climate change itself (Winsemius et al. 2014).

Waterlogging

The problem of waterlogging in the coastal polders, particularly in Satkhira, Jashore, Khulna, Bagerhat and Noakhali districts is the result of three separate but mutually interacting causes. The presence of coastal polders prevents the spreading of the natural tidal flows and restricts sedimentation in low lying areas. Consequently, sediment is deposited on the peripheral river beds, leading to large scale river bed siltation and further reduce of the tidal prism. The silted river blocks the natural drainage (needed for the extensive monsoon rainfall) from the polders. This process is aggravated by the fact that polder infrastructure (khals and tidal sluices) does not function optimally, also due to ineffective O&M. In addition, the development of the road network inside the polders is acting as an internal embankment and is often designed without proper attention to drainage capacity. Water logging also occurs in Noakhali district as a direct result of longer

[24] The coastal zone baseline study describes three types of subsidence: tectonic, anthropogenic and that resulting from the compaction of peat layer. Observations indicate current rates of 2-6 mm/year.

drainage paths due to land reclamation projects at southern Noakhli and natural process of Delta uplifting.

Waterlogging within the polders, FCDI project areas or back swamps lead to unproductive land, large nuisances, health issues and livelihood insecurity for the inhabitants. As sedimentation is not taking place in the polders and the polder further subsides, the differences in polder level and surrounding bed levels will further increase. The relationship between external and internal drivers, pressures and impacts in relation to waterlogging is visualized in the diagram below.

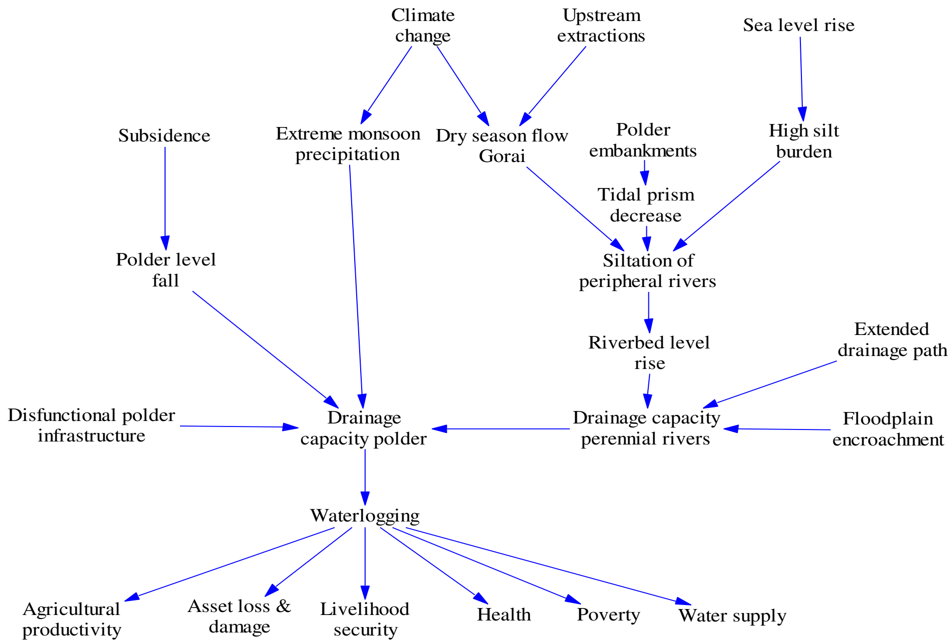


Figure 6.22: Causal Effect Diagram on Waterlogging Problem in the Coastal Zone

Source: BDP 2100 Technical Team Analysis, GED, 2015

Many different causes for extensive waterlogging are only partly influenced by external driving forces identified in the delta-scenarios. More intense rainfall events, lower upstream river flows in the dry season for the flushing of incoming sediment and reducing tidal prism, climate change, sea level rise and subsidence has aggravated waterlogging experienced now. The areas that are not experiencing water-logging now (e.g. non-polder areas in Jhalokati, Patuakhali and Barishal districts) may experience that in the foreseeable future. Several causes directly related to human activity (e.g. floodplain encroachment, polderization, drainage infrastructure blocking and longer drainage paths) only further increase under increasing population pressure and changing economic activities in these areas.

River bed sedimentation as one of the driving forces of water logging also reduces navigation possibilities, fresh surface water supply as well as capture fisheries production.

Delta scenarios describing an attention away from primary sector production in the polders, will probably decrease the general dependency on agricultural land and as such will decrease some of the current experienced impacts from water-logging. Hence, other impacts (e.g. at the household level) may become more intense due to higher dependency on accessibility outside the region, health deterioration and uneven impact distribution in gender and equity.

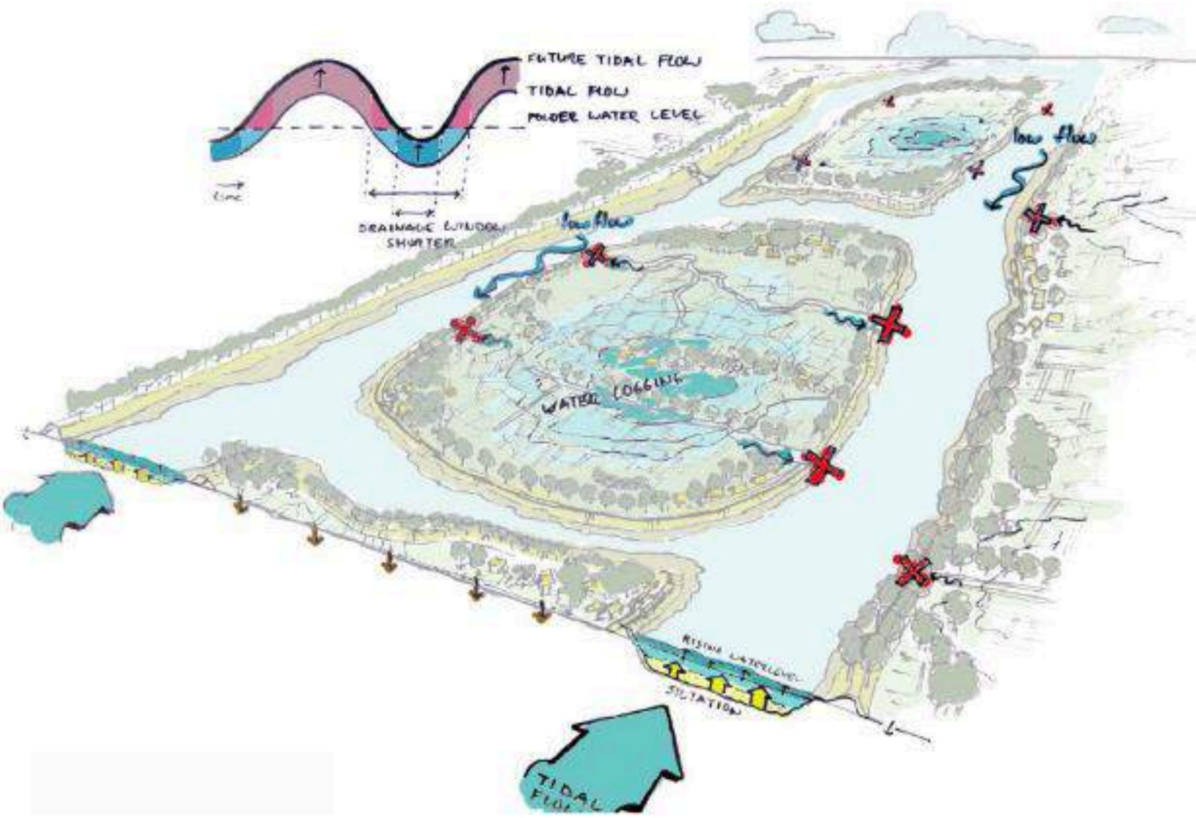
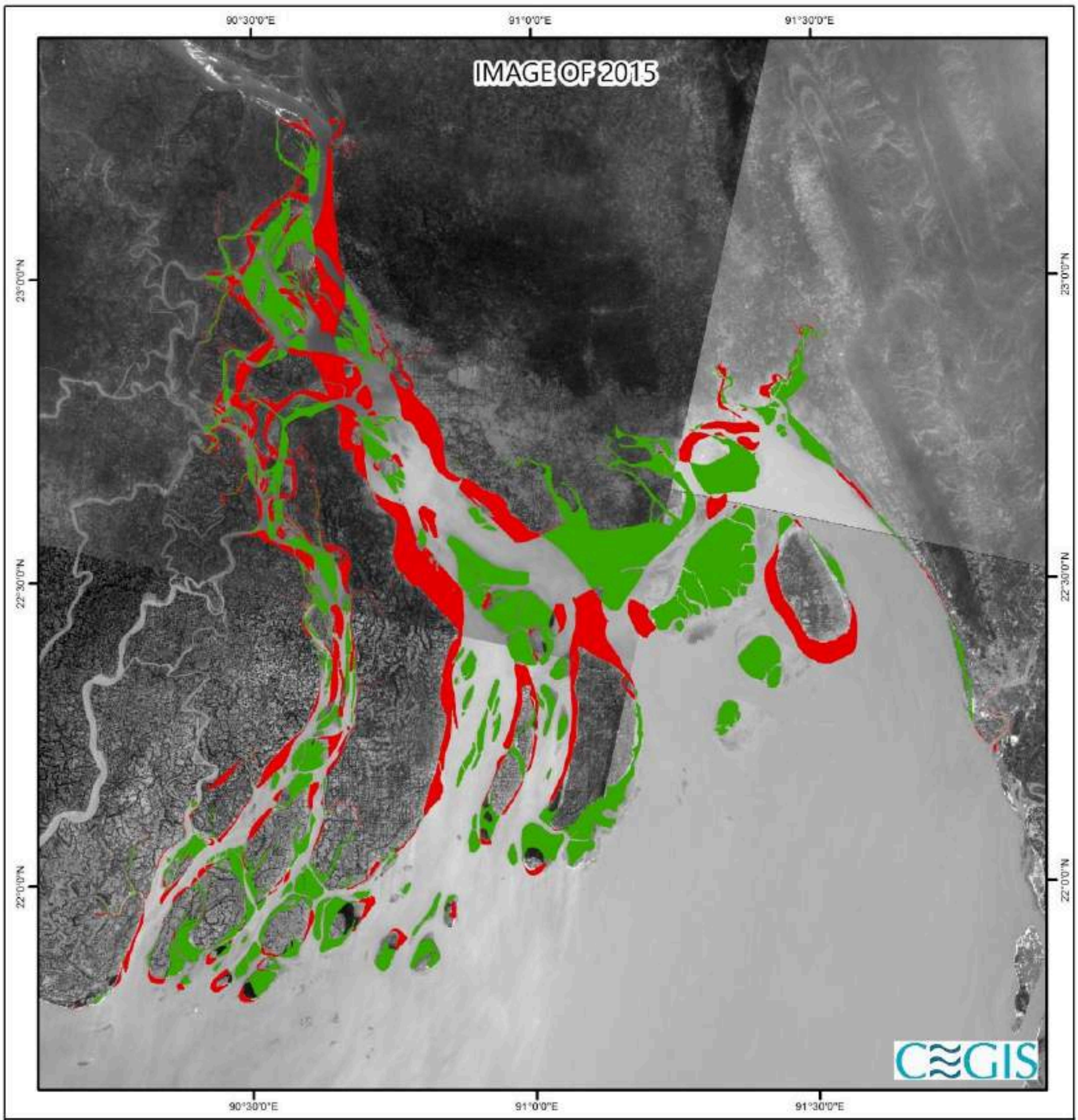


Figure 6.23: Illustration of Several Causes of Waterlogging and Future Changes in the Coastal Zone

Source:BDP 2100 Coast and Polder Issues Baseline Study



Erosion-Accretion in the Meghna Estuary Area during 1973-2015

District	Erosion (km^2)	Accretion (km^2)	Net accreted area (km^2)	Rate of net accretion (km^2/y)
Barisal	169	155	-14	-0.3
Bhola	385	396	11	0.3
Chandpur	76	44	-33	-0.8
Chittagong	105	256	151	3.6
Feni	11	30	19	0.4
Lakshmipur	133	53	-80	-1.9
Noakhali	179	620	441	10.5
Patuakhali	126	230	103	2.5
Shariatpur	20	27	7	0.2
Total	**1205**	**1810**	**605**	**14.4**

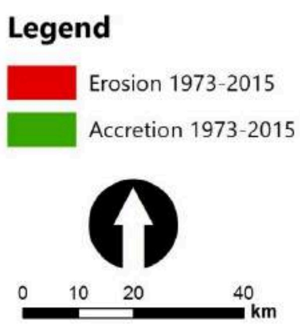


Figure 6.24: Gains and Losses of Land between 1973 and 2015

Source: CEGIS, 2015

River bank and coastal erosion

River bank and coastal erosion occurs on a large scale in the central Meghna estuary due to large discharges as well as a substantial sedimentation load. The tidal floodplain area, more to the west is much more stable, but locally severe erosion is observed. Local riverbank erosion also occurs in the Chattogram floodplain along the Karnafuli River. Erosion leads to loss of productive land, cause damage to houses and infrastructure including embankments, markets, schools and navigation landing sites. Annual land accretion exceeds erosion in the whole coastal zone particularly in the Meghna estuary (**Figure 6.24**). This provides opportunities for land reclamation. Typically, organic matter content is low in newly reclaimed lands due to the highly mineralized nature of sediment deposits. Improving soil fertility and structure is therefore part and parcel of land reclamation in the coastal area (de Wilde, 2011).

Freshwater availability

Currently, the coastal zone is mainly used for (a two-cycle) rice production of rainfed crops in the monsoon, and boro rice in the dry season. This practice is under pressure due to increasing salt intrusion in the river water, also because of diminishing freshwater flow from the Gorai river (main source of freshwater for the southwest coastal zone), as well as groundwater and consequently soils.

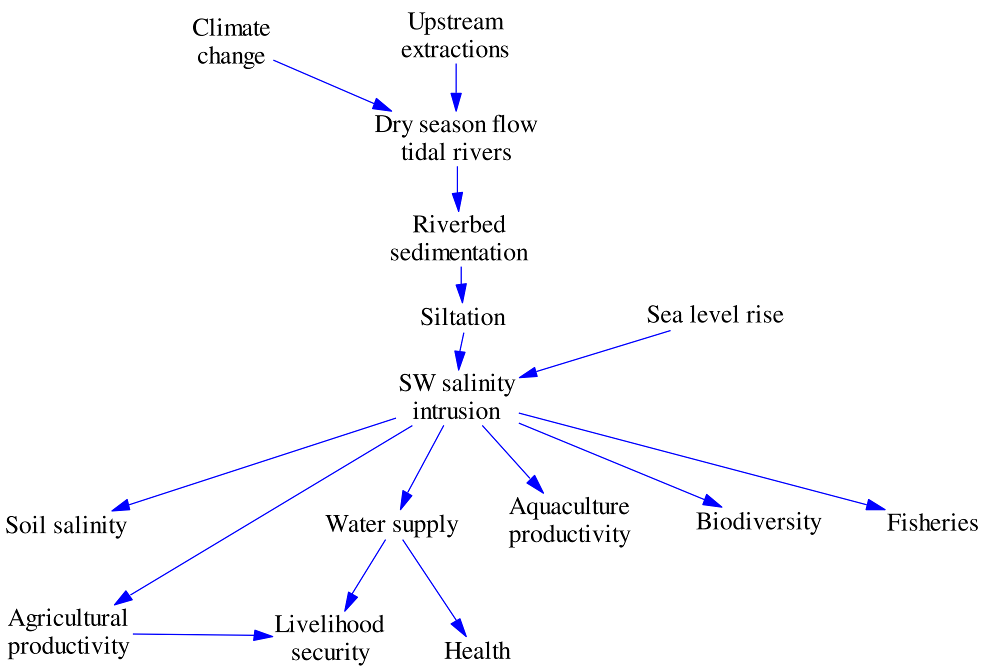


Figure 6.25: Causal Effect Diagram on Salinization in the Coastal Zone

Source: BDP 2100 Technical Team Analysis, GED 2015

In the western tidal floodplain area, shrimp culture is progressing, sometimes in combination with rice production in the monsoon period. Along the gradient, also prawn and fish farming is increasingly practiced in order to adapt the new situation. Freshwater supply for domestic purpose is severely constrained due to the elevated salinity level in the shallower aquifer and arsenic contamination in the deeper aquifer. The south central coastal zone are better fed by freshwater from the Arial Khan and Lower Meghna rivers, making this area less vulnerable for river sedimentation and salinization. However, because of its dynamic nature, navigation in this area remains a continuous concern.

Freshwater availability for different demanding sectors (e.g. agriculture, domestic, industrial, nature) in the coastal zone is a challenging issue now (in particular in the west part of Ganges Tidal Floodplain and the more remote islands) and will be further aggravated by changes in water variability and socio-economic change in the future.

In the southwestern part, gradual movement of salinity towards northern part in the dry season (both in surface and groundwater) will occur due to uncertain dry season flow from the Ganges tributaries (due to upstream extractions, also in the Ganges Dependent Area, limited rainfall in the Ganges- the Brahmaputra- the Meghna basins and siltation) as well as sea level rise. will change the ultimate salinity front in surface and groundwater to more northern areas at the end of the dry season.

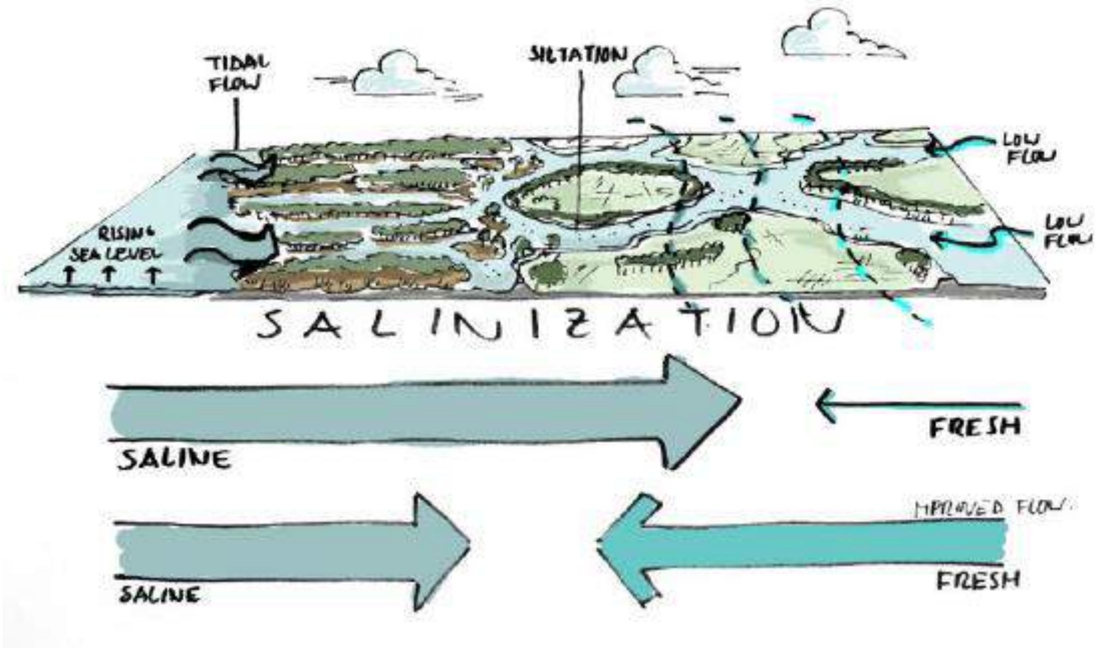


Figure 6.26: Illustration of Salinization Process in Western part of Ganges Tidal Floodplain

Source:BDP 2100 Coast and Polder Issues Baseline Study

In terms of groundwater, projected sea level rise will cause a higher pressure difference between sea level and groundwater level. This difference may create an upward flow resulting in saline seepage inland near the coast. In this area, there are fresh water lenses which float on top of the saline groundwater, which are created by a vertical downward flow of rain water. These rain water lenseswhich are very relevant for currently practiced agriculturemay be threatened by the saline seepage. Their volume of freshwater may be reduced as they are contaminated by the saline groundwater flowing upwards.

The availability of arsenic free groundwater in the coastal zone is probably mostly indirectly influenced by climate change. Arsenic is often found in iron sulphides and oxides, and when the redox conditions change, arsenic can mobilize and can contaminate groundwater further. Climate change may influence the pumping regime due to higher evaporation rates and higher water demands, as well as due to an intensification of droughts. Increased pumping rates during the dry season and heavier rains during the rainy season will influence the fluctuation of the groundwater. This fluctuation induces redox changes, which can increase the mobilization of arsenic. Besides, a change in the regional groundwater flow patterns caused by changes in rainfall distribution in time and space may also increase the mobilization of arsenic.

Developments in water demands for different sectors are most influenced by land-use changes under influence of population growth and diversifying developing economy. Recent autonomous adaptations to decreased availability for irrigation water towards aquaculture land use may locally further decrease freshwater demands for agricultural consumption in the future. Domestic and industrial water demands are likely to increase in each scenario, although their relative share will remain small. Location and time-specific demand projections are needed to assess detailed spatially distributed impacts.

Environmental degradation

In general, environmental degradation is common in the coastal zone, particularly for the Sundarbans.Specifically pressures include illegal encroachment, pollution due to boat transport, and increased surface water salinity. Rising salinity levels will severely affect the biodiversity in the longer term. The scenarios do not specifically differentiate between pressures on the Sundarbans border, although it may be expected that pressure on the Sundarbans protected area will remain high in future.

Increased water demand, pollution and on going urbanization/population increase form increasing pressures on the already sensitive wetland ecosystems and floodplain-river system. In the moderate and active scenarios, pressures will be driven mostly by population increase, urban sprawl and increased agricultural demand, as a result of which many beels are at risk of further encroachment. Sources of contamination will be dominated by the domestic and agriculture sectors. In the productive and resilient scenario, pressures will be mostly driven by urban and industrial development with similar impacts on wetlands encroachment. Pollution from industrial and urban sources will increase.

6.6.3 Detailed Strategy

Strategy CZ 1: Increase drainage capacity and reduce flood risk at coastal zone

The Coastal Zone of Bangladesh will remain hazardous for coastal floods in the foreseeable future. Cyclones and accompanying storm-surges will continue to develop in the Bay of Bengal, as well as high river discharges and monsoon precipitation will continuously put an enormous pressure on the drainage capacity of the Coastal Delta. Besides, possible future changes in discharge regimes or sea level rise, the Coastal Zone will be under increasing pressure of socio-economic change, with economic development and demographic changes as main drivers.

Sub-strategy CZ 1.1: Diminish drainage congestion: The drainage congestion in the coastal zone is a big issue. It happens due to less capacity of the river and sedimentation with the tidal effect. So increasing the drainage capacity will reduce the flood risk. Following measures are suggested to address the drainage issue:

(1) Restoration of rural rivers/canals and livelihood improvement in exposed coastal districts;

(2) Restoration of rural rivers/canals and livelihood improvement in interior coastal districts;
(3) Study on Impact Assessment and Strategic Directions on Tidal River Management;
(4) Improved drainage system in Bhabadha area;
(5) TRM in 7 polders near Khulna;
(6) Integrated management of drainage congestion for Greater Noakhali;
(7) Char Development and Settlement Project- Phase 5
(8) Sureswar flood control, drainage and irrigation project;
(9) Suitability study to potential largescale pumping to allevation drainage congestion

Sub-strategy CZ 1.2: Flood risk protection: The flood risk is very high in the coastal zone and it becomes disastrous when flood coincides with surge. So some measures is needed to reduce the flood risk and save lives in this region. Some of the measures are noted below.

(1) CEIP strategy development, including risk-informed and system-based protection levels;based on proper CBA (also poverty bias) for future change (incl. yet unprotected areas);
(2) Develop multipurpose flood embankment on the right bank of the Ganges, the Padma and the Meghna rivers from Mathabhanga offtake at Jalangi to Muladi;
(3) Cox's Bazar Marine Drive Road (multipurpose embankment);
(4) Regional connectivity with Myanmar and China;
(5) Study to preferred low-maintenance solutions in protection design manual of BWDB;
(6) Morphological dynamics of Meghna estuary for sustainable char development;
(7) Integrated land reclamation project of Hatiya-Dhamar Char-Nijhum Dwip;
(8) Urirchar-Noakhali Cross dam project;
(9) Construction of 11. cross-dams in the Meghna, Tetulia estuary in Patuakhali and Bhola districts.
(10) Flood-free and cyclone robust sea port and SEZ zones;
(11) Stabilize the right bank of the Lower Meghna River along eastern shore in Bhola;
(12) Study on possible impacts of building megastructures in the coastal estuary (salinity barriers/ storm surge barriers) in future;

Sub-strategy CZ 1.3: Flood risk prevention: For flood risk prevention, it is necessary to make the infrastructures sustainable to flood.

(1) Continuous development of flood hazard and risk maps for flood/hazard zoning (incl. continuous update of Disaster Emergency Management, DEM);
(2) Feasibility study for coastal revolving fund subsidiary programfrom Kutcha to Pucca"houses".
(3) Plan to increase the density (secondary and tertiary) all weather roads and bridges network;
(4) Flood proofing: road development along the coast of Cox's Bazar, Chattogram, Noakhali, Barishal.

Sub-strategy CZ 1.4: Flood risk preparedness: to reduce the casualities due to flood, preparedness against flood and its timely implementation is necessary. The projects related to this sub-strategy is given below.

(1) Hazard control centre(s), improve national EWS effectiveness (lead time) and localized warning (hazard impact modelling);

(2) Update cyclone shelter preparatory study of 1998 and construct, maintain multi-purpose cyclone and flood shelters

Suggestion: For the short term, the preferred strategy includes risk-informed rationalization of all the current FCDI projects based on current and future needs in a programmatic way. This includes the assessment of differentiated design protection parameters, (automated) drainage and irrigation capacity and potential pumping capacity. Furthermore, it is preferred in the improvement or development of protection to investigate the potential for low maintenance solutions; e.g. 'building with nature' solutions. Embankments in areas with high erosion risk (throughout the coastal zone), should be sufficiently protected with local hard or soft stabilization solutions.

In the preferred strategy, polders in areas that are considered geophysically stable (e.g. inland polders in southwest region or along Chattogram coast), and have dominant agricultural or aqua-cultural use (also in the foreseeable future), are sustained at a basic level of protection (e.g. ~1:25 year incl. climate change). This ensures a productive environment for the rural population under normal conditions. The needed and feasible differentiated level of protection is to be based on a risk-informed Cost-Benefit analysis, including aspects of income distribution and potential future change (e.g. economic shifts in development: sea ports, SEZs, infrastructure). To mitigate impacts of extreme floods (with a lower probability than protection level), additional flood risk prevention measures, like supporting living on the highest parts of the polder, and policy interventions to decrease vulnerability of the (poor) population, such as income diversification, social safety nets, as well as a coastal-wide revolving fund program "From Kutcha to Pucca houses" should be investigated. In addition, flood risk preparedness, needs continuous attention, by ensuring enough modern cyclone shelters, coordinated flood patrolling and fighting procedures, as well as investment in effective FEWS, e.g. with localized flood impact forecasting.

For more coastal urban areas or areas of national economic significance (e.g. seaports and infrastructure (e.g. Payra) or economic zones) now or in the foreseeable future, higher levels of protection are preferred (e.g. 1:100-1:250 year incl. climate change). This should be defined and maintained based on a comprehensive optimized cost-benefit analysis. It is always no-regret to invest in the highest valued assets at the local highest elevations, as well as to optimize flood proofing of infrastructure buffer zones and to promote preparedness measures (EWS and cyclone shelters). The protection level(s) of the Chattogram floodplain need to be determined based on the same optimized cost-benefit assessment methods.

The current water logging issues in the polders of the Western Ganges tidal floodplain (e.g. Khulna, Sathkira region) and Noakhali mainland need attention. An extensive TRM program needs to be undertaken and assessed for its feasibility both on a regional scale and polder by polder. This assessment may best be related to a full rationalization program regarding the functioning of existing FCDI projects in Bangladesh. Ideally, when new large scale interventions are planned (e.g. land reclamations), its impact on the drainage capacity of the whole system (also upstream) needs to be investigated. The drainage congestion problems in the Noakhali mainland area may be best mitigated by developing an integrated drainage network and by stimulating sediment supply from the Lower Meghna River. A comprehensive drainage and sediment study is a pre-requisite to such a program.

After 2050, depending on the then occurring climate and economic conditions, the government of Bangladesh may choose for further continuation of the strategy up to 2050 or may decide to invest in large storm-surge barriers or cyclonic storm surge proof (climate resilient) embankments in the southeastern river mouths (The Baleswar and The Tetulia River), as well as Chattogram harbour (The Karnaphuli River). The most effective way of reducing total coastal flood risk further is to support (by large investing in infrastructure) new developments on the upper parts of the country (Barind or Madhupur tract). Investment in nation-wide flood hazard zoning maps, based on geophysical characteristics and modelled floods will be of particularly importance here.

Strategy CZ 2: Balancing water supply and demand for sustainable growth

Sub-strategy CZ 2.1: Supply management and additional irrigation.

Construction of the Padma barrage and ancillary works, study on possible impacts of building megastructures in the coastal estuary (salinity /storm surge barriers) under future change, study on restoration of regional tidal rivers, Improvement of FCDI project database (incl. performance indicators) and setup monitoring programs (physical, topographical, socio-economic, landuse etc.); O&M FCDI, rehabilitation of Polder 36/1 project, rehabilitation of water management infrastructure in Bhola district, developing climate smart integrated coastal resource Database (CSICRD), integrated water management in west Gopalgonj needed to be accomplished.

Sub-strategy CZ 2.2: Demand management and efficient water use.

Increasing cropping intensity in the southern region of Bangladesh, Southern agricultural improvement project, Exploration of the production potential of saline soils of Bangladesh, Drought and salinity EWS development with localized warning (agrometeorological services).

Sub-strategy CZ 2.3: Resource planning, protection of environment;

Proper planning procedures of natural resources need to be developed and implemented. These are required to ensure proper restoration of water resources (beels and baors) and as well as the ecosystems that depend on these resources.

Sub-strategy CZ 2.4: Safe and reliable waterway transport.

Develop and maintain main navigation channels for large vessels: Chattogram-Dhaka-Ashuganj regional corridor improvement project (BIWTA) and implement national navigation master plan.

The preferred strategy for coastal freshwater aims to improve living conditions, sustain agricultural and fisheries production, as well maintain environmental sustainability. For the short term, the preferred strategy includes revitalizing surface water supply sources from the Ganges as much as possible. For the coast, the construction of the Padma barrage to restore the freshwater flow through the Gorai and other rivers would be advantageous, certainly with respect to drinking water and reducing salinization in the Sundarbans. But additional study is needed to ensure a long term sustainable situation at the regional level.

Current FCDI infrastructure needs to be modernized as insufficient maintenance and changing external conditions have led to a substantial degree of malfunctioning. Effective O&M is needed for proper functioning of current FCDI stuructures.

Year-round availability of freshwater for different users is currently a problem, particularly in the southwestern region, as freshwater flow and precipitation excess in the Lower Meghna dependent area is still sufficient. Overall, irrigated crops in the dry seasons are the largest consumers of freshwater throughout the coastal zone. Measures to relieve pressure on these demands are recommended. Drought and salinity early warning systems with localized impact and water pricing are considered no-regret. Competing main users of freshwater in the coastal zone are natural ecosystems (e.g. wetlands, beels, fisheries and the Sundarbans) as well as navigation for regional waterway transport. For ecosystems, it is recommended to improve the connectivity between wetlands and floodplains and restore the natural capacities of beels and natural waterbodies where possible. The unique largest mangrove forest, the Sundarbans, need to be protected by (inter) national laws and programs and should be managed to maintain its unique characteristics. Some polders on the northern border of the Sundarbans should be investigated to restore the area to historical proportions, which will improve environmental sustainability, as well as the natural wave attenuation capacities of mangroves in times of storm surges. In this sense, it is also fundamental to monitor and understand the impact of land accretion for the functioning of the Sundarbans, also in terms of flood hazard attenuation. From environmental point of view, Mongla port should be operated in such a way that it does not affect the vulnerable ecosystem of the Sundarbans. Finally, coastal pollution caused by industries with effluents and agriculture with excessive use of fertilizers and pesticides need to be controlled with proper regulations.

Last but not the least, the tidal rivers are part of an extensive network for transport of goods and people.. measures are to be taken to improve navigation possibilities by excavation/dredging and adapted cargo facilities in one hand and to optimize alternative ways of transport; specifically exploring multi-model opportunities on the other hand.

Sub-strategy CZ 2.5: Resoration of rivers for fresh water supply including river basin management for cross boundary rivers

Fresh water supply has become cruicial particularly in the coastal areas where salinity is a key challenge. In order to meet the demand of fresh water in this area as well as to minimize salinity level and its affects restoration of the rivers (including the trans-boundary rivers) are essential.

Strategy CZ 3: Reclaim New Land in the Coastal Zone

The Ganges- the Brahmaputra- the Meghna systems is carrying huge volume of sediment to the Bay of Bengal though several estuaries. Among them the Meghna estuary is the largest. The Meghna estuary has the huge potential for land reclamation as discussed before. So, increasing land availability through accretion/land reclamation in this estuary toward sea and coastal zone is the main purpose of this strategy. There are some land reclamation programmes in this area under CDSP project. Built on the past experiences further efforts are needed to accelerate the pace of land reclamation where natural process may take 60 to 80 years to build the new lands, such efforts may recduce the process to 35 years.

An enormous industrial potential can be realized through this strategy on the new lands and its direct surroundings like economic zones, tidal and wave energy production, wind energy parks, new deep sea port development, exclusive housing as well as tourist developments. Moreover, the new land may decrease the frequency and severity of the cyclone induced storm surges. But for unlocking this development potential, the flood risk needs to reduce significantly which is a huge challenge. This challenge may be dealt through a combination of land filling up to 20 m above sea level for the most critical infrastructure and assets by using the sediment from the Meghna estuary and through building dykes with mangrove belts to reduce wave run off.

Accretion and optimum use of land would significantly contribute to the regional economy and wellbeing of the local people. Accelerating the natural accretion processes with cross dams and other infrastructures in the highly dynamic environment, which would offer new lands which could be developed in a preferred way., These new lands should be used for creating necessary infrastructures for industtrila and other uses. An ample attention will be needed for mitigation or adaptation to wind or storm surge hazards by elevating platforms as well as the fresh water availability issues.

There are three sub-strategies as follows:

Sub-strategy CZ 3.1: Conduct research on morphological behaviour of the Meghna estuary to assess the effect and potential of land reclamation:

Extensive research needs to conduct to gather knowledge about the influence of land reclamation and to realize the potential of further development and artificial interventions for enhancing accretion process.

Sub-strategy CZ 3.2: Accelerate land reclamation process in the Meghna Estuary:

Building cross dams at the strategic locations (**Figure 6.27**) would be useful for accelerating land reclamation process for which potential cross dam projects could be taken with proper feasilbility studies:

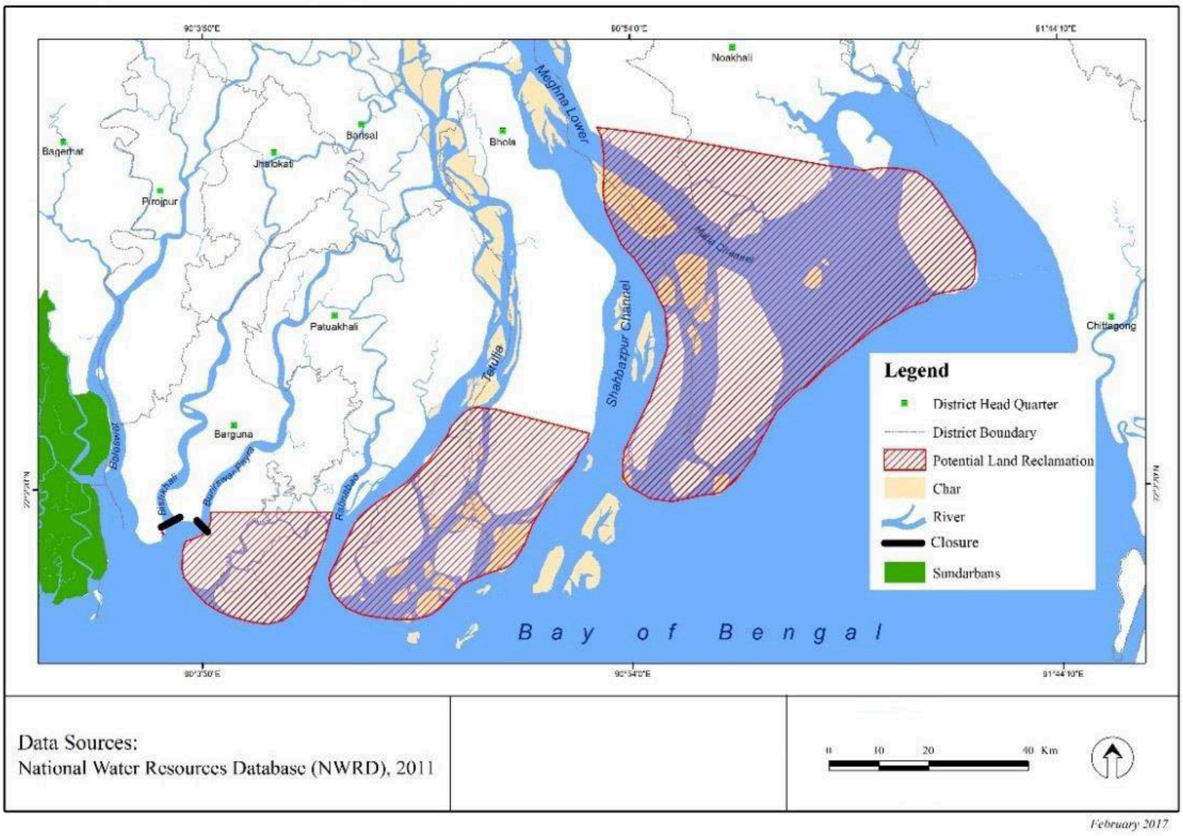


Figure 6.27: Potential Land Reclamation Areas in the Coast

Source: CEGIS, 2011

Sub-Strategy CZ 3.3: Protect, develop and zoning of the reclaimed land: Land reclaimed through accretion process need to be protected and developed with land zoing and other appropriate measures.

Strategy for the Sundarbans

The Sundarbans, largest mangrove ecosystem in the world is situated at the southern part of the country under coastal zone. The Sundarbans is developed through the process of ecological succession. Succession is the process of change in the species structure of an ecological community over time. In other words, is generally defined as the successive occupation of a site by different plant communities. The time scale can be decades or more. The community begins with relatively few pioneering plants and animals and develops through increasing complexity until it becomes stable or self-perpetuating as a climax community. The "engine" of succession, the cause of ecosystem change, is the impact of established species upon their own environments.

In an accreting mudflats such as the Sundarbans, the outer community along the sequence represents the pioneer community which is gradually replaced by the next community representing the seral stages and finally by a climax community typical of the climatic zone. Succession begins in the newly accreted land created by fresh deposits of eroded soil. The pioneer vegetation on these newly accreted sites is Sonneratia (Keora), followed by Avicennia (Baen) and Nypa (Gol Pata). As the ground is elevated as a result of soil deposition, other trees make their appearance. The most prevalent, though one of the late species to appear is Excoecaria (Gewa). As the level of land rises through accretion and the land is only occasionally flooded by tides, Heritiera fomes (Sundari) begins to appear.

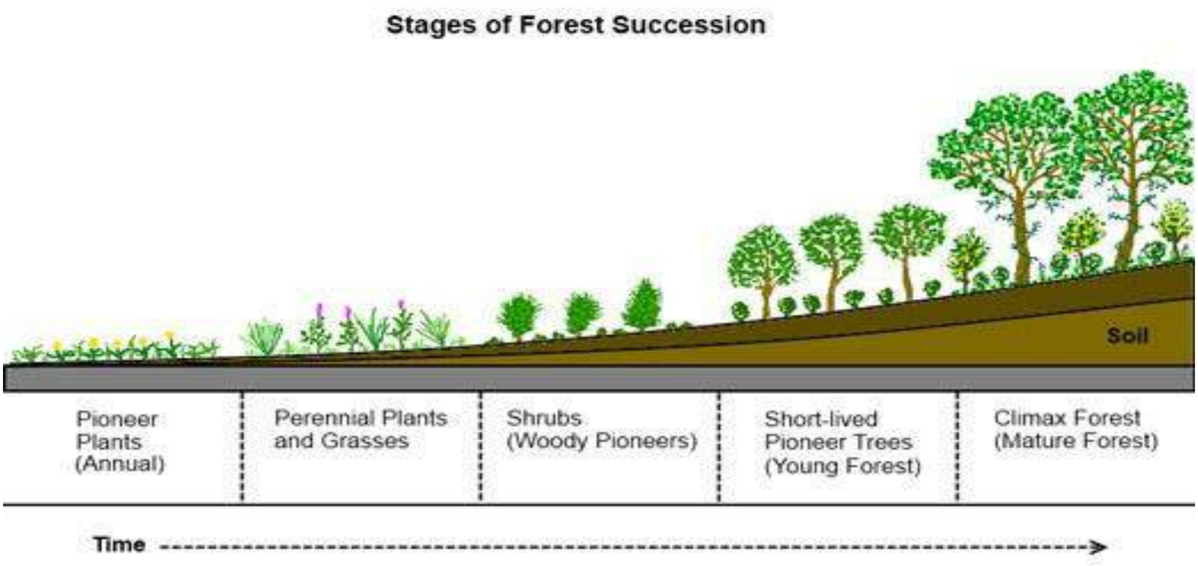


Figure 6.28: Stages of Forest Succession in the Sundarbans

Source: ***Adopted from*** **https://deepgreenpermaculture.com/permaculture/permaculture-design-principles/8-accelerating-succession-and-evolution/**

To expand the Sundarbans, government has already taken initiatives to create artificial mangrove forests. The forest will be expanded towards eastern side across the coastal region.

BDP 2100 has formulated the following strategies for expanding Sundrabans, i.e. mangrove forests:

Strategy 1: planting in all the layers of a forest at the same time

This will be done by creating the multi-tiered structure. The advantage is that one does not have to wait for each step to complete before the next one can commence. This way, one can speed up the process of forest succession immensely, and create an established forest in no time at all.

Strategy 2: Not being competitive against Nature rather being collaborative

Instead of fighting against nature and pulling in the opposite direction to the natural flow the strategy is to push in the same direction together and get to the same mature forest faster. The idea is working with Nature rather than against it, to complement Nature's efforts, so that Nature works for people, and people work for Nature.

The following measures are suggested for the expansion of the Sundarbans as well the mangrove forests under BDP 2100:

1. Using existing plants to build soil;

2. Introducing only hardy plants initially;

3. Raising the levels of organic matter in the soil artificially;

4. Substituting the plants of the forest succession stages with useful species.

Strategy 3: Maintenance of perennial tidal flow

Regular maintenance of required flow is critical for life and ecosystem to thrive in a mangrove setting such as the Sundarban. As the narrow but, relatively deeper dendritic channels of the forest are being silted up due to decreased upstream flow, regular dredging in channels such as Ghashiakhali and others where as required has to be done.

6.6.4 Adaptation Pathways

Where uncertainty is important, adaptation or strategic pathways help in understanding, scheduling measures and developing optimal combinations for measures to meet the policy goals. The Delta scenarios do not predict one single future; rather they describe different plausible stories of possible future developments. The scenarios have been developed to identify bottlenecks arising out of uncertain future developments and represent 'extreme edges' of possible outcomes. Measures that are affected strongly in terms of their effectiveness by external conditions (climate, economic development, technology-innovation) may require further studies or can be delayed until actual conditions become apparent. Other measures, such as improved provision of safe drinking water and wastewater treatment for large urban centers are considered basic measures which can and should be taken dependent of each scenario. Logically, the degree of uncertainty is very high for the timeframe beyond, moderate to high between 2030 and 2050 and moderate up to 2030. As can be observed from the scenario development, climate change is but one of the uncertainties, with socio-economic and upstream developments playing a significant role as well. Against the background of the potential strategies developed above, a number of pathways have been developed. It is also logical that for the freshwater strategy, the key uncertainty is related to water availability.

The issues of waterlogging and surface water salinization are well-suited to demonstrate the use of adaptation pathways for the coastal zone in Bangladesh. It should be noted here, that the effectiveness of measures of solving the problem is now based on expert judgement and ideally should be based on model calculations.

Waterlogging -diminuish drainage congestion

Several polders and areas in the Ganges Tidal Plain West experience persistent waterlogging for which rain water cannot adequately be drained. An adaptation pathway is created for the set of solutions proposed before:

1. Padma barrage to effectively improve drainage capacity of peripheral rivers in the dry season. It is estimated that this intervention may be effective for 30 years under the most favorable future scenario (Moderate). In the least favorable situation,it is estimated the barrage will only be effective for 20 years.

2. Maintenance dredging in the Gorai: The Gorai being the main freshwater source of the area, maintenance dredging will improve drainage conditions of the peripheral rivers for a short time (2-3 years). Maintenance dredging is a no-regret measure and supports every other proposed measures in the long term.

3. TRM : This involves cutting embankments at strategic locations in order to bring polders for a certain period (±10 years) under normal tidal influence. Sediment will be supplied to the lowest locations, and tides will scour the peripheral rivers, improving the drainage capacity of the water system. This measure can have large socio-economic consequences for the current population, and they have to be compensated for it. It is estimated that TRM at strategic locations in the coastal zone may improve drainage capacity for 20 years in the most favourable future and 15 years in the least favourable. TRM can be applied in a cyclic way.

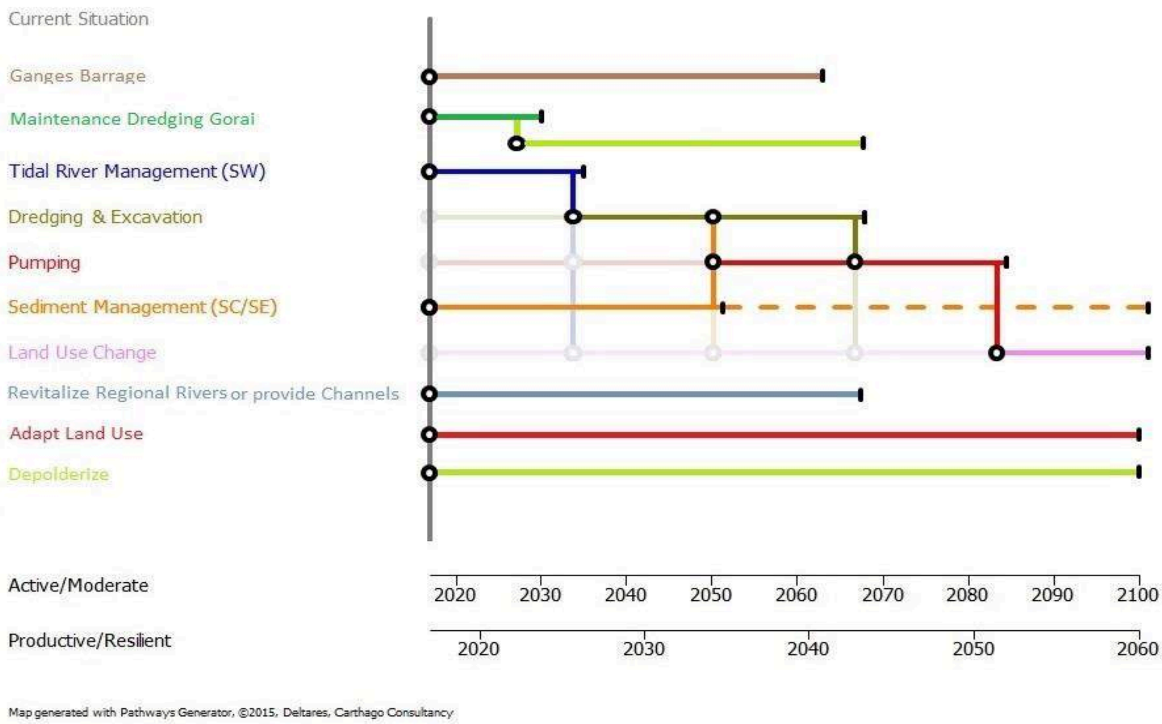


Figure 6.29: Adaptation Pathway for Coastal Waterlogging

4. Pump and drainage improvement: water logging within drainage controlled areas (e.g. polders) can be diminished by small and large mechanical pumping. This measure is including improvement and reparation of the current drainage infrastructure (e.g. khals, sluices). These measures will improve the situation for several years (10- 20 years in favourable conditions, depending on pumping capacity, 7-15 years in the least favorable future conditions).

5. Revitalize regional rivers or provide channels: Several regional rivers have already died in the last decades. A study should be undertaken to investigate potential revitalization projects of the regional rivers or providing supply channels (water and/or sediment) from the Ganges tidal floodplain east or Lower Meghna estuary. This measure comprises a huge intervention in the water system of the Ganges tidal floodplain, but first estimates show effectiveness for more than 60 years in the most favorable future conditions to more than 40 years in the least favorable.

6. Adapt land use: As is currently observed in the area and what may be considered as autonomous adaptation. Many areas are increasingly exploited for aquaculture, sometimes in rotation with rice or fish production. It, however, requires a minimum water quality level (e.g. salt level, biotic deterioration), that can be managed with adequate water infrastructure. It further, changes the polder configuration regarding land management and sometimes lead to conflicts between traditional farmers, fisherman and fish farmers. This autonomous adaptation is considered effective for the long term.

7. De-polderize: This process is often seen as the last resort, when living conditions have deteriorated below an acceptable minimum. This measure can also be used in a strategic sense, as it may enhance drainage capacity in its neighborhood or enhances protection/restoration of environmentally sensitive areas (e.g. the Sundarbans). As population density in Bangladesh is generally high, this measure may be very costly in social terms in order to resettle the current population. When considered, however, as part of an integrated strategy for the coastal zone, it may be of interest considering national stakes. This measure is also considered effective for the longer term.

TRM was introduced in Bangladesh, in order to tackle the problem of water logging which involves taking advantage of natural tidal movement in the river and adjacent low lying flood plains. TRM allows natural movement of tide from the river to an embanked low lying area (beel) through a link channel. During high tide, sediment laden water enters to the low-lying area where the sediments are deposited due to reduced velocity and long duration of storage. During ebb tide the tidal water flows out of the low-lying area with reduced sediment load and erodes the river bed and bank downstream. The natural movement of flood and ebb tide in the river and low-lying area increases the drainage capacity/conveyance of the river through scouring and maintains the river navigability. Subsequently the low-lying area is raised considerably due to deposition of silt. The TRM process is an example of building with nature and a resilient measure for water-logging, river sedimentation and subsidence. TRM was first applied in the Khulna-Jashore Drainage Rehabilitation Project (KJDRP).

In 2013, BWDB prepared a Master Plan to manage the silt coming in the sedimentation prone rivers during high tides and deposited due to lack of sufficient upstream fresh water flow during dry season through TRM as a short to medium term solution of water logging problems in the Southwest Region of Bangladesh. The Master Plan suggested the following measures in Sathkhira, Jashore and Khulna.

Drainage Improvement of Polders 1, 2, 6-8 & 6-8 (Ext.) under Satkhira district: The project covers Kolaroa, Satkhira Sadar, Debhata, Assasuni and Tala Upazillas. The drainage system of this area is comprised of Ichamoti, Marirchap, Betna, Parulia Sapmara, Kholpetua and Kobadak Rivers and Satkhira Khal alongwith a vast network of internal drainage khals. At present, these rivers have lost their conveyance capacity significantly due to river bed siltation. The Master Plan provided a comprehensive water management plan for polder 1, 2, 6-8 and 6-8 (Ext.) and management of sediment for the restoration of these rivers and adjacent drainage khals through TRM and structural measures. As per the Master Plan, TRM can be successfully operated continuously in the Betna and Marirchap river basins using the selected beels for about 40 years for sediment and drainage management. It envisages utilising Sukdevpur and Ticket, Matidanga and Jheelmari, Seeram kathi and Bughmara, Hajikhali, Amudkgali and Govendapur as well as Amtali,Durgapur and Chapra beels sequentially.

Sustainable Drainage and Flood Management of Kobadak River basin in Jashore and Satkhira districts: The Kobadak river flows through Jashore, Satkhira and Khulna districts. More than a hundred years ago, the Kobadak lost its connection with the Mathabhanga river and became a mere seasonal and tidal river. As a result, the flows from upstream has reduced expediting siltation process. In the early sixties the tidal flow of the Kobadak used to flood and deposit the sediment on the adjacent flood plain during high tide. Human interventions such as, encroachment of river by constructing bridge, houses, cultivable area and construction of polders restricts the tidal flooding. As a consequence, the river experiences huge siltation and many of the river/channels/khals in the area lost its conveyance causing severe drainage congestion. This intiative envisages to utilize over a period of 35 years sequentially, the TRM of all seven beels (Pakhimara, Harihar Nagar,Rajapur, Harikhola, Dalua and Jalalpur) along the downstream reaches of the Kobadak river for sediment management and increase of tidal prism and drainage capacity in the river. The other components are capital dredging of rivers and excavation of khals, construction of dwarf embankments etc.

Drainage Problems in the Bhabodah Area: The area comprises the Upazillas of Jashore Sadar, Manirampur, Abhaynagar, Keshabpur of Jashore district and Dumuria, Fultala, Batiaghata and Daulatpur of Khulna district. In order to solve the longstanding water logging problem in Khulna and Jashore area, the wellknown Khulna-Jashore Drainage Rehabilitation Project (KJDRP) was implemented by BWDB during 1994-2002. After implementation of the project the prevailing drainage congestion was removed substantially that resulted in increased agricultural production and socio-economic development. However, northwestern part of the KJDRP area, under Abhaynagar, Manirampur and Keshabpur upazilla, namely Bhabodah area had experienced severe drainage congestions during October 2005 to the end of 2006. Huge sedimentation took place in the Hari river, as the operation of TRM basin was stopped. It appears from the field data analysis that the rate of sedimentation in the Hari-Telegati river during three months from February to April is about 1.2 million tonnes. It implies that in absence of TRM the rivers experience huge sediment deposition causing drainage congestion. The severe waterlogging problems and substantial loss of agricultural production, degradation of social, environmental and economic conditions that were experienced in the year 2005-2006 in the Bhabodah area demand sustainable sedimentation management in this area through TRM.

The proposed sequential operation of TRM basin has been suggested for sediment management and maintaining sustained drainage capacity of the Hari River since all existing 6 beels are effective in generating required tidal prism. These six beels would be used as TRM basin/tidal basin for a period of 40 years for sediment management and sustaining the required drainage capacity of the Hari River. There are four beels along the Upper Bhadra River and these are effective for TRM basin for maintaining the drainage capacity of this river. There are five beels along the Gengrail River that can be used as effective TRM. Hamkura River system has also five beels to be served as tidal basin.

Salinization

Increasing dry season salinization of the surface water in the Ganges tidal floodplain (west part) is an important issue of the fresh water supply in the coastal zone. Improving the fresh surface water situation in the coastal zone will resolve problems for many sectors in need of freshwater. Fresh water is fundamental for boro rice irrigation (dry season), industrial demands, domestic use (drinking water supply) and last but not the least for maintaining biodiversity in the Sundarbans.

Some of the measures proposed here are similar to the measures to diminish drainage congestion. One of the main questions here is to what extent Bangladesh wants to sustain rice agriculture as main land use and income activity for the rural population in this coastal zone. Several measures are focused on restoring freshwater conditions fully (if possible), others are focused on adapting to (new) geophysical conditions.

The following measures are proposed in addition to the measures listed above:

1. Padma barrage: This is needed to effectively improve drainage capacity and freshwater flow of peripheral rivers in the dry season. It is estimated that this intervention will still be effective when salinity levels reach 16 ppt under the most favorable future scenario (Moderate).

2. Revitalize regional rivers or provide channels: Several regional rivers have died the last decades in this region. A study should be conducted to investigate potential revitalization projects of the regional rivers or providing supply channels (water and/or sediment) from the Ganges tidal floodplain east or Lower Meghna estuary. This measure comprises a huge intervention in the water system of the Ganges tidal floodplain, but may be effective up to salinity levels of 10 ppt.

3. Maintenance dredging Gorai Maintenance dredging in the Gorai: The Gorai being the main freshwater source of the area, maintenance dredging will improve drainage conditions of the peripheral rivers for a short time (2-3 years). Maintenance dredging is a no-regret measure and supports every other proposed measures in the long term.

4. Salt-water sea barriers to regulate dry season flow: Large salinization barriers may be constructed in the large river mouths to the sea. This may be not feasible for the river mouths flowing into the Sundarbans, because of environmental concerns. This measure may be of greater use in the Baleswar and Tetulia River mouths or offtakes, when climate change, sea level rise and uncertain dry season flows may increase salt pressure.

5. Groundwater extraction from deeper aquifers: This will investigate sustainable groundwater extraction possibilities from deeper aquifers in the coastal zone. This measure can solve local problems, but certainly will not cover the total coastal zone. This measure may be effective where salinity is above 8 ppt.

6. Rehabilitate polder water infrastructure: current polder infrastructure need reparation on different aspects. This may effective to surface water salinity levels of 5 ppt.

7. Salt-resistant crop farming: New crop varieties may be developed to grow in saline environment up to 5 ppt.

8. Adaptation to shrimp or crab farming: Diversification of cropping patterns including a cycle of aquaculture or complete transition to aquaculture is considered the autonomous adaptation action of the current population. Water salinity levels upto 8 ppt can be managed with this type of farming.

9. Non-farm income activities or inland migration: This is often perceived as a measure of ultimate resort. However, the government can strategically resettle people or promote subsidiary programmes to generate employment in other sectors.

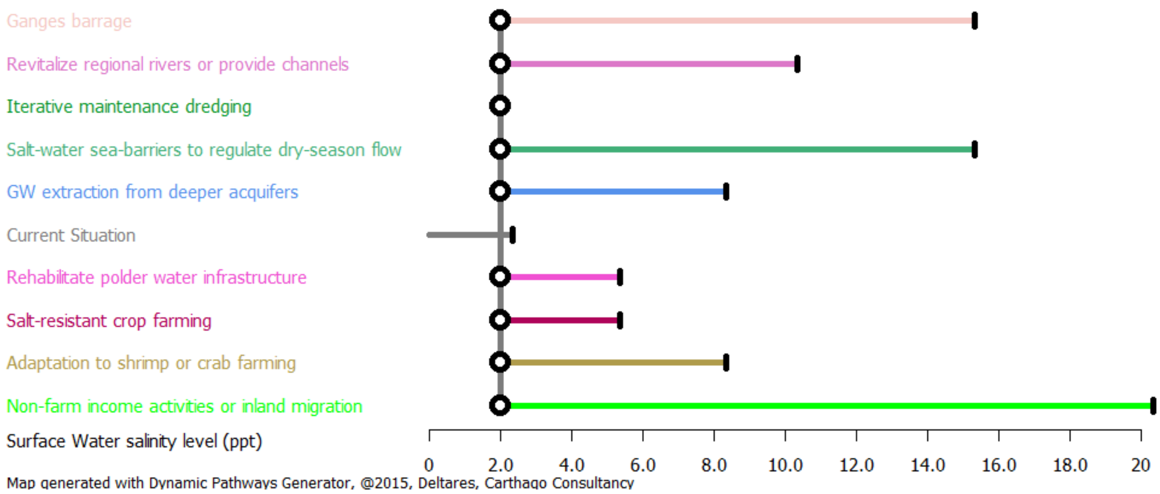


Figure 6.30: Adaptation Pathway for Coastal Salinization

6.7 River Systems and Estuaries Strategy

The Major Rivers of Bangladesh are the backbone of the delta system and therefore play a central role in the BDP 2100. A long term strategy for these rivers therefore has national importance. Many of the water-related challenges in Bangladesh are related to the dynamic mighty rivers.

Key Issues 2015

Five key issues were identified for managing water resources in the River Systems and Estuaries hotspot which are discussed in the following section: Danger Level (DL) is a locally used level that is often related to the height of the lowest embankments built by local communities and that approximately equals 'bankful flow'. Safety Level (SL) is defined as the flood level that is exceeded once in every 25 years, on average. The embankments constructed and maintained by the BWDB are generally designed to withstand flood levels up to SL, so with 1/25 year safety level. The embankment around Dhaka is reported to have a 1/50 year design safety. A design safety of 1/10 is sometimes applied in rural areas. In all cases, the actual stability of embankments may be less due to lack of repair after the monsoon season or due to man made factors such as excavation of side slopes by local people in need for living space.

Flood risk

Related problems are:

- lack of protection against damage during disruptive floods (between DL and DL+1m)
- lack of protection against damage during severe floods (between DL+1m and SL)
- lack of protection against damage during devastating/extreme floods (above SL)

The above problems may be aggravated due to:

- external factors, such as:
    - increased peak discharges due to climate change and/or upstream developments
    - sea level rise resulting in a similar rise of the downstream water level in the Meghna, the Padma and possibly also in part of the Ganges and the Jamuna;
    - subsidence, mainly in the coastal polders due to tectonic and anthropogenic influence and due to compaction of peat layer;
    - sediment waves as the result of earthquakes and landslides.
- man made factors, such as:
    - uncontrolled reclamations by local communities;
    - encroachments primarily occurring along urban water fronts due to people settling in floodplains thus reducing the discharge/storage capacity of these plains;
    - deforestation, resulting in increased sediment loads reducing the transport capacity of the rivers;
    - eventually construction of embankments by themselves reduces the storage capacity for flood waters;
    - constrictions by constructing bridges.

The term 'flood', in this respect, refers to the extreme events that disrupt society and that cause widescale damage to crops, property and infrastructure. Apart from the duration and the depth of the flood, the damage to crops due to floods highly depends on when and where the flood occurs in relation to location and harvest period. Floods as described above must not be confused with regular flooding during normal monsoon periods. In general, farmers are well adapted to regular flooding and even rely on seasonal inundations of their land for fertility enrichment to grow crops.

River bed dynamics and river bank erosion

The major rivers carry large amounts of sediments, especially during the monsoon season when discharge volumes and flow velocities are relatively high. The large sediment load is one of the reasons why the Ganges and especially the Jamuna are braided rivers, characterized by a migrating pattern of channels and char lands.

The unpredictability of this process and the enormous amounts of sediment transported by the Major Rivers pose the following problems:

- uncertain shifting of channels, hampering navigability and endangering stability of river banks and char lands
- siltation at the connections of the major rivers with tributaries and branches, hampering the inflow of fresh water (during the dry season) or the drainage of medium or minor river basins (during the monsoon period)

River bank erosion is asevere problem because of its social consequences. People living alongside river banks or on chars in unprotected areas outside the embankmentsare forced to move elsewhere when the river starts to erode their land. Mostly, these 'landless' migrate to the large cities and become the 'poorest amongst the poor'.

Depending on the location, river bank erosion can be stopped or prevented with a combination of river bank protection works and training works. The investment required, however, is often postponed until the embankment itself is threatened by encroaching river bank erosion.

Fresh water

During the dry season, areas like the Barind and GDAsuffer from lack of fresh surface water, resulting in agricultural, ecological and social problems. The lack of fresh water during dry season is due to:

- insufficient inflow of fresh water during the dry season from India to Bangladesh, because of operations of the Farakka Barrage and (in future) maybe aggravated by the Indian River Interlinking Project
- insufficient connectivity between major rivers and their distributaries
- the large demand for fresh water for irrigation allowing three crops a year.

Ecology

The problems related to this are:

- lack of acceptable fish migration & breeding conditions, due to
    - lack of fresh water free from pollution
    - absence of designated (protected) sanctuaries for safe reproduction
    - insufficient interconnection between river branches and loss of floodplain connectivity
    - absence of vegetation at the catchment area
- loss or neglect of ecological values (assets) of wetlands, due to
    - demographic growth and uncontrolled settlements
    - intensive agriculture activities
    - inequity of land ownership stimulating the continuous search for new land
    - absence of designated (protected) ecological sanctuaries

Waterway transport

Waterway transport volumes in Bangladesh are relatively low and mostly confined to agricultural cargo. With developing economy, it is expected that waterway transport will grow due to its competitive low cost, regardless of a simultaneous expected increase of transport by road and by rail when infrastructure is improved. Present problems regarding waterway transport are:

- lesser amount of cargo in the rural areas, except agricultural products
- insufficient draft as per waterway classification in the dry season
- absence of reliable information on position of navigable channels
- insufficient reliable cargo transition facilities due to instable river banks and migrating channels
- insufficient connectivity between major, medium and minor rivers, partly due to external factors (siltation in offtakes) and partly due to human factors (cross-dams to reclaim land).

6.7.1 Key Issues 2050

The impact and therefore relevance or importance of key issues will change as a result of uncertain factors like climate change, demographic growth or worldwide economic development.

Distinction is made between a change of a hazard itself (floods, drought, river bank erosion) and a change in the impact of a hazard. The impact of a hazard like drought may for instance increase with growing population, because more people will then be effected by drought.

The change of a hazard itself is the first-order change. The change in the impact of the hazard is a second order change. Note that the impact not only changes with a change of the hazard itself (like higher flood levels) but also with different economic or demographic scenarios that developed with the passing of time.

The conclusion is that, if no measures are taken, in future (2050) nearly all hazards and impacts are expected to worsen or, at best, stabilise at the present undesired situation, regardless of the stages of development.

The above scores are briefly explained below:

Key issue: Flood Risk

The flood hazard increases with increasing climate change. Impacts of floods increase with increasing average economic value in flood-prone areas (productive) or with increasing non-flood-resilient population

River Bed dynamics

River bed dynamics are scenario-independent, however the impact of uncontrolled siltation increases with increasing use of the Major Rivers for waterway transport .Also, de-forestation may negatively impact siltation rates in scenarios with large population growth combined with moderate economic growth. Moderate sediment increase is useful for tidal plains to compensate the subsidence and the sea level rise

River Bank Erosion

Hazard of river bank erosion increases with increasing climate variability because bankfull flow - which is the condition when risk for bank erosion is largest - is then likely to occur more frequently. The impact of river bank erosion increases with increase of average economic value in flood-prone areas and with increasing population density in the unprotected areas along rivers and on charlands .

Fresh Water Supply

Lack of fresh water increases with increasing climate variability, depending on institutional strength to negotiate with India on water sharing. The impact of a lack of fresh water increases with increasing dependency on fresh water .

Ecology

The ecological value of a certain river system is, amongst others, determined by its biodiversity, its conditions for reproduction and its importance for rare species. Ecologic values change (become less) with increasing population. Confinement of urbanization and industrialization in concentrated areas, with proper environment-friendly central facilities (resilient) will be beneficial to ecologic values. The impact of changing ecologic values to Bangladesh is large, both in scenarios with low economic development as well as scenarios with higher economic development. This has to do with productivity of agriculture and fishery, with potential for ecotourism and - above all - with the quality of life in Bangladesh.

Waterway transport

Increasing climate variability is expected to negatively affect navigability of the rivers due to more frequent and more extreme high and low water levels. The impact of this change becomes more relevant with increasing use of the River Systems and Estuaries for waterway transport .

6.7.2 Detailed Strategy

The preferred strategies for the River Systems and Estuaries are discussed below. The preferred strategies consist of a sequence of sub-strategies. This sequence is found by following a preferred, adaptive pathway. Along the pathway, with the economic development of Bangladesh as the main driver of change, decisions have to be made or initiatives have to be taken. Depending on decisions made and initiatives taken, a pathway consists of a series of sub-strategies.

The sub-strategies that together form a strategy are theme-based clusters of projects, as illustrated in **Figure 6.31**.

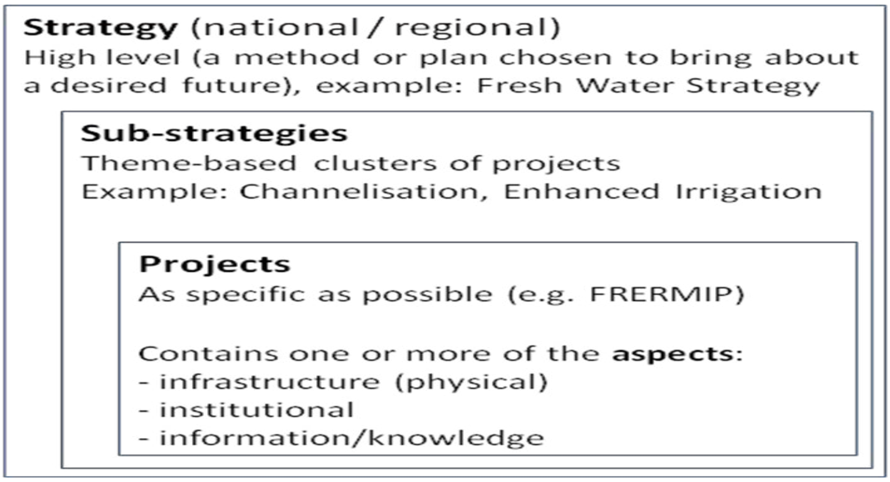


Figure 6.31: Inter-relationship between Strategy, Sub-Strategies and Projects

Strategy RE 1: Provide adequate room for the river and infrastructure to reduce flood risk

Sub-strategy RE 1.1: Reduce flood risk by construction of new embankments and repair, upgrade or maintenance of existing embankments

Sub-strategy RE 1.2: Maintain discharge and drainage capacity of rivers, tributaries and branches by strategic dredging

Sub-strategy RE 1.3: Improve flood resilience of properties and infrastructures

Sub-strategy RE 1.4: Secure discharge and storage capacity by allowing space for the river and by avoiding or removing encroachments and by avoiding constriction by bridges.

Sub-strategy RE 1.5: Reduce extreme discharges

Adaptation Pathway regarding flood risk: At present sub-strategy RE1.1 is the preferred short term strategy. Further economic development towards middle-income status will ask for flood protection works with higher safety levels in order to manage flood risk to remain in balance with the protected economic value. It is expected that differentiation in safety levels is necessary to sustain the high safety levels needed in the high-income scenario. Besides, differentiation is also an instrument to manage the geographic spread of urbanization and economic investments. Areas with high safety levels will attract economic investments and urbanization. In this way, through careful planning, economic developments can be sustained with manageable flood risk and with affordable cost.

Sub-strategy RE1.2 (maintain discharge and drainage capacity by strategic dredging) is considered to be no-regret by adjusting the scale of the projects involved. The sub-strategy is considered to be most effective for regular flood and minor floods, to make sure that floodplains are well-drained and well-irrigated. Strategic dredging is considered to be most effective on local scale, by removing bottle-necks and restoring/maintaining connections between rivers and floodplains.

The preferred strategy for the short term also includes enhanced flood-proofing of properties and infrastructure in flood prone areas (RE1.3) and removal of encroachments in a way that respects social consequences. As Bangladesh only covers a small part of the Ganges and the Brahmaputra river basins, transboundary cooperation remains crucial. Transboundary efforts are undertaken to reduce peak discharges or to avoid that peak discharges increase due to unrestrained construction of upstream embankments (RE1.5).

In particular, the following projects are proposed to implement the above-described preferred strategy:

(1) Formulation of an Integrated River Master Plan for dredging and channelization;
(2) Feasibility study of flood embankments along all major rivers, including definition of different safety levels depending on the (intended, planned) economic value and urban potential of the protected areas;
(3) Feasibility study to flood-proof infrastructure design (roads on embankments, railways, floating bridges). This applies to both international transport corridors (like China - Bangladesh - India corridor) as well as national corridors between large cities (like Dhaka - Chattogram corridor);
(4) National river basin settlement policy that investigates encroachment and settlement in former flood plains and river basins and that explores alternatives either being re-settlement (including rehabilitation) or apply 'living with water' concepts that respect to need for water storage and drainage.

Strategy RE 2: Improvement of the conveyance capacity as well as stabilize the rivers

Sub-strategy RE 2.1: River stabilization and channelization with use of combined river training works and river bank protection

Sub-strategy RE 2.2: Controlled and accelerated stabilization of newly formed (char) lands and land reclamation

Adaptation Pathway regarding river stabilisation: River bank erosion mainly occurs during bank-full flow. To-date, sub-strategy RE2.1 is applied locally at the most critical spots. It is expected that, with economic development of Bangladesh, this will be the approach for all locations that need protection, primarily for the urbanized and economically valuable areas. With increasing river bank length to be protected, a key decision however emerges: should river bank protection works be applied at all locations where economic and urban development so requires (bank protection follows) or should economic and urban development only be allowed along river banks that can be stabilized at reasonable cost (bank protection leads). The Adaptation Chart shows that the 'bank protection follows' pathway ultimately, with ongoing economic development, results in a system with fully stabilized river banks (red boxes). This pathway is considered to be less-adaptive, because it is very costly to respond to future changes. Also, large scale dredging may be needed to compensate for the morphological impact of full river stabilization. The adaptive pathway in this case is to align urban and economic developments with river management in general and with river bank stabilization works in particular. Obviously, this requires an integrated cross-sectoral approach involving multiple institutions. With ongoing economic development, however, such integrated approach becomes more feasible and also more important to avoid a lock-in. Moreover, the Adaptation Chart shows that other important sub-strategies related to land reclamation and sediment balance may only be applied in a sustainable way when balanced with natural river dynamics.

In particular, the following project is proposed:

(1) Integrated the Jamuna-the Padma Rivers Stabilization and Land Reclamation Project supported by feasibility study on hydrological and morphological attributes.
(2) Study of long term effects of river channelization and land reclamation on river bed morphology and discharge capacity during the monsoon season and on downstream morphologic effects in the Lower Meghna Estuary

Recommendations on sub-strategy RE2.2 (stabilisation of char lands and land reclamation) in relation to socio-economic development: The Ganges- the Brahmaputra- the Meghna systems are carrying huge volume of sediment to the Bay of Bengal. After avulsion, the Jamuna River has gone through a rigorous metamorphic changes such as widening, changing planform from meandering to braided and migration towards west. This is due to the changes of the role of different drivers in time and space, such as flow diversion from the Old Brahmaputra to the Jamuna, the sediment slug generated by the 1950 Assam earthquake, and human interventions. The change in width was enormous during the 1910s to 1940s and 1970s till date. Because of higher sedimentation rate, lots of chars has formed in the Jamuna and the Padma. The Jamuna is a braided river and carries huge loads of sediment and therefore sediment management for the Jamuna and other rivers is an important issue to be looked into carefully.

As a consequence, as far as the availability of sediment and the present width of the rivers is concerned, there is an opportunity for land reclamation in the major rivers in this Jamuna and Padma rivers. The Flood and Riverbank Erosion Risk Management Investment Program (FRERMIP) has provided an outline of river stabilization programme for the Jamuna and the Padma. It has been estimated that an area of 0.157 million ha of land could be reclaimed as a result of the stabilization of the Jamuna-Padma river systems. The reclaimed land could be used for agricultural, industrial, settlement and recreational purposes (**Box 6.1**). The FRERMIP has identified the potential locations of land reclamation which is illustrated in Figure 6.32.

Accretion and optimum use of land would significantly contribute to the regional economy and wellbeing of the local people. Accelerating the natural accretion processes with cross dams and other infrastructure in this highly dynamic environment, may offer a large piece of newly gained land, free to be developed in the preferred way. All accreted and reclaimed land should be put to value added use particularly for urban and industrial needs with necessary infrastructure like dikes, high quality road, rail, water transport connection, recreational area with adequate power and energy supply.

At the downside of it, it should be stressed that land once reclaimed and developed, will need continuous protection (river training works, river bank protections) against the highly dynamic river. In absence of a clear forecast on the risks and cost involved with respect to large-scale land reclamation and river channelization, it is strongly advised to start small (RE2.1), to focus on suitable and economically most viable spots (RE2.1) and to carefully tune reclamations with the sediment balance (RE2.2). Reference is made to the related key decisions (blue dots) shown in the Adaptation Chart for RE2.1.

Box 6.1: Strategic Framework for River Management of Jamuna and Padma Rivers

Flood and River Bank Erosion Risk Management Investment Program (FRERMIP) has provided an outline of river stabilization program for the Jamuna and the Padma and preliminary master plan for dependent areas (north-central zone). FRERMIP has five development objectives as: (i) reduced flood and erosion risk, (ii) reclaimed lost flood plain, (iii) developmental value capture in the study area resulting from the stabilized river environment expressed in terms of poverty reduction, intensified agriculture, peri-urban industrial development, etc., (iv) restored navigation, and (v) restored riverine ecology.

The Strategic Framework emphasizes the need for adaptation and flexibility. It emphasizes "hard" interventions in the short run (to 2030) and socio-economic value capture in the medium run (to 2040 and beyond). The Strategic Framework consists of seven strategic Thrusts:

(1) Stabilizing the River Corridor: The first intervention along the Main Jamuna – Padma River course is to control river bank erosion;

(2) Land Reclamation: Land reclamation through Geo-bag erosion protection, plus flood embankments, will result in 150,000 ha of land being reclaimed, enough land to settle at least 1.8 million people.

(3) Flood Risk Reduction: Flood risk reduction through construction of flood embankments will protect livelihoods, provide levees for improved road accessibility, incentivize more intensive agriculture, and enable urbanization.

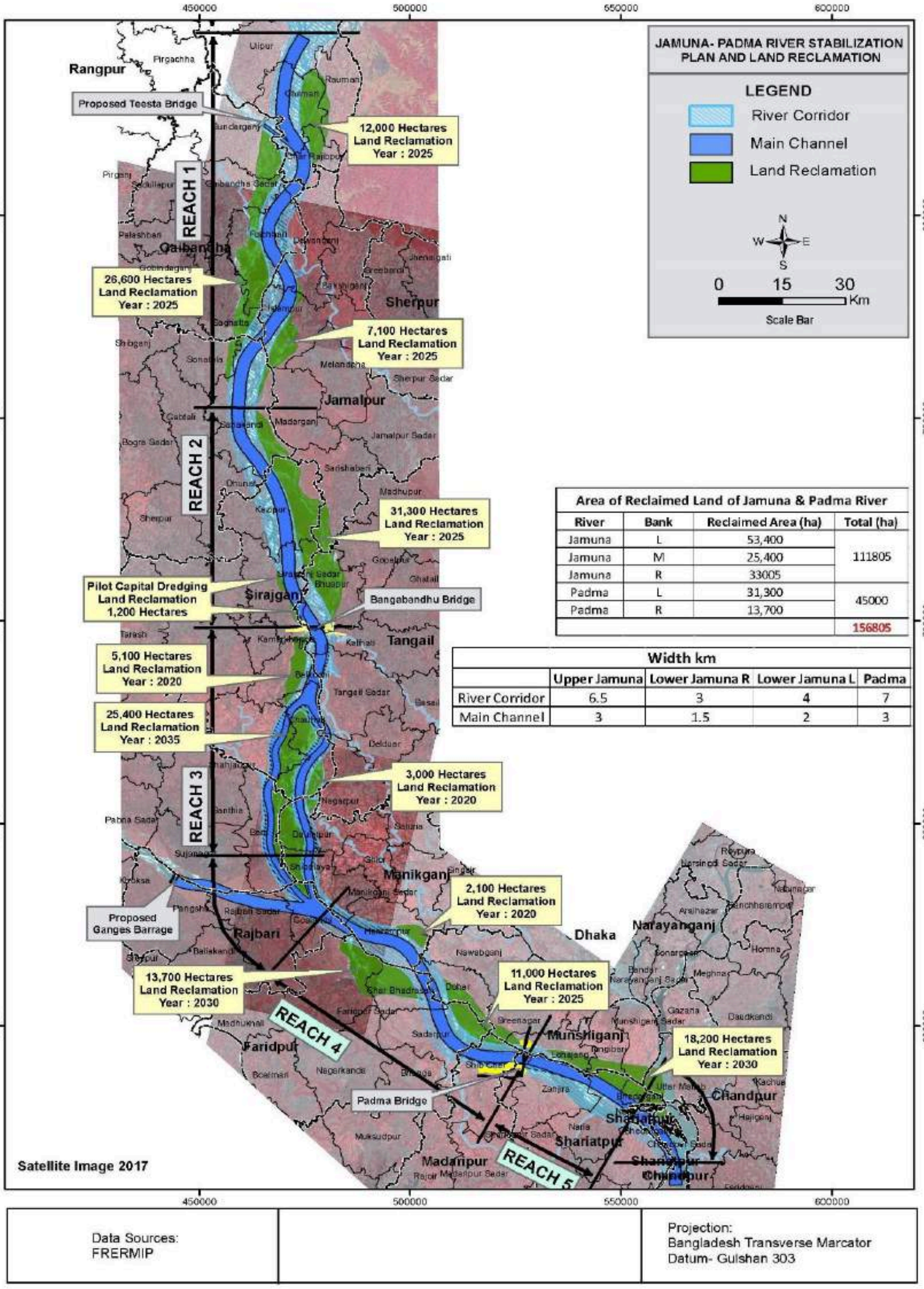
(4) Distributaries Restoration: Distributaries will be stabilized by the construction of off-takes for dry season inflow by constructing Flood Barriers, improving reliability of water quantity and quality year-round in the study area, including Dhaka city.

(5) Navigation Restoration: Navigation would be restored on the rivers in study area by establishing and maintaining safe navigation channels during low flow periods, utilizing low spurs, without restricting the cross section of the river during flood discharges.

(6) Increased Land-Based Productivity: The prime benefit strategy implementation would be to enable high value economic activity, and commensurate human development on reclaimed land, through intensified agriculture, and very importantly by enabling an industrial peri-urban area to be developed at the south of Dhaka employing up to a million workers in manufacturing, propelling Bangladesh to middle income status and beyond.

(7) Environmental Enhancement: Environmental protection zones will be designated along the river courses enabling environmental restoration, and providing flora and fauna habitat.

If the Strategy is implemented, environmental situation in the study area will be improved. Large scale benefits will be manifest in: (i) dramatically decreased poverty levels, (ii) significantly enhanced agricultural productivity, (iii) world-class industrialization with large-scale employment creation, (iv) population migration to areas providing higher standards and quality of life, (v) restored navigation supporting mass scale container barge, feeder vessels, and tourist cruise boat traffic, and (vi) restored riverine ecology.



Area of Reclaimed Land of Jamuna & Padma River			
River	Bank	Reclaimed Area (ha)	Total (ha)
Jamuna	L	53,400	111805
Jamuna	M	25,400	
Jamuna	R	33005	
Padma	L	31,300	45000
Padma	R	13,700	
			156805

	Width km			
	Upper Jamuna	Lower Jamuna R	Lower Jamuna L	Padma
River Corridor	6.5	3	4	7
Main Channel	3	1.5	2	3

Figure 6.32: Jamuna Padma River Stabilization Plan and Land Reclamation

Source: FREMIP Project, BWDB, 2015

Strategy RE 3: Provide fresh water of sufficient quantity and quality

Sub-strategy RE 3.1: Secure sufficient fresh water transboundary inflow during the dry season

Sub-strategy RE 3.2: Restore and maintain flow distribution (connectivity) from main rivers to branches and floodplains

Sub-strategy RE 3.3: Optimise the distribution of fresh water by water retention and flow diversion

Adaptation pathway regarding availability of fresh water:

An obvious no-regret is to invest in transboundary negotiation and cooperation in order to ensure sufficient fresh water inflow in future. A parallel sub-strategy is optimisation of the distribution of fresh water by water retention and flow diversion (RE3.3). This sub-strategy involves construction of barriers and dams to retain or divert water. It is considered to be adaptive (marked green) as long as it is implemented at local sub-district scale to sustain the delicate interaction between agriculture and irrigation. The key decision that emerges here is the following: should emphasis on the longer run be put on local, small-scale interventions in combination with reduction or optimisation or agricultural water consumption, or should large scale interventions like the Padma and the Brahmaputra barrages be implemented to allow for continuous wide-scale agricultural land use. Large-scale and large-impact interventions like the Padma and the Brahmaputra barrages are however not adaptive in the sense that the considerable investments made must be associated with lifetimes of the order of 50 years or more. Still, as shown in the adaptation chart by the dashed line, large scale water retention (for example the use of barrages in the major rivers) and diversion potentially contributes to the restoration and revitalisation of ecosystems.

In particular, the following projects are proposed for the short term:

(1) Impact study of transboundary projects on the dry season flow of the Ganges and the Brahmaputra, including projects such as the Indian River Interlinking Project
(2) Study the impact and feasibility of large scale water retention prior to implementation in order to know the additional cost associated with the mitigation of possible adverse effects, primarily increased net siltation upstream of the barrage causing flood levels to rise

Strategy RE 4: Maintain ecological balance and values (assets) of the rivers

Sub-strategy RE 4.1: Preservation of ecosystems

Sub-strategy RE 4.2: Restoration and revitalization of ecosystems including wise use of resources

Adaptation pathway regarding ecological assets: Implementation of these sub-strategies is independent of the extremity of drought, which is why they are shown below the dashed line. To start with preservation of ecosystems at a pace that is aligned with transformation of an agriculture-based economy towards a modernized and diversified economy. Once ecosystems are preserved and well managed, sustainable ecotourism can be developed. Development of riverine ecosystem habitat preservation program for plants, wildlife, fish and birds including an assessment of endangered species which could be undertaken by a number of relevant Ministries.

Strategy RE 5: Allow safe and reliable waterway transport in the river system

Sub-strategy RE 5.1: Improve navigability of the river system

Sub-strategy RE 5.2: Improve marine infrastructure facilities

Adaptation pathway regarding waterway transport: The improvement of marine infrastructure as an ongoing pathway of continuous investments that are aligned with economic development. Starting with improvement of local cargo on/offload facilities requiring small investments, marine infrastructure is further improved by heightening bridges and waterfront stabilizations towards the middle income status, when higher investments become affordable. Subsequently, in a high income context, waterway transport is sustained by high-standard marine logistic hubs that are logistic nodes and focal points of industrial activity. Improvement of navigability of the river system is best sustained by small scale strategic dredging when investment capacity is low. Strategic dredging means: dredging at the right location at the right moment in order to maintain a dry season river flow in one or two main channels. In this way, the river will help to maintain a navigable depth. When investment capacity increases, strategic dredging may be combined with river training works to further stabilize the river where possible and where necessary.

A key decision emerges when water way transport intensity further increases as shown in the adaptation chart should the rivers be fully optimized for waterway transport, which involves full river stabilization and channelization, or should river dynamics to some extent be tolerated in a controlled way. In the preferred strategy, full river stabilization is considered to be a lock-in. Alternatively, advanced monitoring and marine communication systems offer the possibility to cope with river bed dynamics - within limits - while maintaining navigability. Vessels must then be equipped with GPS systems and with updated electronic bathymetric information so that the position of the main channel and its actual depth is known to each vessel at any position. Here the sub-strategies are supporting each other, as restoration and maintenance of flow distribution from main rivers to floodplains helps to optimize navigation in relation to other functions.

In particular, the following projects are proposed for the short term:

(1) Sustainable restoration of connectivity of major navigation routes, including upgrade of bridges and locks
(2) Monitoring and communication systems for navigation

Strategy RE 6: Strengthening river and estuaries managmenet in the newly accreted Char areas

The suggested measures under this strategy are development of newly accreted char lands in the coast of the Meghna and all other rivers; integration of river management with urban development planning and programming; program for capital and maintaining dredging in the river Padma, Meghna, Jamuna, Brahmaputra, Dharla, Arial Khan, Kushiyara, Gorai, Manu and other important rivers; integrated urban and spatial planning for urban development in newly accredated areas; developing industrial parks and agricultural activities; and also salinity management in the southern rivers during dry season.

6.7.3 Sediment Management

Most of the large deltas in the world are highly intervened and are in eroding phase due to lack of sediment supply from upstream. The case of Bangladesh Delta is different, till now it is able to be in accreting phase. The sediment carried by the Ganges, the Brahmaputra and the Meghna river systems from their catchments have formed a delta, where the land is very fertile and is able to support food and water security for 1,200 people/km^2. Due to different types of natural events such as very large flood, neo-tectonics and seismic events, sediment load and texture of sediment may vary temporally and spatially. Human interventions, at both upstream and downstream, may have large influences on the morphological metamorphosis of the rivers. Due to the characteristics of deposition pattern, the role of sediment texture play an important role. Coarse sediment generally forms the riverbed of the sand-bed rivers and determines the morphology of the fluvial- process-dominated rivers. On the other hand, fine sediment determines the morphology of the floodplain and also the estuary.

The latest available data used for sediment analysis has been taken from BWDB (1966 to 1969) and FAP 24 (1993-1996). In both the cases, coarse and fine sediment were separately analyzed. Method of gauging and the instruments used were different. Total sediment load in the Brahmaputra-Jamuna and the Padma system, has increased in the period from 1960s to 1990s, while bed material load (coarse sediment) has decreased more than 50%. The morphology of the rivers thus responded strongly, with aggradation and degradation of the riverbed, widening of the river and decreasing of braiding intensity. As a result, flow area within bank level increased significantly.

Sediment balance within the river system indicates an aggrading system in 1960s, while it turned into degrading system in the 1990s. During the reducing phase of coarse sediment, river responded by widening and lowering its riverbed. Rate of river bank erosion and widening was very high in the Jamuna and the Padma rivers.

From the observations of measured sediment, it is clear that bed material load had reduced from 1960s and 1990s. Due to lack of routine sediment gauging, it was not possible to assess the present status of the of the sediment input. Investigation of time-series satellite images assess the platform changes and experience gained on the river responses to the changes of sediment load, it could be reasonably considered that present coarse sediment load is close to that of 1990s.

Net accretion in the Meghna estuary however, depends on the sediment load in the river. Reflections of fine sediment measured at Bahadurabad and Hardinge Bridge, could be found in the estuary within few months. But for the coarse sediment, processes of propagation and deposition are different. It may take 15 to 20 years to demonstrate its effects in the estuary.

Sources of sediment depends on its texture, for example, bed materials are generated from their sources and river bank. Fine sediment generally comes from their floodplain. Large number of dams at upstream, mining of sediment would reduce the coarse fraction of the sediment. On the contrary, afforestation and better management of land at upstream may also reduce the fine sediment. On the other hand, land development for construction of infrastructures will increase with the economic development of the country. It is likely that in near future, supply of sediment would reduce, on the contrary, demand of coarse sediment will be increased. Increasing of temperature due to climate change, may cause increased rainfall and increased sediment yield. Earthquake and large-scale landslides also cause increased coarse sediment yield.

Strategy of sediment (coarse) management could be outlined based on the knowledge gained from the analysis of sediment data and also recent understanding on the responses of the river to the changes of sediment quantity and quality. It is needed to recognize that sediment is a resource, but it is not unlimited. Supply of coarse sediment will reduce where on the other hand, mining of those deteriorate the situation.

In case of the Jamuna and the Ganges rivers, it is likely that coarse sediment would reduce further, mainly due to upstream anthropogenic interventions. Responses of the Jamuna and the Ganges might be different, but increase in river bank erosion and scour depth would be common for both the rivers. It will increase coastal erosion as well.

There is a high demand for coarse sediment. This demand is now met by extracting sand from the riverbeds for land development and construction works (road, railway, embankment, township and industrial park) etc, Also, the river beds are dredged to remove the coarse sediment to maintain navigation route

During the last few decades, a huge amount of sediment has been extracted from the rivers around the Dhaka city. These rivers are the Upper Meghna and few under-fit distributaries, such as the Dhaleswari, the Kaliganga, the Turag, the Bansi, and the Sitlakhya. As Dhaka is a rapidly growing city, demand of sand is very high for land development. Unplanned mining of coarse sediment is rapidly diminishing the sediment storage, which would not be replenished anymore. On the contrary, demand of coarse sediment will be increased. Imposing levy on sediment mining may reduce the extraction and planned extraction could reduce the river bank erosion and suffering of the population living on the natural levees.

Capital dredging may not be effective for the large and high energy rivers like the Jamuna, Ganges, Padma, Teesta and the Dharla. Instead, annual recurrent dredging would be more effective to maintain the river navigability. In a very wide river, the dredged-coarse sediment may be dumped into the riverbed in a strategic suitable locations, so that it cannot return back into the dredged channel before the onset of the monsoon, unless the sand users are ready to pay. In the natural fluvial system, the sediment is required to maintain a natural healthy river.

Strategy for Sediment Management

Formulate individual basin-wide sedimentation management policy and plan on the dredging as well as sand extraction from the major rivers and their distributaries, medium and minor rivers in order to preserve ecological balance, protect the river banks as well as the coastal lands from erosion, and disposal of dredged materials, based on detailed morphological as well as sedimentological studies.Sediment management should include a strong capital dredging and maintenance programme.

6.7.4 Long term Perspectives

This section describes perspectives for Bangladesh, called Adaptation by Design and Optimized Water Control. The narratives it is underlined that both perspectives cover the same objectives; therefore meet all Delta Goals; are both effective, feasible and sustainable.

Adaptation by Design perspective: resilience if possible, protection where needed

In Bangladesh rivers are allowed to maintain their natural variability where possible. Valuable assets such as industrial or urban areas and infrastructure are well protected or located outside the river's reach. River bank protections in combination with local river training works stabilize the river where this is needed. Flood risk zones have been established identifying the need for large-scale water discharge and retention capacity during the monsoon period. The certainty on the local flood hazard in these zones allows people to make optimal decisions on permanent settlements and investments. The highest protection standards apply to critical infrastructure and assets of high economic value. People living in areas with higher flood hazards are encouraged and supported to take responsibility for their flood resilience. Using sediments from the river bed, new-built properties in high-risk areas are elevated to cope up with flood resilience.

Ecology is preserved in flood-prone areas in combination with agriculture. Connections between major and medium rivers have been restored by means of local and tailored river training. This positively contributes to the availability of fresh water in the areas along the rehabilitated rivers and it enhances the drainage capacity of these medium rivers. Fresh water is further retained within local small-scale retention basins. Modernization of agriculture and diversification of the economy has resulted in a better-controlled water usage, allowing the water sharing arrangements between sectors.

People that previously suffered from river bank erosion are given the possibility to re-settle and to develop other means of income. The national government has delegated many responsibilities to the local districts that have the best information on local economic developments and local maintenance efforts on embankments. Agreements with India on the management of the river catchment areas of the Ganges and the Brahmaputra have improved knowledge and control over floods during the monsoon period and over available fresh water during the dry period.

Large-scale interventions are only implemented when absolutely necessary, because they are generally costly (construction as well as operation and maintenance), they are irrevocable during a long period and they may have an adverse impact that needs to be compensated by another intervention (cascade effect). A knowledge base is developed first before embarking on large-scale interventions. The same counts for institutional capacity as well as economic development: the scale of the intervention is carefully balanced with the country's abilities to manage and to finance interventions as well as maintenance. Mitigating measures to enhance resilience are applied to buy time until conditions are favorable for an intervention, if necessary. Hard and rigid interventions shall be thoroughly assessed.

Iconic projects for Adaptation by Design

Of the list below of 'iconic projects' is meant to illustrate Adaptation by Design with a view towards 2100. This implies that the projects listed below may not be realistic or (politically) feasible with knowledge and techniques of today. The iconic projects are the result of a session in which the experts were challenged to develop out-of-the-box and inspiring ideas without feeling limited by today's knowledge and economic or institutional constraints in Bangladesh.

- National Inland Islands Project (Jamuna Pearls): development of separate flood-safe areas (string of dike rings) that habitat villages and related central facilities as well as industries at flood-free elevations, leaving sufficient public space inside the dike ring for water retention and leaving ample space outside the dike ring for regular floods, agriculture, ecology etc. The Pearls or flood-free polders are located inside (former chars) or besides the rivers, connected with long bridges. The stability of the river banks that form the contours of the Pearls is maintained through local river training works in combination with river bank protection. The development of the Pearls has transformed the Jamuna River from a hazardous place to live into a popular area to live and invest.
- National Flood Resistant Infrastructure Project: construction of a main flood-resistant infrastructure network to eliminate the largest part of economic set-back due to extreme floods

- Large scale wetlands restoration and creation so as to restore natural water retention and drainage capacities, combined with strong regulation to avoid and to reverse river bank encroachment
- Agreements on cross-country river basin management programs for the Ganges and for the Brahmaputra river basins: co-operation with India has resulted in benefits for both countries for example a reduced cross-boundary migration and improved control on high as well as on low discharge conditions. Flow diversion from India (from Hooghly River) directly into the Ganges Dependent Area (GDA) combined with local water retention measures compensates the increased water demand in the GDA associated with increased living standards. Fresh water demands for agriculture in the GDA have reduced as a consequence of diversification of the economy.

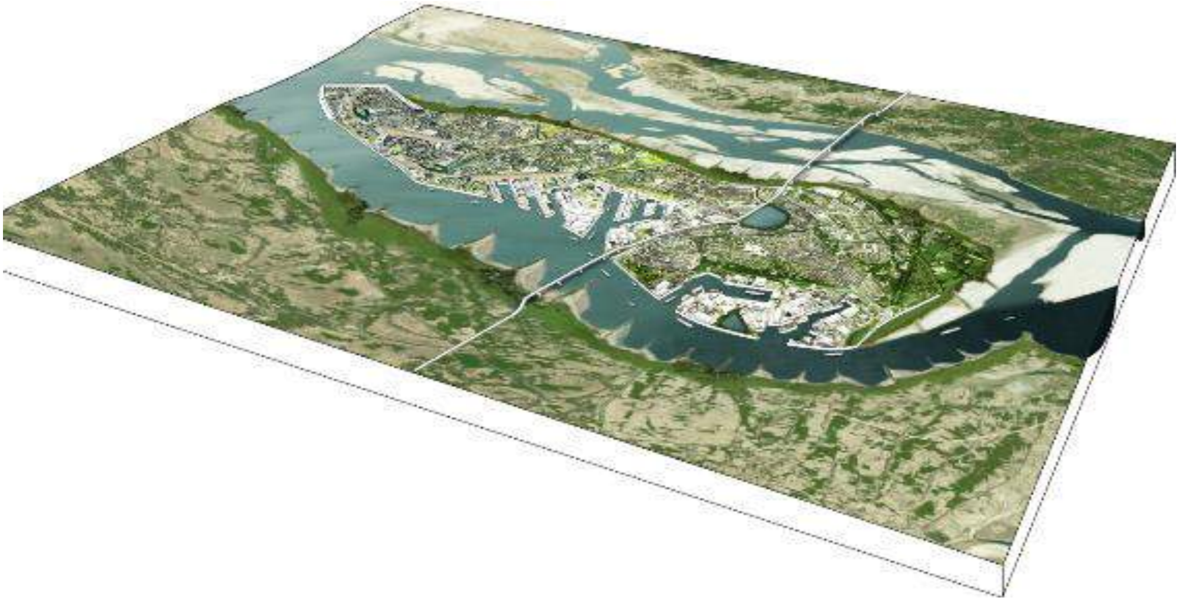


Figure 6.33: Example of Iconic Project for Adaptation by Design (Jamuna Pearl)

Source: BDP 2100 Water Resources Bseline Study

Optimized Water Control perspective: protection if possible, resilience where needed

With the help of developing partners funds, large investments have secured the interests of Bangladesh and to optimize conditions for economic development. A strong national government oversees proper and timely implementation and has a central role in the monitoring and the maintenance of all structures.

River training works and river bank protection works are implemented in a phased manner, so that the lessons learned from one intervention may be applied in the next. The motto is: 'learning by doing'. Rivers are trained so as to sustain two channels: one large channel suitable for waterway transport and one smaller and more natural channel to sustain ecological values.

Some interventions have had unexpected adverse (downstream) effects, but this was accepted beforehand and the development of knowledge by evaluating these effects has allowed for optimization of the designs. The funds to develop this knowledge base and to mitigate the residual adverse effects by means of new interventions (protection works, dredging works) were secured. A national Delta Fund is available to carry the continuing high cost of maintenance.

Like India, Bangladesh has plans to construct barrages to retain fresh waterWithin Bangladesh, water is diverted from the Brahmaputra towards the Ganges and from the Brahmaputra towards the upper Meghna, using as much as possible old river trajectories and natural slopes. This is to divert fresh water from the Brahmaputra to the Ganges-dependent area, amongst others via the Gorai, and to reduce salt intrusion in the Meghna estuary. These large interventions were however postponed until sufficient knowledge of their impacts was available, until the investment could be justified and carried by sufficient economic growth, and until institutional capacity was developed to manage construction, operation and maintenance properly. Lessons learned from Farakka, a barrage suffering from excessive upstream net siltation and from lack of maintenance were taken to heart by the government of Bangladesh.

A 1/100 maximum flood risk level is secured nation-wide by well-constructed and well-maintained primary embankments along the banks of the Major Rivers and the char lands, equipped with sluices and culverts for controlled inflow and outflow of water. The location of this continuous embankment is aligned with river training works and river bank protection; a safety margin is strictly maintained between the embankment and the river bank. A yearly monitoring program identifies critical locations that need additional protection. The flood-prone 'unprotected' area in between the embankment and the river bank is popular with private real estate investors for its magnificent view: high-value and flood-free houses and resorts are developed to explore eco-tourism.

Future 'Optimized Water Control' is based on interventions, however implemented in a smart and phased way so that lessons are learned from earlier interventions when designing a new intervention. Mitigating measures to enhance resilience are applied as temporary solutions to allow for a carefully orchestrated process of learning by doing. An intervention may have an impact that requires a second intervention, and so forth, thus resulting in a cascade of interventions. This must be acknowledged beforehand prior to implementing the first intervention. The end result of this strategy is a trained and controlled river system that is in control through new, carefully designed interventions.

Iconic projects for Optimized Water Control

The list of 'iconic project' given below is meant to illustrate Optimized Water Control with a view towards 2100. This implies that the projects listed below may not be realistic or (politically) feasible with knowledge and techniques of today. The iconic projects are the result of a session in which the experts were challenged to develop out-of-the-box and inspiring ideas without feeling limited by today's knowledge and economic or institutional constraints in Bangladesh.

- Full stabilisation of Jamuna River with two channels, one for waterway transport and one to maintain ecological values, combined with large-scale land reclamation and with continuous embankments alongside both river banks
- National fresh water retention and flow diversion project, involving the construction of the Padma barrage and re-vitalisation of disconnected rivers primarily the Old Brahmaputra and the Upper Meghna
- Construction of a national flood-free infrastructure network consisting of long bridges and roads on dikes equipped with culverts
- Reclamation of a large flood-free area named 'New Dhaka' by the Padma River to accommodate a new airport and a business district as well as governmental offices, with high-speed rail connections to 'Old Dhaka' thus creating opportunities in Old Dhaka to create public open space suitable for temporary water storage

- Creation and restoration of several big lakes for water storage purposes, combining with ecological and recreational functions by careful management of the water level and by strict regulation of access for recreation.

Figure 6.34: Example of Iconic Project Idea for Optimized Water Control

Source: Padma Barrage Study Project, BWDB, 2014

6.7.5 Adaptation Pathways

Figure 6.35 shows the adaptation pathways for Key Issue 1 (flood risk) and 2 (River bed dynamics and river bank erosion). The above pathways contain seven sub-strategies, RE1.1 – RE1.5 and RE2.1 - RE2.2. The sub-strategies are presented in two groups, each with some advice regarding the Adaptation Pathway and with a set of short term recommended projects.

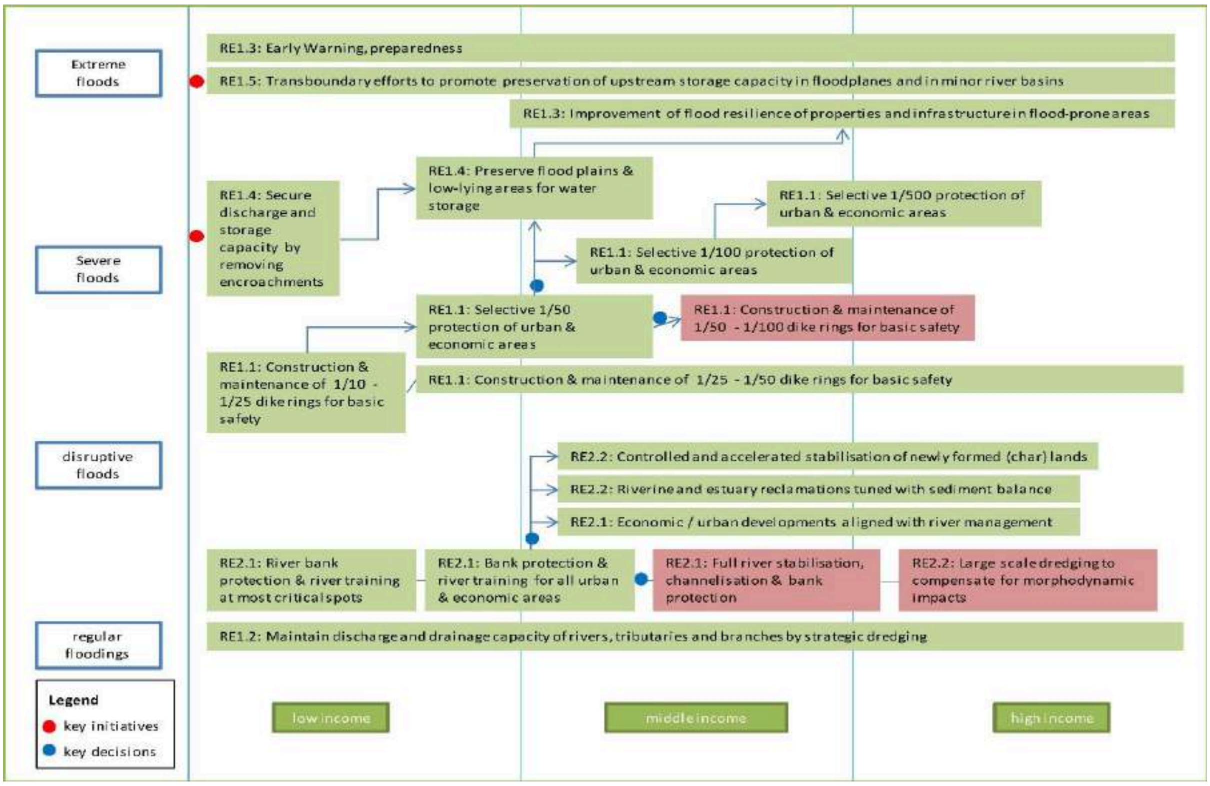


Figure 6.35: Adaptation Chart for Flood and Erosion Related Sub-strategies

Adaptation pathways for Key Issue 3 (Fresh Water), 4 (Ecology) and 5 (Waterway Transport) are shown in **Figure 6.36**.

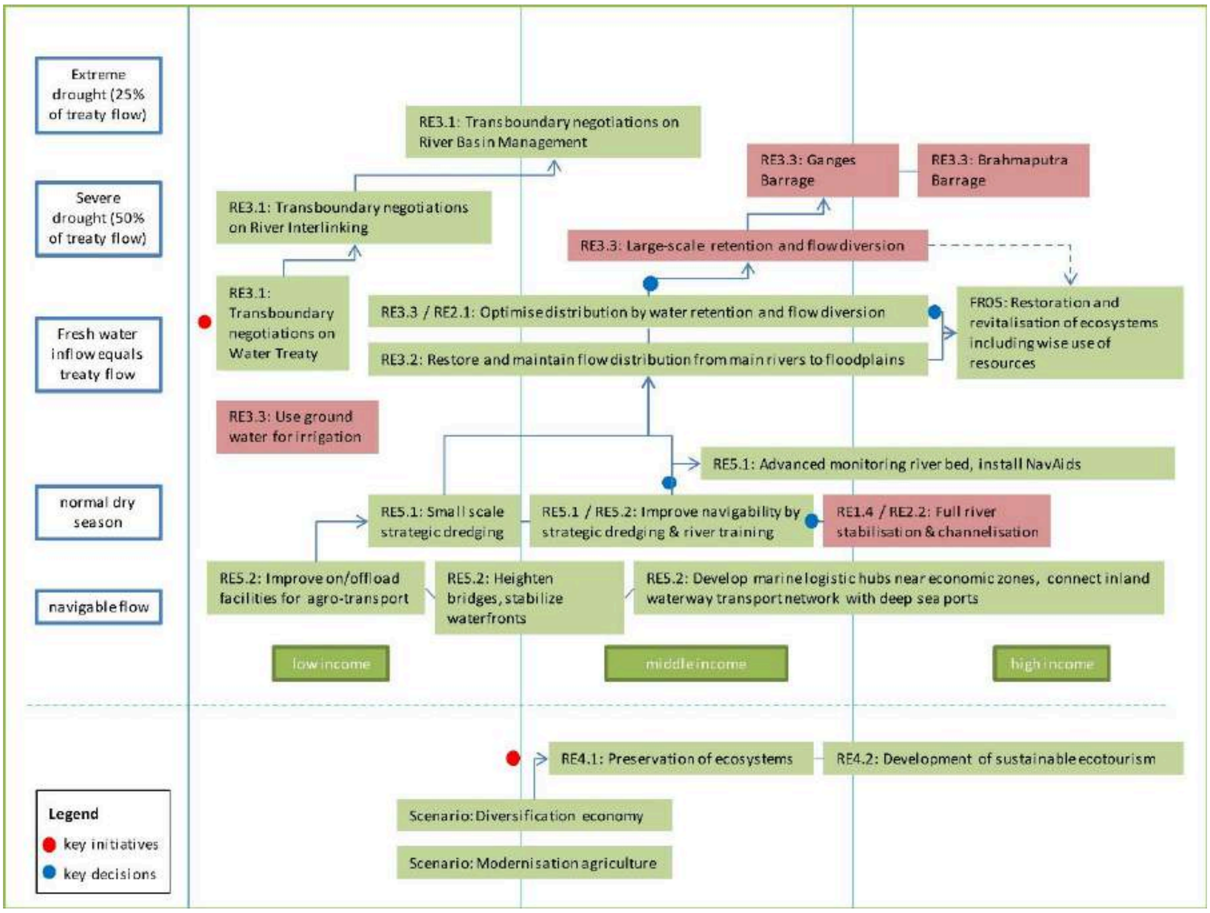


Figure 6.36: Adaptation Pathway for Fresh Water Related Sub-strategies

The adaptation pathwayfor strategies 3, 4 and 5 contain seven (7) sub-strategies, RE3.1 – RE3.3, RE4.1 – RE4.2 and RE5.1 – RE5.2. The sub-strategies were presented in three groups, regarding the Adaptation Pathway and with a set of short term recommended projects.

6.8 Urban Area Strategy

Most of Bangladesh's urban areas are in an early stage of development, Although the focus is on water-related issues in this strategy, it is important to consider the wider context and challenges that face urban areas now and in the future. 'General' issues in planning, like the current malpractice of uncontrolled urban growth and haphazard development have a close connection to water-related issues like flood risk management, for example. Underlying issues include high population density and various socio-economic and political factors that are responsible for the currently challenged state of urban service delivery. Moreover, addressing the various institutional and governance issues will be very important to implement the BDP 2100 strategies.

6.8.1 Key Issues 2015

The key issues for the Urban Area Hotspot have been identified in the 'Urbanization & Settlement' baseline study, which was conducted as approaches to the formulation of BDP 2100. The baseline study is based on desk research, literature review, expert interviews and stakeholder consultations, and provides an elaborate problem statement for each of the issues. A selection was made of issues that are water related, and other 'general' issues that were found relevant for the urban area hotspot. The issues that are listed are generic for the urban areas in Bangladesh. Naturally, the manifestation of these issues in a specific urban area will vary in extent depending with the exact geographical context of an urban area.

General issues with regard to 'Urbanization and settlements'

The general issues with regard to urbanization and settlements are not specifically targeted by the BDP 2100 (which focusses on water related issues), but they can be essential for the wider context of the strategy. While defining the preferred strategy, its impact and effectiveness in relation to 'general' urbanization issues have been considered and have been part of the formulation process.

- Unplanned and unsustainable rapid urban growth
    - Lack of urban vision
    - Insufficient affordable and quality housing
    - Informal urban growth, fringe development and urban sprawl
    - Informal settlements
- Lack of comprehensive spatial planning, amenities and liveability
    - Lack of amenities and services, including solid waste disposal
    - Environmental degradation
    - High urban density
- Absence of sustainable land management
    - Land scarcity
- Issues in relation to institutions, governance and the spatial planning process
    - Lack of a hierarchical planning system, including the absence of national and regional level spatial visions and spatial strategies
    - Weak coordination between government, agencies and institutions
    - Weak enforcement of spatial plans and building regulations and almost uncontrolled private sector
- Dhaka's primacy and unbalanced national and regional development
    - Centralised government and largely unbalanced development

Water related issues for the urban area hotspot

The 'Urbanization and Settlement' Baseline Study holds an elaborate analysis and background to the water related issues in urban areas. The following issues were identified as key issues and are listed belo:s

- Water logging and urban drainage
    - Rain fed drainage congestion
    - Rain fed flash floods
- Vulnerability to Flooding: riverine and coastal and cyclones
    - By peak river discharges
    - By cyclones/ storm surge
- Water availability and quality
    - Scarce water availability
    - Over exploitation of groundwater and related dropping groundwater tables
    - Surface water pollution and environmental degradation

  - SInsufficient surface water availability
  - Ineffective operation and high leakage
  - Poor revenue generation and cost recovery
- Sanitation
  - Low sanitation coverage, environmental issues are not taken care of.
  - Lack sludge disposal options and collection systems on a large scale.
  - Lack of effective governance in sanitation cycle.
  - Unabated environmental degradation
- Encroachment of water bodies and wetlands by land grabbers
- Increasing flood vulnerability (decreasing the water storage and flow capacity)
- Absence of water focussed urban design

6.8.2 Key Issues 2050

Apart from human interventions, key issues will change as a result of uncertain factors like climate change, demographic change or worldwide economic development. This autonomous change of key issues is explored with use of the four BDP 2100 scenarios for the future of Bangladesh, on the basis of expert opinion.

Two aspects of change for key issues can be distinguished viz., hazard and impact. The hazard itself is the first-order, direct change. For instance: a more extreme climate change will result in more frequent or more severe floods. A large demographic growth will - combined with economic stagnation - negatively impact ecologic values.

The impact is then the second-order change. Given increased flood frequency, or reduced fresh water availability, or increased siltation in river beds: what is the impact of this change on Bangladesh for different scenarios? In general, economic impacts become larger when economic value of flood-prone areas increases.

A third-order aspect of change could be the potential for Bangladesh, given its future development according to the developing scenarios, to respond to the second-order impact of change. In line with the previous example: in a scenario with substantial economic growth it becomes more likely that Bangladesh will have the resources, both financially as well as in institutional and knowledge capacity, to gain control over the key issues and their impact. The third-order aspect, involving the human response to autonomous change, was not addressed.

6.8.3 Detailed Strategy

Bangladesh is yet a predominantly rural country that is in a process of rapid urbanization since the 1970’s. The country’s current urban centers will continue their growth in the coming decades under the influence of rural-urban migration and by 2045 the majority of the population will live in cities. Although the focus is on the water-related issues in this strategy, it is important to consider the wider context and challenges that face urban areas now and in the future. More general urban planning issues, such as uncontrolled urban growth and haphazard development have a close connection to water-related issues, like flood risk management. Underlying issues include high population density and various socio-economic and political factors that are responsible for the currently challenged state of urban service delivery. The impact and effectiveness of the preferred strategy in dealing with water-related and more general urbanization issues has been considered in the formulation process of the BDP 2100 strategy for the urban areas.

Strategy UA 1: Increase drainage capacity and reduce flood risk in urban areas

Sub-strategy UA 1.1: Integrated urban drainage improvement. Restoration of existing drainage systems, including the removal of silt, solid waste, and any physical elements that obstruct the discharge or retention capacity. Re-excavation of natural khals is the key. Maintenance budgets have to be secured. Existing wetlands, khals and retention areas have to be formalized as water storage areas, protected from encroachment through land use regulations. Public space can be redeveloped to enlarge the retention capacity of the drainage system; the flood recurrence in an area is matched with specific urban functions. This structures flood protection levels and reduces overall flood vulnerability. The integration of urban development with urban drainage systems is necessary when conditional improvements of water quality are met. Improvements in urban drainage are inextricably linked with solid waste management projects and measures to improve the quality of open water.

Suggestion: The preferred strategy is to enlarge open drainage systems in cities, allowing storm water to be temporarily stored open water storage areas before it is drained. Initially the capacities of existing drainage systems are restored. Where possible, the capacity of the system is extended by using existing water bodies, including wetlands, as water storage areas. The areas are protected from encroachment. For the medium term, conditional advances in urban water quality allow for the extension of the drainage system as an integral part of public space and urban project development. Overall, the urban water storage capacity will keep pace with increasing runoff due to increased precipitation and expansion of impervious surfaces. Higher flood standards will impose additional demands on drainage systems.

Sub-strategy UA 1.2: Integrated flood risk management (in cooperation with the national flood risk strategy). To secure space for future reinforcements, embankments in high density urban areas can be kept free of development by spatial reservations and building restrictions. Development of a national integratedstrategy for flood risk protection (based on both probability and consequence reduction) that is well balanced with a national strategy for development of compact urban township and land use is needed. Protection of existing and future urban centers and economic zones is also crucial.

Application of land use planning should not stimulate urban growth, directly or indirectly by creating pull factors, in areas with high flood risk calculated at national/regional and urban scale. Buildings and settlements outside the dike ring should be flood proof by elevating the settlements , (placing it on a mount or pole or building floating or amphibious houses). Vital and critical infrastructure connections outside high protection level zones also requires flood proofing. Protection of vital infrastructure such as power stations with local dike rings or land elevations. Flexible, robust embankments that add to urban quality. Maintain sufficient space for the river to discharge.

Definition of national and regional integrated spatial strategies of which flood risk conditions are an integral part. Prevent unwanted encroachment of embankments, floodplains and waterfronts in urban area.

Suggestion: As the BDP 2100 national flood risk strategy states, the current and future key economic zones will be protected from floods on a priority basis. It is to be expected that most of these key economic zones may overlap with the major urban areas, such as the city corporations. The flood risk strategy for the areas outside these protected zones focuses on increasing the resilience of communities. Settlements and buildings are protected with local measures, such as elevated mounts or flood proof dwellings (on elevations, poles or floating), and infrastructure is made flood-proof. An advanced flood forecasting and early warning system informs the inhabitants. The urban flood protection strategy goes well together with the concept of urban compact townships. Land use regulations and risk sensitive land use management are to be applied to prevent unwanted development outside the protected urban centers.A spatial-economic strategy at national-regional scale can be instrumental to further integrate flood risk management strategies with spatial development.

Strategy UA 2: Enhance urban water security and water use efficiency

Sub-strategy UA 2.1: Water availably and accessibility.

- Limit leakage and pursue full metering to reduce the percentage of non-revenue water use.
- Develop of piped water systems to allow more conformable water consumption, and central water treatment (including arsenic removal).
- Increased use of surface water for drinking purpose, if needed throughinstallation of water treatment plants, specifically for Dhaka, Chattogram and other major urban centers is emphasized.

Sub-strategy UA 2.2: Improved water quality.

- Initiation of faecal sludge management, entailing sludge collection, disposal and treatment.
- Categorization of waste for easy and effective treatment; separate treatment facilities for electronic, hospital and other toxic waste.
- Reallocation of small and medium heavy polluting industries, from residential/commercial areas to dedicated economic zones though land use regulation and enforcement.
- Regulation and monitoring of pollution of river and other water bodies from industries and other anthropogenical sources.
- Integration of water sanitation concepts with density control.
- Improvement of Dhaka's and Chattogram's sewerage system, linked with improvements in urban drainage to prevent sewerage overflows.
- Education programmes on water pollution, environmental degradation, and raising of public awareness.
- Advanced monitoring, data sharing and research into local groundwater abstraction equilibria and groundwater quality.
- Research the potential of groundwater recharge and (Managed) Aquifer Recharge in urban area. Actively participate in research and experiments towards new, future proof sanitation concepts.
- Urban water supply projects in the city corporation areas and secondary towns. The development of sanitation services in city corporation areas. Water supply and sanitation projects (including faecal sludge management and piped water supply) in selected Paurashova.

Suggestion: Groundwater will always be a major source for drinking water in Bangladesh's cities. To curb (potential) constraints in the availability of qualitative groundwater in the short/medium term, surface water is to be developed as an additional source, as part of a strategy to meet the demands for fresh water for the growing populations of Dhaka, Chattogram and other major urban areas. This shift to surface water goes hand-in-hand with the ambition to provide full piped water coverage in urban areas by 2050. To boost the development of water supply services, a fully metered system has to be developed together with a gradual increase of water tariffs to achieve effective cost recovery for the sector. Solid waste management, urban sanitation solutions and industrial effluent management are required to raise the general quality of urban areas, to stop the current trend of environmental degradation and to prevent contamination of surface water sources. In the short term, the establishment of faecal sludge management systems in cities is important to stop the current practice of sludge dumping in open drains and rivers.

The level of robustness of traditional sewerage sanitation concepts is currently heavily debated, and therefore it is not advised to pursue the large scale application of these concepts in the short term. In the medium term, the choice can be made to continue with conventional sewerage concepts and develop innovative sanitation solutions. Still, qualitative improvements of metropoliton cities' existing sewerage systems will have to be taken urgently. The regulation and treatment of industrial effluents are a priority as well.

Local water saving techniques such as rainwater harvesting can be low-cost and are regarded sustainable. Although in water supply "every drop counts", the contribution of such measures to meeting (or reducing) the water demand in urban areas will be marginal at best. The same goes for innovative wastewater re-use techniques, including sustainable on-site solutions.

Strategy UA 3: Managing river systems and estuaries in newly developed areas

Sub-strategy UA 3.1: Land reclamation. River stabilization and control is aligned with the distribution of economic activities and population centers on national and regional scale. Preservation of the unique character of Bangladesh's river landscape, through integrated urban and landscape design for land reclamation.

Sub-strategy UA 3.2: Integration of River stabilization/erosion control and land reclamation with urban development. Definition of national and regional integrated spatial strategies of which land reclamation is an integral part. The formulation of a regional strategy for the coastal zone is to be prioritized.

Suggestion: As the river-hotspot preferred strategy for riverbank erosion and sediment transport puts forward, it is to be expected that river stabilization and channelization will be applied to primarily the urbanized and economically valuable areas. The strategy also advocates that 1) "it is needed to align urban and economic developments with river management in general and with river bank stabilization works in particular" and 2) "sub strategies related to land reclamation and sediment balance may only be applied in a sustainable way when balanced with natural river dynamics". In line with this strategy, the decision is that on the short term the formulation of national and regional scale integrated spatial strategies and framework plans are required to balance the distribution of economic activities and population centers with the natural river systems.

The meandering wide rivers are a strong characteristic of Bangladesh that contributes greatly to its identity. In strategies for controlling the rivers through stabilization this characteristic should be taken into consideration and protected. Land reclamation projects can follow the 'Jamuna pearl' concept, in which river stabilization and land reclamation is combined with urban and economic development, whilst securing space of ecology and landscape qualities. For the coastal zone an essential decision is the strategic directions for land reclamation and flood risk in relation to economic and urban development.

Strategy UA 4: Conserve and preserve urban wetlands and ecosystems and promote their wise-use

Sub-strategy UA 4.1: Urban wetland preservation. Establish the required water retention and discharge capacity in (peri-) urban wetlands, related to the urban drainage strategy and the river/flood risk strategy. Reach broad consensus on water retention and discharge targets. Define ecological targets for the wetlands, establish the formal function and conditions (e.g. water levels). Integrated development in public private partnerships for wetlands that experience high levels of spatial pressure due to high land prices and uncontrolled urbanization. The formally planned area development allows for both economic growth and housing as well as maintaining the wetlands' ecological and hydrological values.

Feasibility study and pilot to develop the wetlands in a sustainable way in which the ecological and water storage capacity remain

Suggestion: To effectively protect wetlands in and around urban areas, it is important to know what the value of the contribution to urban drain waterbodies is. When the ecological and hydrological (retention and discharge capacity) values are established, targets for water retention and ecological value can be set. In the short term, placeholder functions are introduced to protect wetlands from unwanted development. Wetlands in the urban fringe that experience high spatial pressure (due to high land prices and land grabbing) may be developed in Public-Private-Partnerships. This allows the development agencies to guard essential function design elements including the provision of sanitation infrastructure, open-area ratios and retention capacity.

Sub-strategy UA 4.2: Promote urban green and blue spaces. Make a regional spatial plan/strategy in which green and blue ecological and recreational spaces and networks are defined and create an urban strategy for green blue and recreational networks of different scales (urban parkways, city parks, neighbourhood parks and green routes. Invest in green and blue parks and spaces (add trees to the city). Deploy land use zoning to keep existing green and blue spaces open. When developing street profiles include green strips and trees, in some neighbourhoods prescribe green strips between the street and building envelope (on the private plots). When designing new buildings preserve the Bangladesh characteristic of including spaces for plants in the interior and green exterior spaces of buildings. Formulate a vision including guidelines for sustainable urban development

Suggestion: Urban green and blue spaces roughly include all spaces that hold vegetation or water in a city, regardless of its specific function, wherever it is publically accessible or not. When integrated with urban planning these green and blue space can serve a multitude of purposes. Large city parks that include waterbodies can provide much needed space for public recreation, space for water storage and contribute to the general quality of urban life, the mitigation of the urban heat island effect and ecological values. Green and blue space do not necessarily have to be large of scale, lots of small initiatives can be combined (in a spontaneous organization or in designed city-wide network) to make a large contribution to a sustainable, healthy urban environment. Moreover, the integration of retention areas and khals in functional green spaces (such as parks) is a successfully tested strategy for preventing waterbody encroachment. The strategic development of green and blue spaces requires a sufficiently developed spatial planning system and enforcement of spatial plans.

Strategy UA 5: Develop effective urban institutions and governance

Sub-strategy UA 5.1: Improved urban planning. Strengthening of the institutional capacity in city corporations, Pourashava and other urban areas. Research into the options for decentralisation, focused on subsidiarity in infrastructure development and spatial planning.

Sub-strategy UA 5.2: Improved implementation of urban plans

- Research the possibilities for local urban government into increase local revenue streams to reduce the cost of land redevelopment, and to cover investments in infrastructure. Examples are; user charges, land readjustment schemes or betterment levies.
- Capacity development for integrated urban design and spatial planning by advancements in the educational program for spatial planning and design professionals.
- Study into the principles and functionality of the current land ownership system.

Suggestion: The capacity of local urban government is to be strengthened in the short term to come to a more effective delivery of urban services and local infrastructure development in urban areas. Options for the gradual devolution of authority from national agencies to local government institutions are explored, specifically in the fields functional and financial decentralization. The current practice in physical planning needs to be reviewed to eliminate overlapping mandates and bring hierarchy and organization in planning, in line with the strategies for integrated spatial planning.

Strategy UA 6: Integrated and sustainable use of urban land and water resources

Sub-strategy UA 6.1: Introduction of integrated spatial planning in spatial policy making on national/regional scale. Formulation of generic principles for sustainable urban development as guidelines for urban planning to provide a sustainable, qualitative and integrated perspective on key planning aspects; mobility, the provision of essential urban spaces, protection of waterbodies, risk management and other aspects that are elaborated in chapter ''Sustainable Land Use and Spatial Planning Across the Dynamic Delta". Strategic spatial reservations; to prevent encroachment of critical open areas (water bodies and green space) it is needed to develop a strategic vision on spatial reservations in urban area. This includes the early acquisition of yet undeveloped land for future use as recreational space or infrastructure. To guard these areas from land grabbing, 'soft functions' (e.g. sports fields, green recreational space) can be assigned to occupy the area as a 'placeholder'.

Sub-strategy UA 6.2: Advancements in local urban planning and land use regulations.

Establish a national spatial strategy and plan (including links to the FYP's and Annual Development Programming).

- Prioritization in the development of economic zones.
- Formulation of a vision including guidelines for sustainable urban development.
- Development of guidelines for town and city planning, including improved assessment of socio-economic factors, disaster vulnerability factors and environmental factors in town and city planning.
- Creation of maps that show the relation between the natural landscape, infrastructure and occupation.
- Capacity development for integrated urban design and spatial planning by advancements in the educational program for spatial planning and design by professionals.

Suggestion: A strategic vision is required in which a spatial framework for national physical development can be set. The vision includes key aspects such as the distribution of growth centers, locations for special economic activities (economic zones, ports), fresh water availability for specific sectors, flood risk vulnerability, transportation, land reclamation, and the protection of valuable natural areas. In order to anticipate change and allow for the appropriate degree of flexibility and adaptability in the vision, robust spatial policy is identified by the use of scenarios. Important aspects of this vision include; Land use management and risk sensitive land use planning; with the natural characteristics ***come*** hazards, of which floods, earthquakes and cyclones are most apparent in Bangladesh. By considering the natural system and its inherent hazards in land use planning, unwanted high vulnerabilities and risks can be avoided. Strategic reservations and development restrictions; the location and footprint of physical water management measures (e.g. embankments, retention areas) can be roughly anticipated before the measure is constructed. A spatial reservation can be made to keep the area open and prohibit development, to prevent high costs for land acquisition when the measure is developed. Integration of new development policy and projects; the strategic vision can be used to test proposals for new spatial development or projects in the wider spatial-economic perspective of the country.

6.8.4 Adaptation Pathways

The strategies for the urban area hotspot are shown the following generalized pathway. Further research is required to identify key Tipping Points associated with the identified BDP 2100 strategies for Urban Areas.

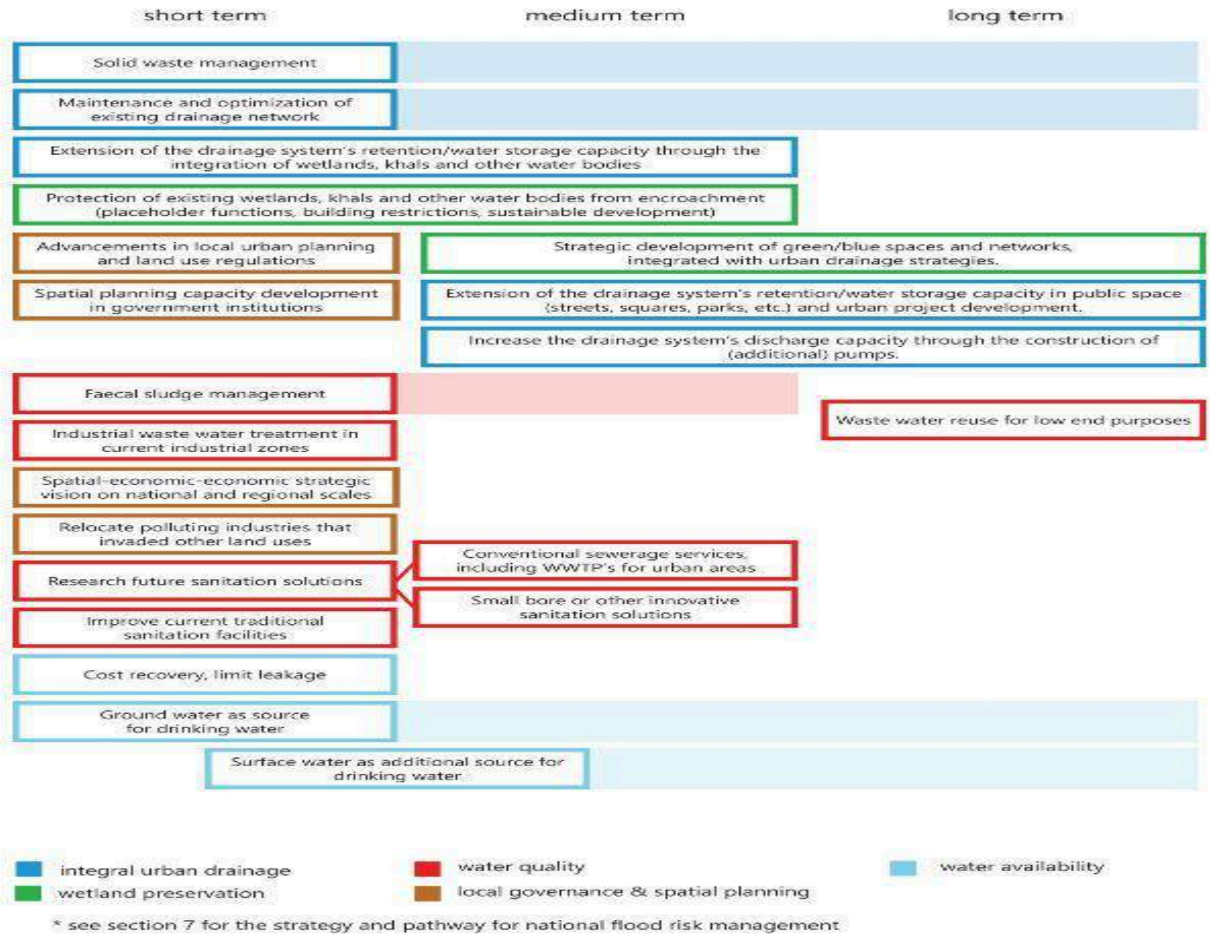


Figure 6.37: Adaptation Pathways for Urban Area strategies

6.9 Haor and Flash Flood Areas Strategy

The haor basin has been identified as one of the food insecure regions of the country covering about 1.99 million ha of area with both opportunities and constraints for the inhabitants. Due to longer period of annual flooding, only a single crop (rice) can be grown resulting in food insecurity. Access to safe and sanitary latrine facilities is of great concern in this region. As Haor and Flash Flood areas are flooded for almost six (6) months from May to October, access to safe water and sanitary latrines becomes very difficult. Groundwater of Haor and Flash Flood areas are also contaminated with arsenic.

BDP 2100has developed the Haor and Flash Flood Area strategies through optimal utilization of natural and human resources for the next 100 years (up to 2100) following the principles of the IWRM. Key indicators of measuring these sub-goals in the Delta Vision include: i) Economic productivity; ii) Economic losses; iii) Food Security and Health; iv) Population affected (also Gender and Poverty specified) and v) Ecosystem (services) quality.

6.9.1 Key Issues

Flash Flood and Monsoon Flood

- The Haor and Flash Flood area is highly vulnerable to flash floods from the hills of Indian part. Low conveyance capacity of flashy rivers in combination with intense rainfall cause rapid increase in flash flood intensity during late April to early May inundated around 2,200 km^2 area which is 11% of total haor and flash flood area.
- The settlements are exposed to wave attack for around five months in a year. As the deplantation of Koroch tree is taking place at a large scale in haor and flash flood area, the vulnerability due to wave action has increased a lot.
- During the period from 1993 to 2010, about 2.44 million tonnes of rice, 64,000 tonnes of jute, 40,000 tonnes of other crops could not be harvested because of flood damage. The occurrence of floods varies widely from year to year. The devastating floods of 2004 inundated most of the haor in the middle of April and farmers lost their boro production amounting to about six lac tonnes.
- It has been known that in normal monsoon flood around 67% of the haor and flash flood areas become inundated. Among the seven districts of this area, Sunamganj is the most vulnerable.

Inadequate drinking water supply, safe sanitation and water for irrigation

- The poor and disadvantaged people in the haor have limited access to basic water supply services.
- During monsoon flooding period (May-October), most of the tube-wells become submerged creating scarcity of drinking water and threatening the health of the haor community.
- Apart from the usual sources of water like DTWs/STWs/tara pumps, alternate sources of drinking water supply such as the PSF, ring wells, rainwater harvesting system (RWH), etc. are still insufficient in the area, especially during flood periods.
- Total irrigated area is about 8.17 lac ha of which surface water coverage is 4.72lac ha (58%) and groundwater is used for 3.45 lac ha (42%) causing lowering groundwater table.
- Poor water and sanitation conditions compound the vulnerability of people.

Low water flows, sedimentation and drainage congestion

- Increased sedimentation of major flashy rivers due to decreased dry season rainfall, water flow and encroachment of rivers, khals and haors and increased peak discharge cause higher drainage congestion.
- Due to unavailability of surface water, farmers depend on groundwater irrigation, reducing the fertility of agricultural land and productivity.
- The stated issue also causes degradation of wetland habitat and ecosystem, particularly for fish habitat, mother fisheries, carp spawning ground in the haor and flash flood areas.

Haor ecosystem and biodiversity

- Wetland and ecosystem habitat (mother fisheries, carp spawning ground, fish breeding and grazing ground, Ecological Critical Areas (ECA), Ramsar Site, Swamp Forests, etc.) are under threat of habitat aggradations due to siltation, habitat alteration and fragmentation,
- Disturbance to pre-monsoon spawning migration caused by some the FCDI projects.
- Over exploitation of swamp forests casuing environmental degradation of this area.

Sectoral coordination and community participation

- Sectoral coordination and community participation are inadequate to address the critical water resource management of this area.
- O&M funding is also insufficient and often not available in due time.
- WMG, WMA and WMF for ensuring actual community participation are yet to be functionalized under newly enacted Participatory Water Management Rules (2014).

Integrated water/land resource management

- The transportation and communication system follow a special seasonal calendar. Navigation is not possible during dry season due to the reduction of water in the rivers. On the other hand, during wet season road networks cannot be used because of being inundated by flood water. At the start of autumn (midOctober) people can hardly move either by road or by waterways when water level starts to decrease.
- The submersible embankments and dykes are not repaired often in time after flood season and thus most of the roads remain unsuitable for use during the rest of the year.
- The submersible embankments and dykes in the haors generally obstruct navigation facilities also between main rivers/canals and canals/rivers inside the haor and flash flood area, although a vast network of submersible roads serves as artery of local communication.
- Disturbance to pre-monsoon and monsoon breeding and spawning, migration of fish due to establishing notfish friendly water control structures under FCDI projects reduced open water fish production.

6.9.2 Detailed Strategy

In this section, medium term measures are detailed out for infrastructure, institutions and innovation based on short term measures. First the longlist of measures is presented, with the aim to provide a comprehensive overview for the future. according to.

Strategy HR 1: Protect agriculture and vulnerable communities from flood

Disaster management for the haor and flash flood area is to protect lives and properties from any kind of hazards where particular emphasis is given on water related disasters (such as flash floods). The Disaster Management Act (2012) identifies a group of broad-based strategies, which focus on the management of risk and consequences, community involvement in protecting lives and properties with greater involvement of local government bodies and emphasis on both structural and non-structural mitigations. The strategic recommendations for flood protection management are presented briefly in the following (**Figure 6.38**).

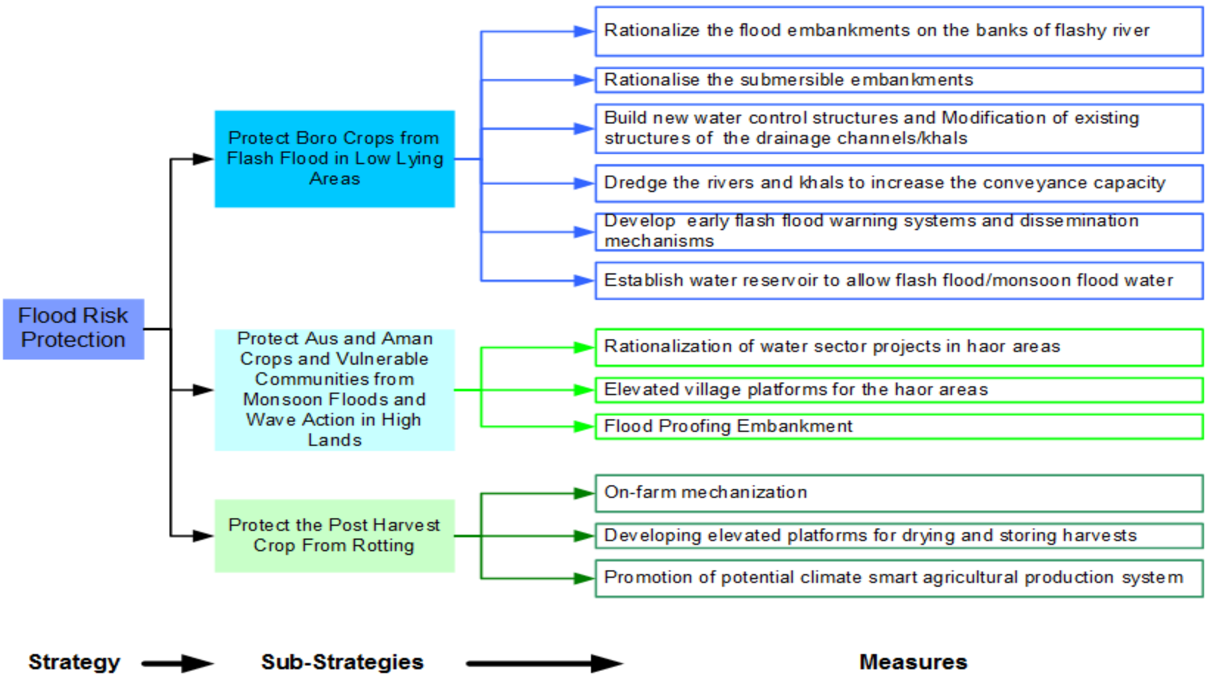


Figure 6.38: Sub-strategies and Measures of Flood Risk Protection for Haor and Flash Flood Areas

Sub-Strategy HR 1.1: Protect Boro Crops from Flash Flood in Low Lying Areas

Pre-monsoon flash flood from the neighboring hilly region is a common phenomenon in this hotspot. As a result the numerous large, deep depressions are flooded casuing damages to the Boro crop immediate before the harvest. A number of FCD/FCDI projects havereduced damages from flash floods particularly in Surma-Baulai and Kushiyara River systems. These existing FCD/FCDI projects should be maintained with developing integrated water control structures in response to the future climatic scenarios (rainfall intensity and peak discharges of the major rivers) developed by BDP 2100. It is, also, in need of increasing the conveyance capacity of the flashy rivers through strategic and maintenance dredging and re-excavation. Another possible measure could be the use of natural elements (sand banks with vegetation) or cribs to narrow the main bed, but still to provide a sufficient flood plain. Moreover, the smart water storage systems should be introduced at Juri, Khowai and Kangsho River.

Sub-Strategy HR 1.2: Protect Aus and Aman Crops from Monsoon Floods in High Lands

The existing FCD/FCDI projects should be rationalized with developing integrated water control structures in response to the future climatic scenarios (monsoon and annual rainfall intensity and peak discharges of the major rivers) developed by BDP 2100. Wave erosion (Afal) would be minimized through building wave breakers to protect settlement from strong wave action during even extreme monsoon flood. Moreover, elevated village platforms by using dredged sludge and other sustainable interventions are also proposed to cope with flood water.

Sub-Strategy HR 1.3: Protect the Post-Harvest Crop from Rotting

To protect the post-harvest crop from rotting in haor and flash flood areas, private and public initiatives and investment in intensive agriculture should focus on areas where much higher returns on investment are possible through homestead gardening and intensive livestock production. Mechanization needs to be promoted in the haor and flash flood area for quick land preparation, planting, weeding, harvesting, processing, drying etc. The raised platforms which are proposed to be built with dredge spoil may be utilized to increase cultivation of homestead vegetables, pulses, spices and fruits. This in turn will improve nutrition and increase household income.

Strategy HR 2: Achieving Water Security

Following sub-strategies and measures are proposed in **Figure 6.39** to ensure water availability for agriculture, drinking and household purposes.

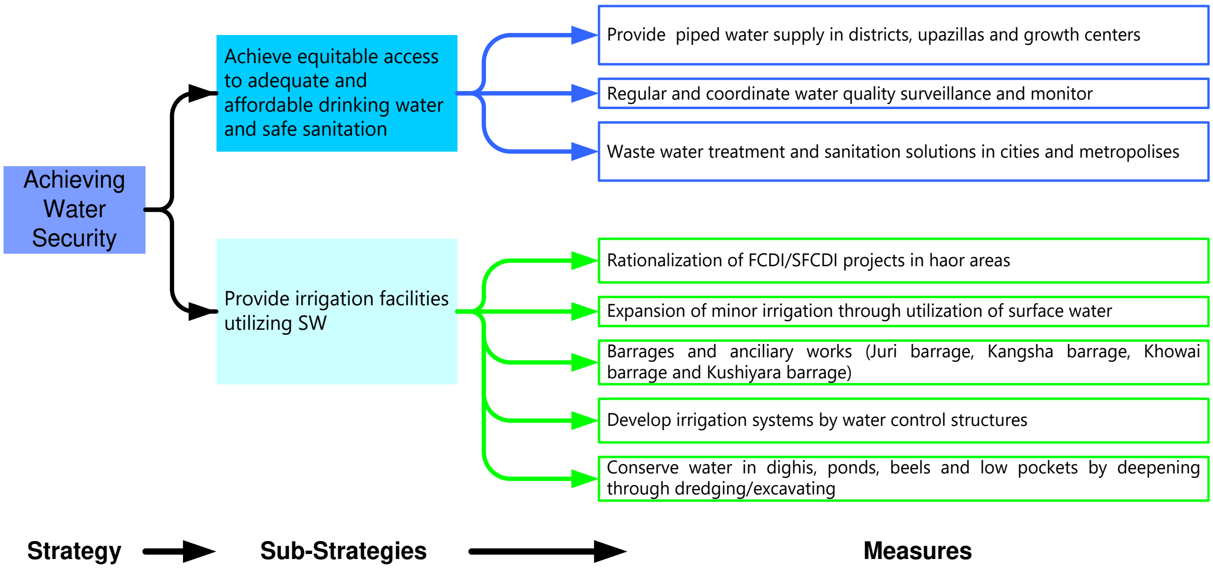


Figure 6.39: Sub-strategies and Measures of Achieving Water Security in Haor and Flash Flood Areas

Sub-Strategy HR 2.1: Achieve equitable access to adequate and affordable drinking water and safe sanitation:

Water supply systems giving emphasis on the use of surface water should be introduced. Piped water supply system in districts, Upazilla and growth centers should be installed with regular monitoring and water quality surveillance. Wastewater treatment and sanitation solutions should be introduced in cities and metropolises. Moreover, sustainable and community based haor friendly flood proof hygienic sanitation system should be promoted in haor and flash flood areas.

Sub-Strategy HR 2.2: Providing irrigation facilities utilizing surface water:

Minor irrigation by low-lift pumps and double lifting pumps needs to be promoted with efficient irrigation system in all upazillas of Sunamgnaj, Habiganj, Netrokona, KIshoreganj, Sylhet, Maulvibazar and Brahmanbaria districts. Re-excavation of canals will serve the twin purposes of moisture retention and distribution for irrigation. Moreover, developing irrigation systems utilizing the perennial flows of the minor rivers and hilly streams by water control structures would play an important role in using surface water for irrigation. Furthermore, conserving water in beels and low pockets within haor basin by deepening through dredging/excavating and through excavating large water bodies, and ponds would be beneficial for irrigating Rabi crops in dry season. Development of barrage and ancillary works at Kangsha, Juri, Khowai and Kushiyara Rivers can ensure water availability for irrigation to northwestern and southern parts of this hotspot.

Strategy HR 3: River Management

Presently Kushiyara River carries higher sediment than the Surma River. Other transboundary rivers are also transporting sediment into this area. Estimated sediment yields for the streams of tripura hills as observed in the Khowai River was 1.7 million tonne/year, Manu River was 4.9 million tonne/year, Dhalai River was 1.6 million tonne/year and Juri River was 1.0 million tonne/year. The Sediment yields from the Meghalaya streams ranged between 139 tonne/km^2 and 229 tonne/km^2 and the highest amount was about 360 tonnes/year on the Dhansiri River. The estimated suspended sediment loads for the other Meghalaya streams were 0.81 million tonne/year on Jadukata River, 0.07 million tonnes/year on Jhalukhali River, 0.09 million tonnes/year on Chela River, 0.05 million tonnes/year on Dhalai Gang River, 0.16 million tonnes/year on Hari River and 0.14 million tonnes/year on Lubha River. The total inflows were estimated as 0.2 million tonnes/year from the streams of Susang Hills. It is indicated that the highest sediment concentration has been found in case of Dhalai River followed by Manu, Surma, Khowai, Someswari, Kushiyara and Upper Meghna Rivers. On the other hand, the highest annual sediment load has been found in Upper Meghna Rivers followed by Kushiyara, Manu, Surma, Khowai, Dhalai and Someswari Rivers. This causes higher sedimentation rate in case of flashy rivers in haor and flash flood area. The following sub-strategies and measures are proposed for this area.

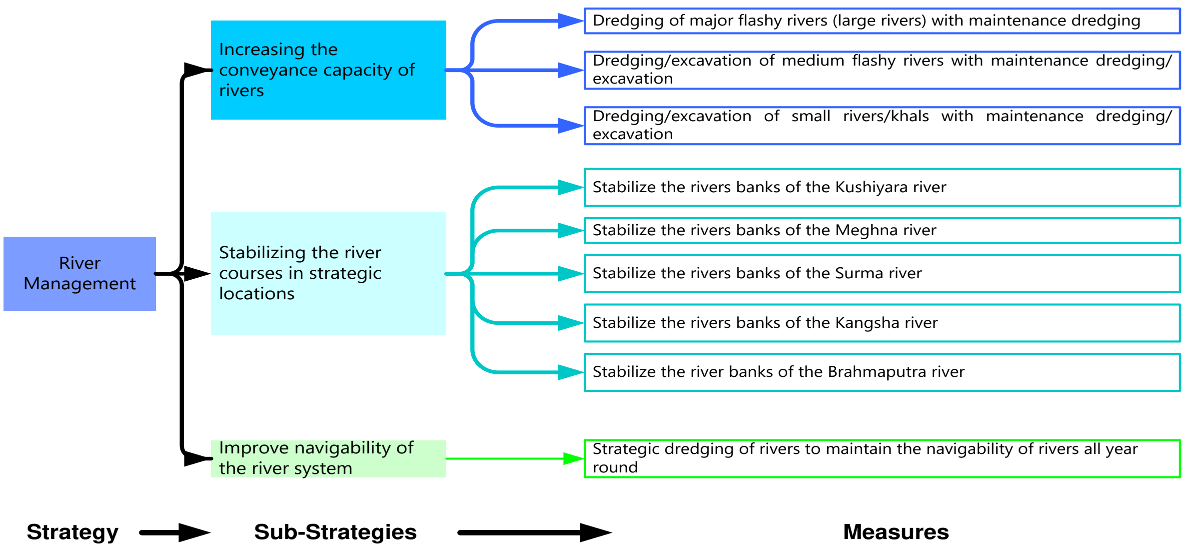


Figure 6.40: Sub-strategies and Measures of River Management for Haor and Flash Flood Areas

Sub-Strategy HR 3.1: Increasing the conveyance capacity of rivers

BDP 2100, is proposing to improve the conveyance capacity and maintain the navigability of the Upper Meghna, Surma, Kushiyara, Kangsha, Bhogai, Jadukata, Pagla, Buri, , Titas, Mogra, Monu, Piyain, Sari Gowain, Ghora Utra, Khowai and Sutang river systems through dredging with vegetation cutting. It is also needed to increase the navigability of the Kushiyara River upstream of Markuli by building weirs and navigation locks. Regular hydrographic measurements of these river routes of these need to be conducted with strengthening of hydrological and morphological monitoring..

Sub-Strategy HR 3.2: Stabilizing the river courses in strategic locations for protecting urban and rural areas

In addition to increasing conveyance capacity, the river banks of Surma, Piyain and Sari Gowain River systems (northeastern part) are in need of protecting urban and rural areas from river bank erosion in , Kangsha, Dhanu and Baulai river systems (northwestern part) and Kushiyara, Juri, Manu, Langla, Sutang, Khowai and Ghora Utra river systems for (southern part) of this hotspot.

Sub-Strategy HR 3.3: Maintaining navigability of the medium and minor rivers

Both the strategic and maintenance dredging of medium and minor rivers should be carried out for improving all the year round navigability of rivers.. This sub-strategy would have some positive impact on flood regulation, removing drainage congestion, improving water availability, waste assimilation, economy, livelihood, etc.

Strategy HR 4: Sustainable Haor Ecosystem and Biodiversity Management

This strategy covers biodiversity and wetlands management as well as development of forest resources in the haor and flash flood area. The wetland biodiversity of this area makes it a unique wetland ecosystem. It plays an important role in the ecology, environment, economy and livelihood of the hotspot. Therefore, natural resources of this hotspot need to be protected and conserved to maintain ecological balance, and to protect the environment and improve livelihoods of the poor people through adopting following sub-strategies (**Figure 6.41**).

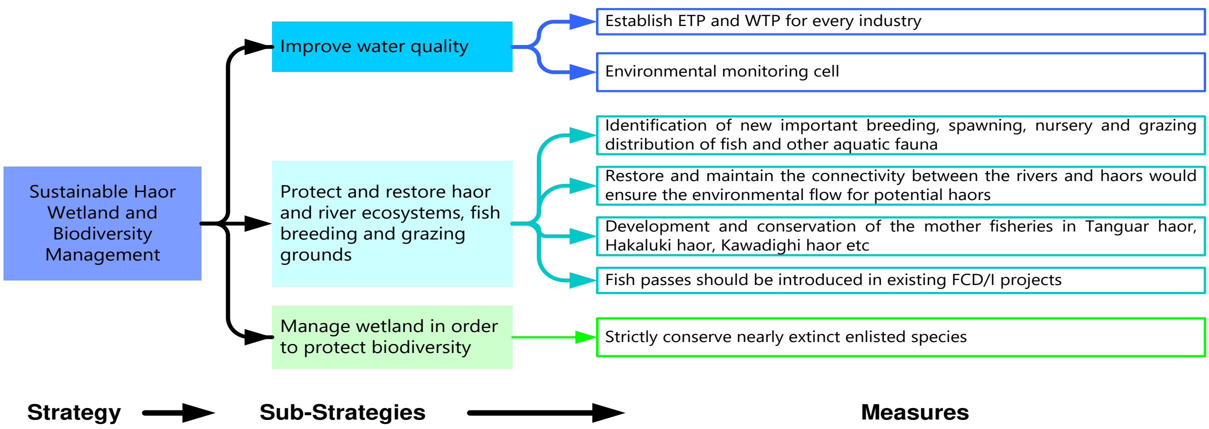


Figure 6.41: Sub-strategies and Measures of Haor Wetland and Biodiversity Management for Haor and Flash Flood Areas

Sub-Strategy HR 4.1: Improve water quality

Maintaining environmental flows in the river systems is the natural process to improve the water quality for wetland biodiversity. However, different awareness building program should be initiated and Environmental regulations needs to be strictly implemented to protect the river, haor and wetland from agricultural and industrial pollutants and dumping of wastes both from urban and rural areas. Protection of environment from industrial pollution should be ensured through establishing ETP and WTP for every industry in this hotspot.

Sub-Strategy HR 4.2: Protect and restore haor and river ecosystems, fish breeding and grazing grounds

Identification of potential breeding, spawning, nursery and grazing grounds of fish and other aquatic fauna is needed. Research and education programs should be conducted identifying potential threatened, vulnerable and endangered aquatic flora and fauna. Restoration and maintaining the connectivity between the rivers and haors would ensure the environmental flow for potential haor benefitting terrestrial and aquatic flora and fauna. Development and conservation of the mother fisheries in Tanguar haor, Hakaluki haor, Kawadighi haor, etc. are required. Restoration of river *duars (deep depression)* in the Surma and Kushiyara river systems would be helpful for protecting brood/mother fisheries. Fish passes should be introduced in existing FCDI projects wherever needed.

Sub-Strategy HR 4.3: Manage wetland in order to protect biodiversity: Water pollution should be controlled through applying above mentioned measures. Furthermore, the nearly extinct enlisted species comprises Nandina (Labeo nandina), Angrot (Labeo angra), Pangus (Pangasius pangasius), Tor Mohasol (Tor tor), Baghayre (Bagarius yarrelli), etc. Some fish species which are at risk of extinction include Chital (Notopterus chitala), Raik/Lasu (Cirrhinus reba), Ghonia (Labeo gonius), Rani (Botia dario), Kani Pabda (Ompok bimaculatus), Madhu Pabda (O. pabda), Kajuli/Banshpata (Ailychthys punctata), Telo Taki (Channa orientalis) and Kuchia (Monopterus kuchia) need to be strictly conserve for maintaining environmental health.

Strategy HR 5: Institutional Development

Sub-strategy HR 5.1: Increase Institutional Capacity: Different national policies, strategies, goals and plans should be synchronized to formulate long term developmental plan. Manpower of both BWDB and DHWD is suggested to be increased for meeting future project planning, operation, maintenance and monitoring. The professionals need also national and international capacity building training programs which are significantly related to field level water sector project management. People's participation in maintenance of water structures must be ensured.

Sub-strategy HR 5.2: Sectoral Coordination: Water sector development projects should be coordinated with all sectors within the impacted area. It would be helpful for knowledge sharing, information sharing in order to promote IWRM in each level. According to the Bangladesh Haor and Wetland Development Act (2013), DBHWD is responsible to coordinate different agencies for developing haors, baors, flood land and beels and all concerned for the management and development of the haor and wetland areas. DBHWD should coordinate implementation of water management projects among the government and non-govt. organizations.

Sub-strategy HR 5.3: Resolve water issues of common/border rivers through regional cooperation: It is needed to develop a mechanism for resolving local-level water issues in common/border rivers by forming local level committees under the purview of Joint Rivers Commission and build the capacity of those committees. It is also needed to assess the impact of any type of interventions in the river basins upstream of the international boundary.

Sub-strategy HR 5.4: Strengthen the community participation: A dynamic and integrated approach should be designed in such a way that each and every member of WMO, WMG, WMA and WMF is involved in all decision-making processes, meeting arrangement and human resource management matters. Participatory Water Management Rules (2014) needs to be rigorously implemented at the local, regional and national level for ensuring stakeholders participation and accountability.

Strategy HR 6: Integrated Water/Land Resource Management

This strategic theme deals with tbuilding of physical infrastructures, transport and tourism. Infrastructure development in the H~~h~~aor and Flash Flood area will contribute to regional economic growth in general and pro-poor growth in particular. Building infrastructures such as road, railway and inland waterway links will help economic development, employment generation and poverty reduction (**Figure 6.42**).

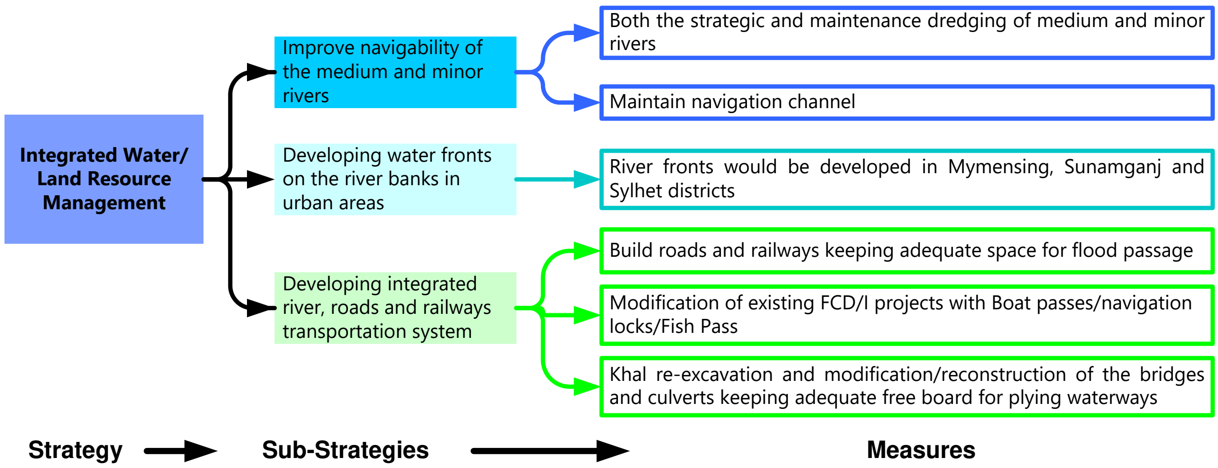


Figure 6.42: Sub-strategies and Measures of Integrated Water/Land Resources Management for Haor and Flash Flood Areas

Sub-Strategy HR 6.1: Maintaining navigability of the medium and minor rivers

Both the strategic and maintenance dredging of medium and minor rivers should be maintained for improving the navigability of rivers all year round. This sub-strategy would have some positive impact on flood regulation, removing drainage congestion, improving water availability, waste assimilation, economy, livelihood, etc.

Sub-Strategy HR 6.2: Developing water fronts on the river banks in urban areas

River fronts need to be developed in the district towns of this hotspot to protect the river banks and creating recreational cum developmental facilities through establishing eco-parks.

Sub-Strategy HR 6.3: Developing integrated river, roads and railways transportation system

It is needed to build roads and railways in such a way that adequate space for flood passage is kept in order to avoid drainage congestion. In building roads and railways free passage should be kept for water crafts plying. Boat passes/navigation locks in existing FCDI projects should be build wherever necessary. Excavation of khals and modification/reconstruction of the bridges and culverts keeping adequate free board for plying river crafts need to be ensured.

6.9.3 Long term Perspectives

As was discussed above, the long term perspective is shaped by elaborating on two potential strategies or development philosophies. The two potential strategies are called Optimized Water Control and Adaptation by Design. Both visions and associated strategies will never be implemented in their entirety. Each region will have a different mix and over time, when the water system has been developed to a sufficient extent, the vision will change, along with societal values and economic development. The two philosophies should therefore be seen as cornerstones.

Both end visions have the variable hydrology and climate in mind, and are based on an understanding of the multiple uses and functions of the water system. To gain control, the country needs to ensure the right amount of water at the right time, and of the right quality.

Optimized Water Control

The ultimate goal in this strategy is to maximize exploitation of the economic and social potentials of the Haor and Flash Flood areas. It considers the Haor and Flash Flood areas as one of the main economic engines for the future of Bangladesh, notably: its strategic value for shipping and goods transport, high agricultural potential, eco-tourism and aquaculture. In order to unlock these potentials it is necessary to improve the infrastructure such as roads, canals, barrages and embankments in order to make the Haor and Flash Flood areas more safe and connected to the hinterland to attract investors. Hence, infrastructural measures in this strategy include:

- Go with the flow and
- Grow with the flow

Also government regulations and policies are focused on making the Haor and Flash Flood areas more attractive for investors and include:

- Active govt. subsidies and free economic zones for industrial development
- Incentives for modernization of agriculture and agro-industries
- No restrictions on urban development.
- Vast expanse of haor areas may be exploited for solar energy generation.

Go with the flow: The first guiding principle is the go with the flow. This will be achieved by cherishing vital connections within the water system. Riverbanks should be freed of unplanned manmade obstructions, but also river and water management measures should focus on preserving and strengthening the free flow as much as possible. Within this guiding principle different potential measures could be addressed and (better) positioned. Think of flexible water control structures or fish friendly and irrigation-friendly (submersible) embankments Opportunities for creating river by-passes need to be investigated.

Grow with the flow: Guiding principle 2 is Grow with the flow: the elevation of land with sediment. Rivers need to be dredged and the riverbeds need to be widened. Priority is given to the main transboundary rivers entering the region. River dredging/re-excavating is urgently needed, but hampered by a lack of technology and capacity (and not so much due to budget constraints). A market for dredging and riverbed mining needs to be stimulated. This market could be stimulated by giving the sand and sediment material an economic purpose. By using sediment and river bank material to elevate areas, this will attract future settlement.

Adaptation by design strategy

This strategy is less optimistic that the economic potential of the Haor and Flash Flood areas can be realized considering the increasing challenges the natural environment will pose. It is simply too expensive to force nature into an armour of dikes and dams, assisted by pumps and desalination plants. Considering that on the longer term the Haor and Flash Flood area population will eventually decrease it would be better to invest in other areas of Bangladesh and to make life agreeable for those who remain. Because there are no large investments needed for big civil engineering works, budget can be reallocated to essential infrastructure such as good roads and a good working drinking water supply.

Infrastructural measures in this strategy include:

- Stay with the flow and
- Cherish the flow

Stay with the flow: Guiding principle 3 is the further development of stay with the flow. Embankments (primary embankments along the rivers and secondary embankments within the hoars) and regulatory structures are crucial in protecting the boro paddies, but also to provide evacuation routes and to make new elevated lands accessible. The primary embankments along the river suffer from erosion. Regulatory structures and secondary often block the connection between rivers and haors and divide the hoars.

Primary embankments can be reinforced. A technical solution is coating the dike with hard materials (rock/stone tiles) or an alternative could be the use of vegetation as natural fixation.

Inflatable embankments can be used only in times of need. In the dry season, the haors stay connected to allow for navigation, exchange of aquatic species which is beneficial for fisheries and biodiversity.

The system of barrages can be enhanced by introducing smart water storage systems (in addition or as alternative). At the moment water is discharged when there is too much, but afterwards it is needed. Regular barrages causes problems downstream because the lower the discharge in dry periods.

Cherish the flow: Guiding principle 4 is cherish the flow: ecotourism and wetland protection. The Haors are a vital natural asset for the area. The wetland ecosystems provide the backbone of the region. People live on the wetlands. The area has great biodiversity values. The Haors are unique in the world. They are however rapidly decreasing and degrading. Only few Haors have a protected status. Wetland protection schemes and ecotourism facilities and infrastructures need to be developed. Development of ecotourism facilities by the private sector ensures generation of income.

6.9.4 Adaptation Pathways

Where uncertainty is important, adaptation or strategic pathways help for understanding, scheduling measures and developing optimal combinations of measures to meet the policy goals. Other measures, such as e.g. increasing conveyance capacity of small, medium and large rivers and rationalization of embankment along the rivers and within the haors, are considered basic measures. Logically, the degree of uncertainty is very high for the timeframe beyond, moderate to high between 2030 and 2050 and moderate up to 2030. As can be observed from the plausible scenario development, climate change is but one of the uncertainties, with socio-economic and upstream developments playing a significant role as well. The following figure shows the strategic pathways against various uncertainties (**Figure 6.43**).

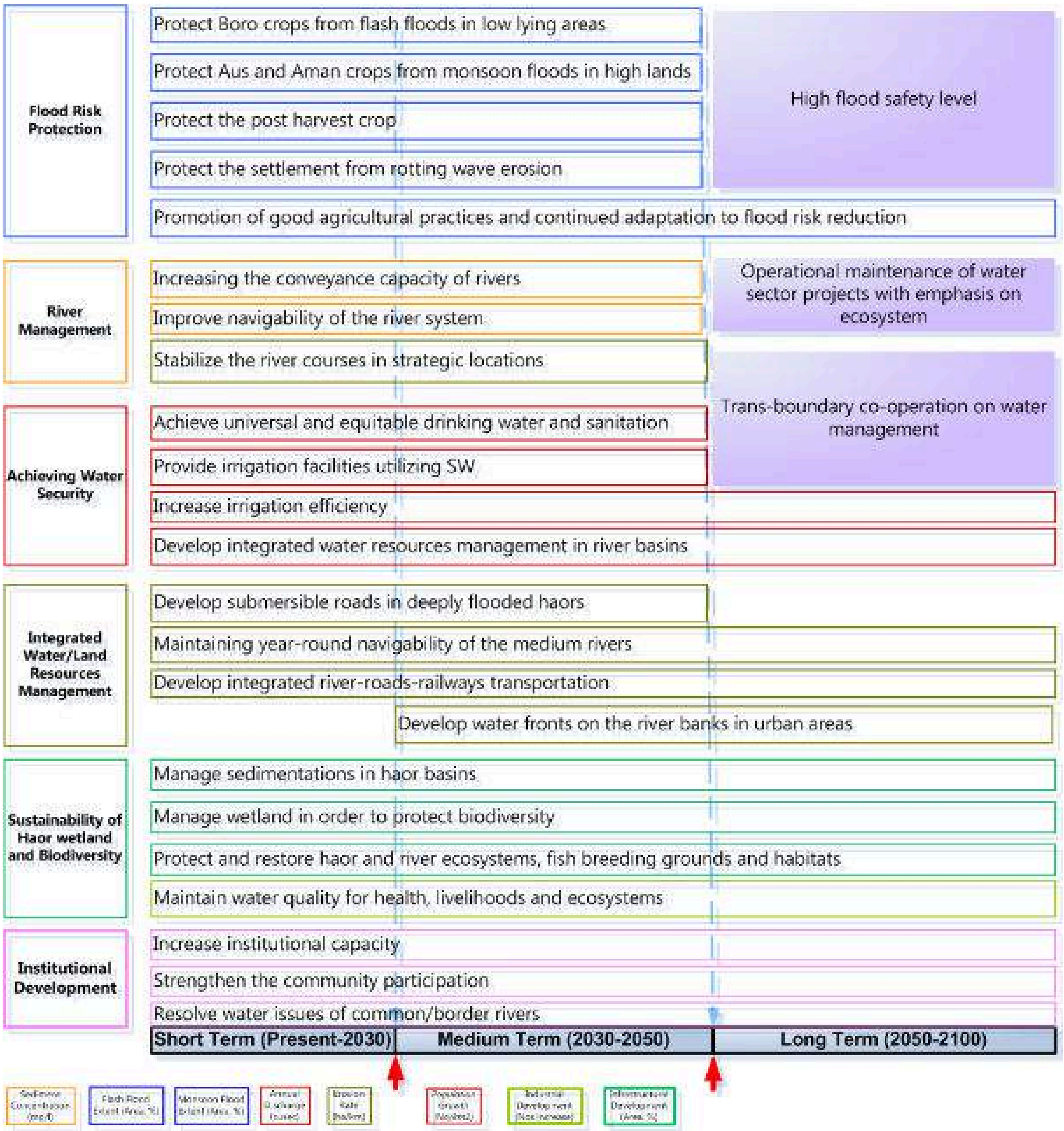


Figure 6.43: Adaptation Pathway for Haor and Flash Flood Areas

6.10 Strategy for Chattogram Hill Tracts

The CHT hotspot consists of three distinct landscape zones: 1) the coastal zone, 2) the plains and 3) the hill area. 43% of the area under forests in Bangladesh is in the Chattogram Hill Tracts and largely characterises the hill area (BDP 2100 Socio-Economic Characteristics of Chattogram Hill Tracts Baseline Study). The forest have been rapidly degraded due to poor management, like monoculture plantation, illegal logging and shifting cultivation with devastating consequences for the people and the environment in the hill area as well as for impacts on down-stream areas. In the hills, for example, springs started to disappear in the dry season. Major impacts for down-laying areas are siltation of rivers and reservoirs due to increased soil erosion in the hill area.

Climate variability and change, population density and unsustainable agricultural and forestry practices lead to erosion and landslides after larger rain showers, especially in the rainy season. Water shortage, both for household consumption as well as for agriculture are experienced especially in the pre-monsoon season. The flood plains at the coast are susceptible to flooding due to flash floods and monsoon floods, as well as related to cyclones, storm surges and water logging. Furthermore, there are many governance and institutional issues related to land ownership and use. Partly this is due to its historical background and it is compounded by the multiple uses of land and water and the high population pressure.

6.10.1 Key Issues

Flooding, drainage congestion, cyclones

- The coastal zone is vulnerable to cyclones, storm surges and flash floods from the hills. Steep gradients in combination with intense rainfall cause rapid increase in discharge, which rivers and other drainage channels across the flat coastal plain cannot convey safely.
- River sedimentation and water logging have posed serious threats to the plains in the last three decades.
- During flash floods up to 80% of crops, vegetables and Aman bed seeds are damaged by hilly land erosion and landslide (BDP 2100 Socio-Economic Characteristics of Chattogram Hill Tracts Baseline Study).

Water supply, fresh water shortage and sanitation

- Water shortage, both for household consumption as well as for agriculture are experienced especially in pre-monsoon season.
- In many Upazillas water is not available in the dry season, whereas there is too much water during the rainy season.
- Water scarcity is increasing due to drying up of springs, chharas (rivulets), canals and beels during the dry season.
- Market and domestic waste and other waste regularly fall into water bodies.
- Poor water and sanitation conditions compound the vulnerability of people.

Erosion, sedimentation, land slides

- High rainfall, non-sustainable agricultural and forestry techniques aggravate erosion related problems. Landslides occur frequently.

- Many chharas and rivers are filling up due to the hill erosion, causing occasional flash floods during the rainy season.
- Soil erosion causes siltation of rivers and reservoirs in lower downstream areas.

Loss of biodiversity, forest and ecosystem services

- CHT is very rich in biodiversity, though situation is worsening with human interventions and encroachments.
- Negligence of customary use and management rights of forests has accelerated deforestation and mono-culture plantation.
- Springs started to disappear in the dry season.
- The role of soil management, forestry and ecosystems in water supply remains unacknowledged.

Institutions and cooperation between governments

- Governance and institutional issues relate to cooperation between authorities, land ownership and use. Partly this is due to the historical background, compounded by multiple uses of land and water and high population pressure
- Currently issues are often solved locally and in isolation. For example, when in the coastal plains there is a problem with siltation of drainage canals, these are being dredged. Processes that are causing erosion in the hills are not integrated in water management.

Loss of livelihoods and food production

- Food deficiency in CHT is met by net imports and suppressed consumption. Current level of rice production falls short of demand.
- Agriculture is highly dependent on access to water resources management (especially lake levels) and agricultural inputs.
- Substantial portion of fish, fruits and vegetables produced is wasted due to a lack of storage and transport.
- Despite potentials, there is little eco-friendly tourism in CHT region.

6.10.2 Detailed Strategy

In the hotspot ‘Chattogram Hill tracts’, both the hills and related coastal plains are considered, as problems experienced in the hills, like landslides, are related to coastal plain problems like sedimentation and recurrent dredging. Importantly, while for the larger rivers in Bangladesh much of the catchment is outside the country, in the Eastern Hill area most of the catchments of the important rivers is within the country’s borders, offering excellent conditions for integrated river basin management and opportunities to address problems holistically.

The strategy has been developed through analysis, design sessions (workshops) and stakeholder consultation. The developed strategies need to deal with both the present and the future.

Strategy CH 1: Protect economic zones and towns from floods and storm surges

Sub-strategy CH 1.1: River flood risk management. Flood protection and control structures for Khals and rivers to protect floodplains and towns from floods of Chengi, Karnafuli, Sangu, Matamhuri, Bakkhali rivers and hilly streams. This project also pilots soil and water conservation measures in hills for flood risk management.

Sub-strategy CH 1.2: Cyclonic storm surge and tidal flood risk management. Rationalize management of existing sea and river facing polders and extend soft coastal defense and shelters against extreme floods, including flood resilient housing (together with hotspot Coastal Zone)

Suggestion: Protection of economic zones, seaports and city centers, early warning, green belts and cyclone shelters are the preferred strategy for the short term. For the mid-term opportunities for multifunctional dikes and sea walls are explored alongside protection of cities and major economic centers.

Strategy CH 2: Ensure water security and sustainable sanitation

Sub-strategy CH 2.1: Increase water use efficiency of all sectors and ensure sustainable water use. Establishment of flow control and water reservation structures for water availability in dry season, including small scale (cross)dams and reservoirs for irrigation, livestock and aquaculture. This project requires location specific planning for coastal plains and hills. Rationalization of existing irrigation projects (Karnafuli and Dhurang irrigation Project, Fatikchari FCDI Project), including lessons learned for further expansion of modern and efficient irrigation in hills and plains.

Sub-strategy CH 2.2: Development of sustainable and safe water supply and sanitation system. Installation of location sensitive water supply mechanism to ensure safe drinking water (including gravity flow systems, water harvesting, tube wells where applicable). Project includes state-of-the-art groundwater survey. Sustainable water supply and sewage system in large cities + financial sustainability and cost recovery (elaboration of city master plans). Master plan to improve water quality by reducing pollution in hills, including motivational work on sanitation.

Suggestion: Local water supply and sanitation (spring restoration and protection, water harvesting, gravity flow system, cesspools) and partial cost recovery (cost of maintenance recovered in kind) are the preferred strategy for the short and midterm in the Hills. Piped water and sewage system, priced for full cost recovery of service, are the preferred strategy for the longer term depending on the scenario (under high population pressure, GDP and climate change).

Strategy CH 3: Ensure integrated river management

Sub-strategy CH 3.1: Integrated sediment and erosion management. Integrated erosion management in the hills by creating green belt, eco-friendly structures, soil and water conservation, and reforestation.

Sub-strategy CH 3.2: Integrated management of rivers and hilly streams. Development of catchment and sub-catchment management plans.

Suggestion: Catchment management with particular attention to erosion management in the hills and restricted cultivation on steep slopes (agroforestry) are the preferred strategy. Dredging of rivers, river engineering (e.g. groynes) and smart drainage are selected as support action for specific locations.

Strategy CH 4: Maintain Ecological Balance and Values (assets)

Sub-strategy CH 4.1: Protect and restore water related ecosystems, including forests and hill sides. Promotion of sustainable cultivation practices and regeneration of degraded areas. This project includes creating awareness on role of forests in water management, replace mono-plantation and promote agroforestry with native (fruit) trees in support of livelihoods and water availability.

Sub-strategy CH 4.2: Promote wise-use of soils and water bodies for sustainable livelihoods. Establishment of small scale (cross) dams and reservoirs for irrigation, livestock and aquaculture.

Suggestion: In the hills the preferred strategy is to implement sustainable practice of indigenous agriculture and replace teak forest by indigenous species, to enhance CHT nature value and protect springs and to promote income from eco-tourism. Construction of dams and reservoirs to expand irrigation is first implemented on the coast. In the mid-term this strategy is developed for the hills (e.g. drip irrigated fruits). In all projects careful consideration of local context and property rights / land tenure are required.

Strategy CH 5: Increase institutional capacity for integrated water resources management

Sub-strategy CH 5.1: Strengthen institutions and cooperation for integrated holistic watershed management. Develop catchment and sub-catchment river basin management plans in cooperation of departments and communities (incl. hill district council, agriculture, fisheries and forestry departments). This project includes evaluating the role of multifunctional small scale reservoirs, and hills-plain interaction as well as the need for regional cooperation and creating knowledge infrastructure under CHT council

Sub-strategy CH 5.2: Early warning, storm surge and flood risk preparedness. Revision of flood warning systems / flood patrolling/ fighting procedures and establish disaster management social group and community based early warning and forecasting systems.

Suggestion: For the short term the preferred strategy continues to rely on centralized decision-making and regional cooperation. Decentralization is explored and capacity is built for local representation in governance. This capacity will be capitalized upon in the midterm, together with a land tenure system to support sustainable settlement and (water) resources management.

Strategy CH 6: Develop multi-purpose resources management system for sustainable growth

Sub-strategy CH 6.1: Development of safe, reliable and optimal use of land, water ways and energy. Kaptai Lake rehabilitation project and lake-level optimization (rehabilitation of reservoir and surroundings). This project includes pilots for Lake Compartment management and optimized lake level management for hydropower, agriculture, fishing and water communication.

Sub-strategy CH 6.2: Strengthen resilience of livelihoods and sustainable food production. Create markets, marketing and value chain development for income diversification (e.g. processing, high value crops, fisheries, agroforestry value chain, and local storage and transportation facilities)

Suggestion: To manage Kaptai lake in particular, dredging and optimal hydropower production are reality at present. In the short term pilots are started to explore the potential for optimizing lake management for hydropower, agriculture, fishing and water communication. Lake Compartment is practiced at small scale and lake and hill slopes are replanted with indigenous (fruit) trees. A participatory appraisal study of various lake rehabilitation options (short term) is needed to identify trade-offs and will guide mid-term decisions.

6.10.3 Long Term Perspectives

Potential Strategy 'Optimized Water Control'

Short term: For the CHT this strategy entails that measures in the short term focus on getting to grips with food and water securities as well as safety against climate change and natural disaster. Drinking water shortages will be solved by installation of wells and gravity fed systems. Locally, technological solutions will be applied to ensure the quality of the water. To deal with landslides, erosion control measures will be taken and protection works installed. In the coastal zone pumping can be introduced to control water logging conditions in urban areas as well as warning systems can be applied for cyclone and storm surges.

Medium term: In the medium term both in the coast and in the hills, infrastructure measures are proposed to deliver appropriate water management in agriculture: pumping excess water away, and delivering water in in times of shortages. Improved drainage systems, will allow both agriculture and urban drainage. In the hills, infrastructure will be planned to reduce overland runoff and land-slides. Like suggested in the atelier in Chakuria, new urban infrastructure will be designed to limit urban sprawl and conserve agriculture land (construction of fly-overs, high rise buildings instead of horizontal expansion).

Longer term: In the longer term, this strategy foresees infrastructure in place to automatically regulate the water system in the coastal zone (urban and agriculture). Coastal protection levels will increase in the longer term, a necessity when employment opportunities and value of assets increase. For instance when Sonadia port development is realized, this creates more employment, resulting in more densely populated coastal zone. Coastal infrastructure will need to take this into account.

Governance strategy entails a close collaboration between different government agencies to look for synergies between investment agendas and different infrastructure works. Intergovernmental cooperation is actively taken up to make arrangements for cross border rivers. Studies are foreseen of current and future infrastructure projects, to assess their impact on the river basins, and whether additional mitigating measures are needed to cope with any adverse effect.

Potential Strategy 'Adaptation by Design'

Short term: For the CHT hills, in this strategy, the first measures to take are soil and water conservation measures that tackle the land-slide, erosion and water availability problems. Measures are in harmony with local practices and are piloted in such a way as to enhance our knowledge base of the area. An example are practices to increase rainwater infiltration in the hills. The focus is on agriculture and nature-based management strategies, rather than on infrastructure. Drinking water problems are solved by using flexible and small-scale solutions, such as transferring spring water to communities using gravitation flow or solar energy to pump water up. Rainwater harvesting possibilities at household level and awareness raising are important measures which reach all people. In the coast, mangrove plantation is boosted, which will in the longer term limit the requirements for large-scale infrastructure. Maintenance of existing small-scale water infrastructure is boosted as well as of cyclone shelters and early warning systems.

Medium term: For the mid-term, nature-based land and water management practices are realized through measures in the hills focusing on creating a green belt, and in the coast on green coastal protection and flood resilient housing. Importantly the measures in the hills and coast are implemented in synergy. The low-land benefits of interventions in the hills is actively monitored and rewarded. This has a governance side, as well as a knowledge side. For example, farmers and researchers co-produce a better understanding of sustainable Jhum cultivation and traditional agricultural practices in the CHT region.

Longer term: For the longer term, a nature park and protection of nature is foreseen in the CHT. Degradation of biodiversity is halted and natural habitats are monitored and rehabilitated. Eco-tourism brings income. Traditional indigenous agriculture is promoted, and teak forest is replaced by indigenous species, thus enhancing the natural value of the area.

Governance strategy foresees in conservation, restoration and sustainable use of terrestrial and inland (hill) freshwater ecosystems in CHT. Larger scale infrastructure is avoided, and thus costs as well as collaboration for such infrastructure is not required. Decentralization and capacity building are important in order to ensure awareness raising, and local population taking responsibility for the development and conservation of the area. A long term integrated eastern hills resources management program will be part of the strategy, including a land registration system to support sustainable settlement.

6.10.4 Adaptive Pathway

Adaptation pathways are part of the preferred strategy. The adaptation pathways in

Figure 6.44 indicate roughly when certain projects and decisions are expected to be necessary and appropriate for the CHT and coastal plains.

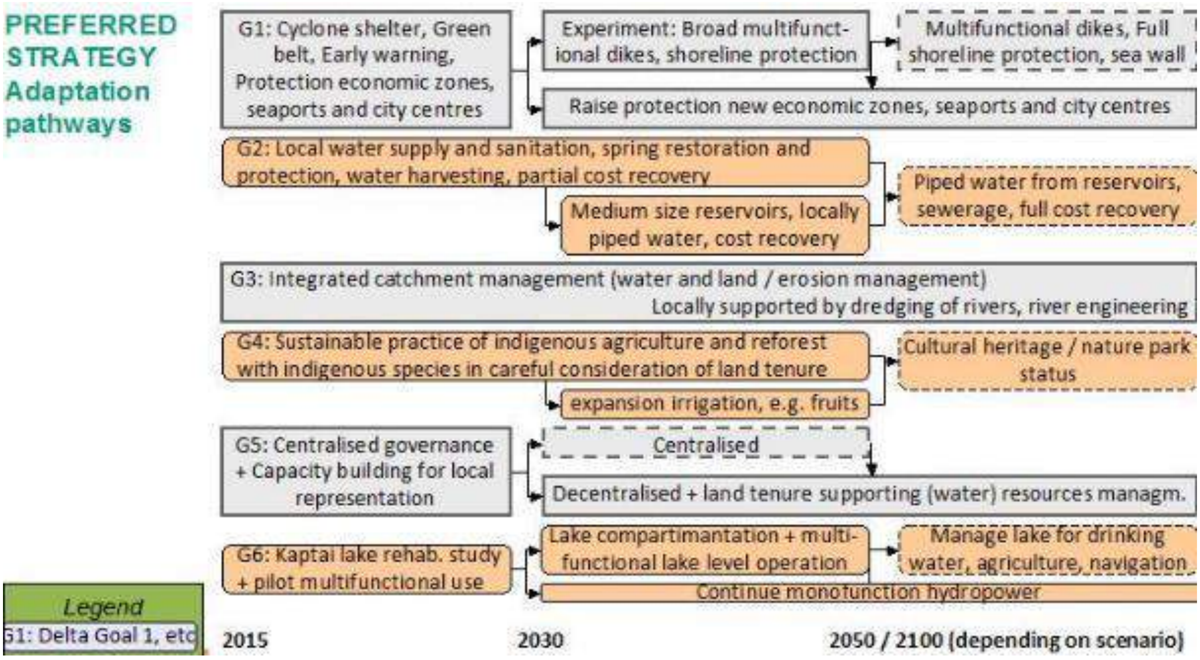


Figure 6.44: Adaptation Pathways for the CHT Hotspot

6.11 Strategy for Advancing the 'Blue Economy'

6.11.1 Key Issues and Challenges

At the end of the final settlement of maritime border disputes with neighbouring states Myanmar and India in 2012 and 2014 respectively, Bangladesh has received entitlement on 118,813 km^2 in the BoB comprising her territorial sea, Exclusive Economic Zone (EEZ) and Continental shelf (MoFA, 2014). The shallow shelf sea constitute about 20% and 35% respectively, the rest (45%) lying in deeper waters.

In this section, key issues and challenges in relation to the Blue Economy have been described. More details on the Blue Economy are provided in Annex C.

Lack of Investments

Future development potential of a Blue Economy for Bangladesh strongly depends on the ability of the economic actors to find a business model which fits the development stage and the national and global developments. However, once confidence of the future potential is established, new players will enter the business, invest, upscale and grow the business. Once risks subside, large industrial players (e.g. from marine fisheries, energy, utility and mining companies but also pharmaceutical, chemical and cosmetics) are expected to become interested in the opportunities of the Blue Economy. Access to finance is therefore amongst the most important barriers for the maritime economic activities. Clearly, investment risks are substantial in this phase, but so can be the rewards. Apart from funding of activities in the development phase, access to finance can block the realisation of investment plans and new business initiatives.

In investing, one needs to realise that development in Blue Economy is associated with forward and backward linkages. Simultaneous investments are essential. For example, investments in deep sea fishing should be supported through investments in fish landing and processing set ups followed by marketing, usually in international markets. One cannot be developed in the absence of the other. Large multi-national companies, able to make such investments, need to be pursued to make this happen.

Private Sector, engine to 'Blue Economy' Growth

To develop the full potential of the blue economy, full involvement of the private sector is considered crucial. Globally the private sector is the engine to Blue Economy growth. Especially for sectors in their pre-development and development stages, the availability of financial credit, tax incentives, favourable investment climate are crucial. The government has a clear role in providing investment support and a conducive regulatory mechanism.

Financing through bilateral or regional agreements

Like Bangladesh, African SIDS countries lack commercial fishing fleet that has decreased their ability to fully reap the benefits of the fish stocks. They have entered bilateral fisheries agreements with the EU. The countries are paid a fee per boat annually as well as a fee per metric tonne of fish caught. They are intended to allow EU vessels to fish for surplus stocks in that country's Exclusive Economic Zone (EEZ), in a legally regulated environment. At least half of the revenue is invested in developing national capacities. A similar model can be considered for Bangladesh's Blue Economy.

Lack of knowledge and assessment of ocean resources

Bangladesh currenly lacks deailed knowledge on many aspects of emerging Blue Economy sectors, such as marine aquaculture, marine aquatic products, marine biotechnology, deep sea mining, ocean tidal energy, low-cost desalinization, marine spatial planning (MSP), etc. The country particularly needs capacity building in deep sea marine fisheries and energy exploration. The latest marine stock assessment is decades old. Universities which could have been the leaders of knowledge creation are poorly funded for research. The UN and other inter-governmental bodies should device strategies, facilitate capacity building and mobilize financial mechanisms to help the nations in achieving the targets. Particularly, SDG 14 stressed on increased scientific knowledge and research capacity as well as the transfer of marine technology, which will enhance capacity of countries like Bangladesh in marine science and technology.

Lack of Skilled/trained manpower

Human resource- A thrust in blue economic growth may come from a large army of skilled coastal and offshore engineers, navigators, merchant mariners, fisheries technologists, biotechnologists, etc. and in a variety of other professions. There are reportedly shortage of marine officers worldwide and the shortage is escalating about 20% every year (BDP 2100 Coast and Polder Issues Baseline Study). Philippines, China and India are providing most of the officers to all the merchant ships around the globes. Even Myanmar and Sri Lanka are ranked ahead of India in terms of providing ratings. Bangladesh has enormous potential for seafaring job opportunities from its 18 private and public marine academies provided it can arrange on board practical training facilities. Recently the Bangladesh Oceanographic Research Institute (BORI) has been established for coastal and oceanic research.

Absence of Maritime Spatial Planning (MSP)- MSP is a mechanism for the integrated management of maritime areas in which a central vision for the future of the area, in conjunction with knowledge of activity interactions and impacts, guides the location, timing, intensity and future development of all activities in the maritime space. It recognizes that seas and oceans are drivers for the economy with great potential for innovation and growth. A comprehensive understanding of the maritime environment is crucial for successful MSP, as is a thorough understanding of how maritime activities impact each other and the environment.

Ocean & Coastal Framework Policy

From the review and discussions of the existing legal documents, it becomes apparent that there have been quite a lot of policies, laws, orders and rules which are used to manage various sectors and organizations related to marine management, development and economy. The current practice of fragmented 'sector-by-sector' or 'use-by-use' planning, managed by discrete laws and regulations, and implemented by disconnected agencies and bodies, is causing competition or conflict among multiple users of the ocean.

Absence of adequate institutional 'home' for development of Blue Economy

Although the Blue Economy is an emerging opportunity for Bangladesh, it is difficult to allocate an institutional home or institutional responsibility to a single Ministry or agency. Responsibilities are fragmented. Bangladesh seems to have nearly adequate number and type of bodies, from supervisory entities to implementing agencies, in various sectors of ocean affairs (as shown in **Table 6.7**). What seems lacking in the institutional backbone is the mechanism of 'interaction' (Hossain et. al. 2014) and the ability to see the marine-coastal system as a highly integrated entity, which would require vision and policy backed by multi-sector strategies translated into highly organized and closely coordinated actions.Examples of fragmentation is evident:

(i) Maritime Affairs Unit of the Ministry of Foreign Affairs deals with the legal issues.
(ii) Department of Fisheries is responsible for research and enhancement of marine fisheries.
(iii) Private sector invests in marine fish catches
(iv) Ministry of Shipping is responsible for coastal shipping
(v) WARPO is entrusted with the complex and multidisciplinary task of coastal zone management,
(vi) Bay of Bengal Large Marine Ecosystem (BOBLME) project is represented by Fisheries Research Institute,
(vii) International Hydrographic Office (IHO) is represented by BIWTA not having any presence in the sea;
(viii) Intergovernmental Oceanographic Commission (IOC) is represented by the Ministry of Education, not by the Ministry of Science and Technology according to the mandate given in the Rules of Business of the GoB.

Table 6.7: Indicative List of Institutions Related to Different Sectors of the Blue Economy

Sectors	Institutions
Marine Fisheries	Ministry of Fisheries & Livestock Bangladesh Fisheries Development Corporation Department of Fisheries (DOF)- 'Marine Fishery Resource Survey Unit
Energy & Mineral Resources	Energy & Mineral Resources Division PetroBangla Bangladesh Petroleum Exploration & Production Co. Ltd (BAPEX)
Shipping, Trade & Commerce	Ministry of Shipping Department of Shipping Mercantile Marine Department, Chattogram Mercantile Marine Office, Khulna Government Shipping office, Chattogram Deep Sea Port Cell Chattogram Port Authority Mongla Port Authority Payra Port Authority Bangladesh Shipping Corporation
Tourism	Ministry of Tourism Bangladesh Parjatan Corporation
Ship breaking & ship building	Bangladesh Ship Breakers Association Bangladesh Shipbuilders Association
Water resources	Ministry of Water Resources
Defence & Law enforcement Ministry of Home	Ministry of Defence Bangladesh Navy Coast Guard
Research & Education	Bangladesh Fisheries Research Institute (BFRI)- Marine Fisheries & Technology Station of BFRI in Cox's Bazar National Maritime Institution Bangladesh Oceanographic Research Institute Institute of Mining, Mineralogy & Metallurgy Marine Academy Marine Fisheries Academy- Fishing Trawler Cadet Training Institute Academic institutions Institute of Marine & Fisheries Science, Chattogram University Fish. & Marine Resources Technol. Discipline, Khulna University Bangladesh Agricultural University

Under these circumstances, the Government of Bangladesh, through a gazette notification dated 22 October 2014, has constituted a 25-member 'Coordination Committee to tap marine resources and its proper management'. Principal Secretary, Prime Minister's Office is the coordinator of the Committee. Recently, Energy & Mineral Resources Division of the Ministry of Power, Energy & Mineral Resources has been entrusted with the coordination. A 'Blue Economy Cell' has been established within the Energy & Mineral Resources Division and a Director General of the Cell has been appointed.

6.11.2 Approaches and Actions for High Priority Sectors

Bangladesh is yet to develop and significantly invest in the 'Blue Economy'. Bangladesh Delta Plan 2100 provides a sound basis to create strategies and measures over different time frames.

Approaches for High Priority Sectors

To create and maintain a prosperous and sustainable Blue Economy, the following 16 approaches are proposed (**Table 6.8**) based on qualitative assessments.

Table 6.8: Key Approaches of High Priority Sectors with Implementation Time Frame

Sector	Approaches	Time Frame		
		Short 2016-30	Medium 2031-50	Long 2051-2100
Shipping and related	Enhance coastal ship fleet & capability including port facilities	*	*	
	Maintain existing (e.g. ship building) and develop new maritime industries	*	*	*
	Enhance environmental ship recycling	*		
Marine Fisheries	Stock survey of marine fisheries	*		
	Develop & grow shallow and deep sea fishing	*	*	
	Technology based fishing in areas beyond EEZ and international waters		*	*
	Marine aquaculture & permaculture	*	*	
	Protect and conserve fish biodiversity	*	*	
Tourism	Development of ecotourism & marine cruises	*	*	*
Land Reclamation	Develop long term plan for continuous land reclamations	*		
	Construct cross dams to reclaim lands	*	*	
Renewable Energy	Developing a strong renewable energy sector using ocean and atmosphere forces	*	*	*
Manpower and capacity building	Developing a strong human resources base for domestic utilization and export to foreign job markets	*	*	
	Building a solid science, research and education base	*	*	*
Governance	Establish 'home' for coordinating developments in blue economy	*		
	Private Sector participation	*	*	

Source: BDP 2100 Analysis

Indicative Actions to support Approaches

Indicative actions are proposed for each of the approaches:

Shipping

- Invest in procuring new ships through private or public-private partnership.
- Continue to develop new deep sea ports.
- Modernise existing sea ports at Chattogram and Mongla

Ship Building

- Investment support to this newly emerging industry
- Provide tax incentives for export contracts of ships
- Developing market campaigns globally, particularly among EU ship yards as well as potential buyers.
- Seek capacity building cooperation with the Netherlands, Denmark, etc.

Ship recycling

- Ensure environmental compliance in recycling in view of Hong Kong Convention and the EU Ship Recycling Regulation.
- Ensure safety standards for recycling workers
- Facilitate recycling of ship parts in international markets
- Policy support to maintain Bangladesh's global position in ship recycling.

Fish Stock survey

- Procurement of modern survey vessel (procurement completed)
- Capacity building in survey works (science and techniques)
- Regional collaboration (BoBLME, FAO, India)
- Stock and maximum sustainable yield/total allowable catch (quota) must be determined by thorough assessments on a regular basis.
- Digital Marine Fisheries Resource Mapping for the marine waters using digital cartography of the marine fisheries resources Digital Marine Fisheries Resource Mapping (DMFRM) is an essential tool for efficient and sustainable harvesting of the marine resources. However, in all SAARC countries this is either absent or not in a state of art position. If a common DMFRM can be developed for the SAARC countries, that will be very useful all the countries and at the same time will save the required investment in this respect.

Shallow and deep sea fishing

- Issue licenses for long line fishing (four issued)
- Financial credit line to private sector, tax incentives
- Introduction of Vessel Tracking and Monitoring System (VTMS)
- Capacity building in deep sea fishing
- Seek FDIs in building deep sea fishing fleet
- Simultaneous development of fishing efforts, fish landing, processing facilities and marketing. One element cannot be developed in the absence/lack of others.

Fishing in international waters

- Joint collaboration with regional and international countries
- Creation of 100% export oriented market mechanism
- Invest in value added activities within Bangladesh fish processing etc.

Marine aquaculture and mariculture

- *Sea Weed* - Seaweeds play a major role in marine ecosystems and it has multipurpose uses such as human food, medicine, manure & fertilizer and industrial materials. It is also possible to earn a huge amount of foreign currency by exporting seaweeds. A number of initiatives were taken under Ministry of Agriculture for development of production and processing technology of Seaweeds. However, considering the importance, further inititaives are needed to take up seaweed culture on commercial scale.

Maintaining biodiversity to ensure long term fish availability

- Protecting and managing the fisheries for the present and the future generations
- Establish marine protected areas (MPAs) – one declared around 'Swatch of No Ground'.
- Enforce ban on fishing during breeding season
- Participation in international for an international fisheries management agreements
- Promote efficient waste minimization measures and techniques which will ultimately lead to 'Zero Waste' practices.
- Continue research and study

Renewable energy

- Setting up Research & Development activities, in cooperation with international developers and technology providers
- Assessment of the potentials for various categories of ocean renewable energies in Bangladesh waters

Coastal tourism

- Launch domestic and international tourism campaign at frequent intervals
- Establish joint coastal tourism programme with Myanmar
- Develop all season tourism boat fleet
- Promote dolphin and sea whale watching tour packages
- Popularise 'tour' as incentives/prizes for performance achievers in corporate and govt. offices
- Promote ecotourism as part of the tourism
- Provide investment and tax incentives to tour promoters/operators and facilitators
- Create professional tour guides.

Human Resources Development (HRD)

- Assess need for continuous human resources development
- Assess existing facilities and institutions available for HRD
- Establish joint collaboration for HRD with regional countries
- Cater to the needs of global demand for skilled manpower in maritime industries

Science and research

- Linkage with national universities and institutes for research and development
- Encourage market oriented research for the need of the private sector
- Establish joint research initiative with national and regional research centres to develop non-traditional blue economy sectors
- Study the impacts of climate change on sectors of the blue economy

Governance

- Establish strong institutional home base for development of blue economy.
- Develop policy framework for integrated coastal and maritime issues including Maritime Spatial Planning (MSP)
- Create investment friendly environment for private sector involvement

6.12 Strategy for Renewable Energy

Bangladesh's power sector is experiencing a transition period at present. Until now, the power sector has been heavily dependent on natural gas. However, the gas reserves of the country are declining. It is expected that, in near future, the power sector will shift its dependence from natural gas to imported coal and then local coal. Bangladesh has quite a good reserve of high grade coal and it is the cheapest alternative to natural gas. Moreover, the country has been experiencing a gradual shift towards exploring renewable energy resources as a driving force for overall development. The public and private sector and some NGOs have started to develop renewable energy technology projects in rural and urban areas.

6.12.1 *Present Status of the Energy Sector*

The installed generation capacity was 200 MW in 1972-73, which has increased to 13,179 MW by April, 2017 (SREDA 2017). The contribution of natural gas is 62.7% of total installed capacity of 8,267MW. Coal based power is 1.9% of present installed capacity (250MW). There is only one hydropower plant in Bangladesh with a capacity of 230MW. Moreover, the installed capacity of liquid fuel (HFO, HSD) based power plants have reached 3,832 MW and 600MW power is imported from India. At present, 80% of the total population has access to electricity (including renewable energy) and per capita electricity generation is 371 kWh. Among selected South Asian countries, Bangladesh stands third in term of production.

6.12.2 *Renewable Energy at a Glance*

Renewable energy is collected from resources that are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geo-thermal heat. The country is blessed by considerable solar radiation, and receives an average daily solar radiation of 4.6 $kWh/m^2/day$ and has considerable potential for renewable energy (SREDA, 2017).

The Renewable Energy Policy 2008 envisions that 5% of total energy production will have to be from renewable sources by 2015 and 10% by 2020. Under the existing generation scenario of Bangladesh, Renewable Energy has a very small share of the total generation. The share of Renewable Energy is 2.7%. At present total renewable energy capacity is about 447.5 MW (SREDA, 2017). Bangladesh aspires to become a developed country by 2041 for which the country is needed to get free from fossil fuel combustion as energy source as much as possible and increase the use of renewable energy more and more. It is not unlikely that Bangladesh would be able to raise the share of reneawable energy upto 30% of total energy production by 2041 with implementation of proper policies and programme.

Government has launched "500 MW Solar Power Mission" to promote the use of renewable energy to meet the increasing demand of electricity. Power Division is hosting 500 MW solar power development programmes which is the largest ever solar power development initiative in Bangladesh. Out of 500 MW solar power, 340 MW will be generated by private sector and rest 160

MW will be generated by public sector. Public utilities are involved in large scale grid-connected renewable energy based power project development. On the other hand, private sector is involved with off-grid home-based renewable energy solutions.

6.12.3 Proposed Strategy

Bangladesh is expected to have enormous potentiality in renewable energy development. Solar photovoltaic (PV) panels are gaining acceptance for providing electricity to households and small businesses in rural areas. Development of off-grid solar home solutions has achieved international benchmark. However, potential of other renewable resources is still at the exploration stage.

Wind Energy: Potential of wind energy varies across the country. The main potential for harnessing wind energy lies mainly in coastal zone and offshore islands. **Figure 6.45** illustrates the wind energy potential of the country.

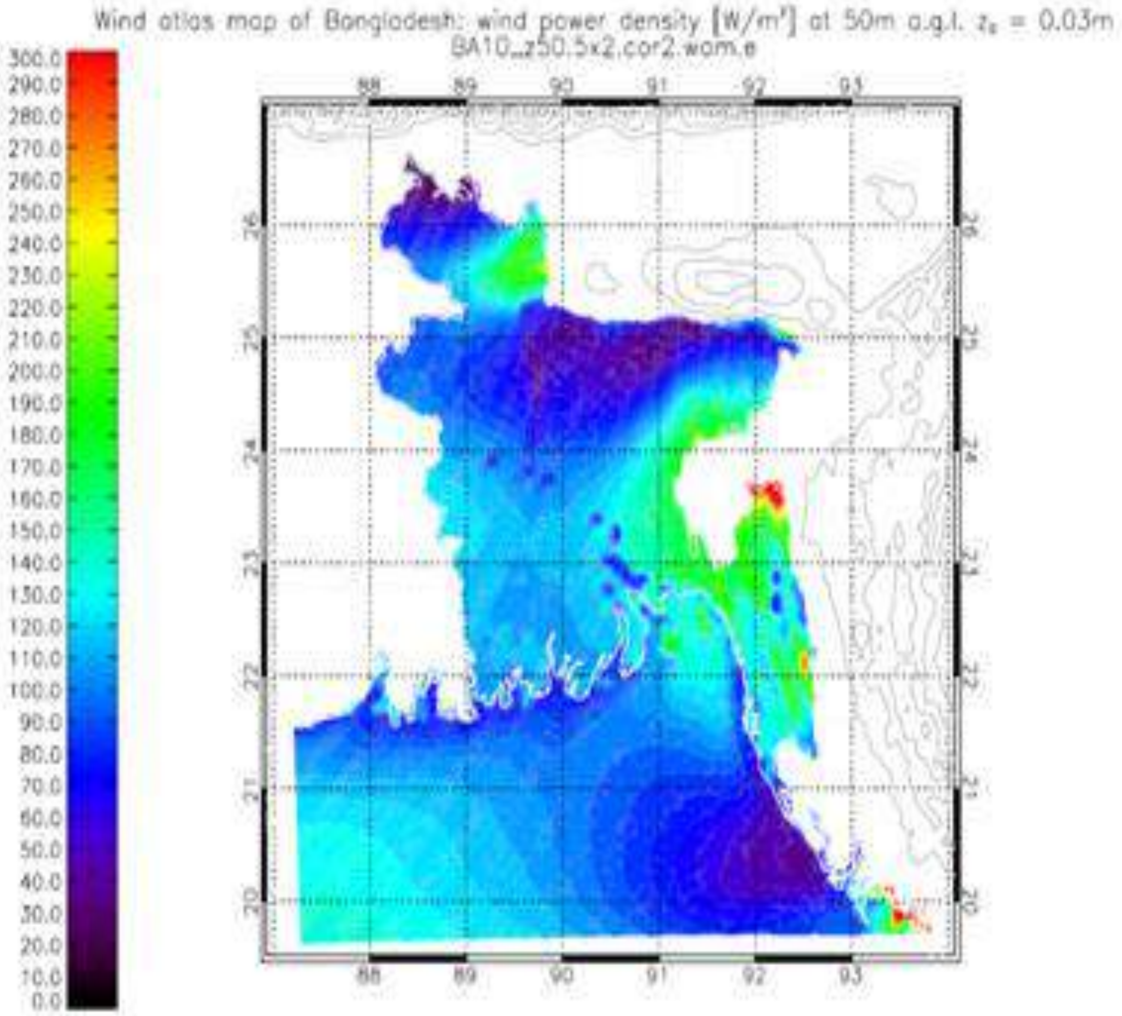


Figure 6.45: Wind Atlas Map of Bangladesh

Source: Sustainable & Renewable Energy Development Authority (SREDA), Ministry of Power, Energy and Mineral Resources

Biomass: Bangladesh has potential for biomass gasification based electricity. More common biomass resources available in the country are rice husk, crop residue, wood, jute stick, animal waste, municipal waste, sugarcane, etc. Exploration of these resources for electricity generation is still at preliminary stage. Potentials for utilizing biogas technologies derived mainly from animal, kitchen and municipal wastes may be one of the promising renewable energy resources.

Hydropower: The BDP 2100 has proposed barrages on major rivers, i.e. the Padma Barrage, the Brahmaputra barrage, etc. which can generate electricity and contribute to the national grid. The southwestern region of Bangladesh would benefit greatly from the Padma Barrage project generating about 100 MW (130,000 HP) of electricity (BDP 2100 Water Resources Baseline Study). The Brahmaputra Barrage would also contribute for generating electricity, which requires further study and research.

The Sangu project would be a new project with an annual energy production capacity of about 300 GWh per year. For an installed capacity of 140 MW, the annual plant factor is 23%, and it is estimated that the plant would operate in peaking mode (BDP 2100 Water Resources Baseline Study). However, this project needs a detailed environmental, social and economic study in the present context.

The Matamuhuri development would be a new project of capacity 75 MW and an approximate average annual energy production of 200 GWh per year (BDP 2100 Water Resources Baseline Study).

Several attempts have been made in the past to find out the potential of small hydropower generation, which is believed to be more environmental friendly in comparison to large dams. Micro hydro and mini hydro have limited potential with the exception of Chattogram Hill Tracts region. Hydropower assessments have identified some possible sites from 10 kW to 5 MW (BDP 2100 Water Resources Baseline Study). Other renewable energy sources include biofuels, gasohol, geothermal, river current, wave and tidal energy. Potentialities of these resources are yet to be explored.

Challenges

The power sector is facing many challenges such as, lack of adequate resources (private/ public/ external); issues relating to good governance; lack of adequate co-ordination; lack of appropriate cost and asset accounting system; irregular and insufficient gas supply; inadequate maintenance of power plants; tariff rate and structures; delay in implementation of power projects; organizing funds for project implementation; lack of prioritization of projects; lack of maintenance budget; failure in routine maintenance and forced shutdown of power plants. In addition, the power sector will face more challenges in future mainly due to expansion of the sector due to the increasing energy demands. GoB is gradually relying on innovation of new power technology like renewable energy. While expanding it in the rural areas several challenges have been identified. These challenges or bottlenecks are of threefold: (1) lack of technology and related knowledge and skills, (2) insufficient networks of actors, and (3) weak institutions.

For successful implementation of Renewable Energy (RE) technology in a certain area, local knowledge and skills must be available to implement as well as repair and maintain the systems. Furthermore, the relevant network of actors should be involved from the very start - future owners and people who will have to implement and maintain the technology. Finally, the local institutional context should fit with the technology including policy, programmes, financial incentives, levels of education, etc.

Recommendations to meet the future challenges

Renewable Energy provides attractive and environmentally sound technology options for power generation. It could offset a significant proportion of foreign exchange that is used for importing oil for electricity generation. Most renewable energy technologies utilize locally available resources and expertise, and would therefore provide employment opportunities for the locals.

Bangladesh has considerable renewable energy potential, and significant past experience in developing renewable energy projects. Most of the existing Renewable Energy investments have been in off-grid technologies such as solar home systems (SHS), solar micro-grids, and solar irrigation pumps. The GoB has set several investment targets for grid-connected technologies including utility-scale solar, wind, and waste-to-energy.

Despite significant potential, the development of these grid-connected renewable energy technologies, however, has been slow to materialize. There are a number of regulatory, financial and technical barriers that, if addressed, could accelerate renewable energy investment in the country. Improved regulations, such as establishment of a formal feed-in tariff and provisions for compensating mini-grid investors after transmission expansion, would reduce risk and send strong signals to investors. The following strategies could contribute to the development and dissemination of successful Renewable Energy programs in the country.

Proposed Strategies

Institutional

- Develop long term renewable energy policy as well as strategies and formulate a master plan for 50-100 years to harness the potential of renewable energy resources in the country involving public and private sector investments;
- Promote research on the development of technology in the field of renewable energy in universities and research institutions as well as build capacity for its application;
- Enhance Green Growth through research and development of renewable technologies including clean development mechanism (CDM).

Hydropower

- Develop hydro-power in the hilly rivers such as the Sangu, the Matamuhuri and other rivers and hilly streams;
- Develop and install hydro-power units in the existing barrages, such as the Teesta barrage, Manu barrage, etc. and include such units in the Padma Barrage, the Brahmaputra Barrage and other barrages;
- Develop mini-hydropower in hilly streams in the northeastern and eastern hills regions of Bangladesh.

Harnessing tidal water

- Harness tidal current and tidal waves for generating electricity in the coastal and offshore islands;
- Develop dynamic tidal power by installing generating facilities in high tidal fluctuating areas in the Sandwip areas by interaction between potential and kinetic energies in the tidal flows.

Solar Power Energy

- Install solar panels in land strips available in flood embankments, barrages and other hydraulic structures;
- Develop pumping facilities driven by solar power for pumping water from both surface water and groundwater;
- Develop floating solar systems in water bodies of haor and hard to reach areas.

Financing

- Devise innovative financing packages for grant funding and low interest financing to address affordability for both grid and off-grid renewable energy projects.
- Devise a financing mechanism for procuring land in order to make land available to private investors for implementing renewable energy projects.

6.13 Strategy for Earthquakes

The geology of the Indo-Australian Plate on which Bangladesh lies, is predominantly the result of plate tectonics. According to Rashid (1991), the Indo-Australian Plate was separated from the Euro-Asian Plate by the Tethys Sea prior to the Palaeocene (65 million years ago). During the Eocene (54 to 38 million years before the present) the Indo-Australian Plate collided with the southern edge of the Euro-Asian Plate (Rashid, 1991). Since then, the Indo-Australian Plate has advanced about 2,000 km northwards, passing beneath the Euro-Asian Plate, uplifting it and crumpling its southern edge to form the Tibetan Plateau and the Himalayas, respectively. The Indian Plate is sub-ducted along the line of the Himalayas, but at the eastern boundary the plates rub past each other along transform faults (**Figure 6.46**). During the Oligocene Epoch (38 to 26 million years before the Present), the northeastern part of the Indian Plate in the vicinity of the junction of the sub-duction zone and the eastern transform fault, fractured and sank below the sea-level to form the Bengal Basin. The northern part of this basin was then gradually filled up by sediments carried by surface waters draining into it

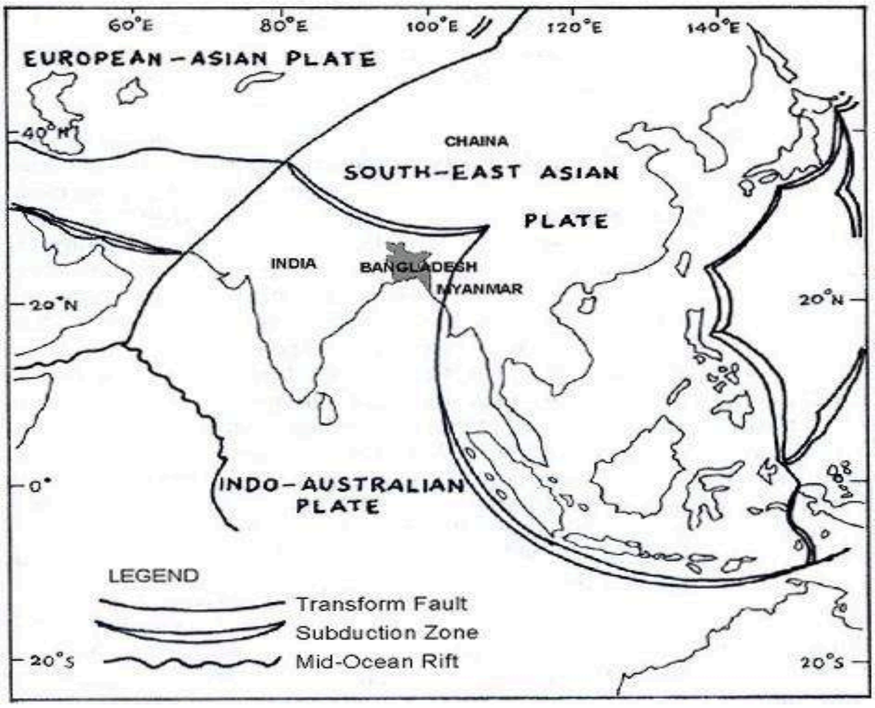


Figure 6.46: Tectonic Map of the Indo-Australian and Euro-Asian Plates

Source: Rashid (1991)

A seismic zoning map of Bangladesh was proposed in 1979 by Geological Survey of Bangladesh (GSB) dividing the country into three seismic zones, which was accompanied by outline of a code for earthquake resistant design. Later, a new updated seismic zoning map and detailed seismic design provisions have been incorporated in Bangladesh National Building Code (BNBC, 1993:2006).

Bangladesh and the north eastern part of India states have long been one of the seismically active regions of the world, and have experienced numerous large earthquakes during the past 200 years (BDP 2100 Disaster Management Baseline Study). The Great India earthquake in 1897 with a magnitude of 8.7 caused serious damage to masonry buildings in Sylhet town where the death toll rose to 545. The origin of the earthquake was in the north of Bangladesh inside India and the shaking was felt in Burma, approximately thousand miles from the origin. The casualties from this earthquake were not much since there was limited number of masonry buildings at that time. On 18 July in 1918 an earthquake hit Srimangal with a magnitude of 7.6 and intense damage occurred in Srimangal. Another earthquake in 1930 with a magnitude of 7.1 with the epicentre at Dhubri, Assam caused major damage in the eastern parts of Rangpur district. A severe earthquake occurred in Assam on 15 August 1950 having a magnitude of 8.6. The epicentre was located near Rima, Tibet and the causalities were between 1,500 and 3,300 people. There were also large landslides in the Himalayas, which contributed to considerable sedimentation load in the Brahmaputra River (BDP 2100 Disaster Management Baseline Study).

The records of approximately 150 years show that Bangladesh and the surrounding regions experienced seven major earthquakes (with Mb = 7). In the recent past, a number of tremors of moderate to severe intensity have taken place in and around Bangladesh. The Sylhet Earthquake (Mb = 5.6) of May 8, 1997, the Bandarban Earthquake (Mb = 6.0) of November 21, 1997, the Maheshkhali Earthquake (Mb = 5.1) of July 22, 1999, and the Barkal (Rangamati) Earthquake (Mb=5.5) of July 27, 2003 may be cited as examples (Choudhury, 2005).

6.13.1 Key Issues

Probabilistic seismic hazard maps of PGA (Peak Ground Acceleration) were prepared for 5 levels of return periods: 50, 100, 200, 500 and 1000 years. All maps were prepared on the seismic analysis results at the bedrock site condition. For the two return periods i.e., 50 and 100 years, the observed seismicity in and around Bangladesh controls the hazard of structural periods. But for the longer periods: 200, 500 and 1000 years, hazards are controlled by significant tectonic structures. The recurrence interval found from crustal fault model for Dauki fault is 250 years which is close to 200 years. Maps of PGA corresponding to 500 year return period are shown in Figure below.

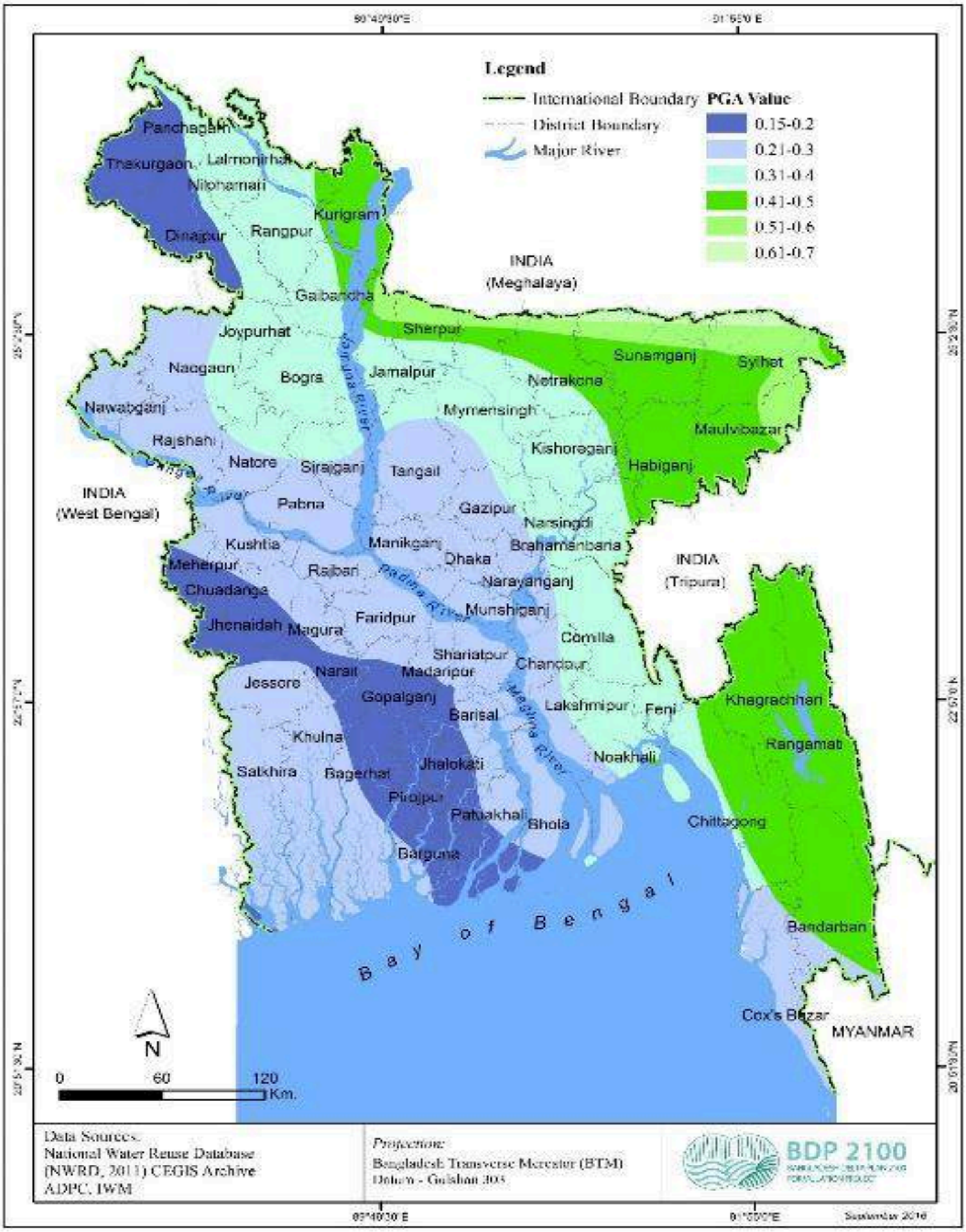


Figure 6.47: Bangladesh Seismic Hazard Map of PGA for 500-year Return Period

Source: BDP 2100 Disaster Management Baseline Study

6.13.2 Impact of earthquake on river evulsion and sedimentation process

The Ganges- the Brahmaputra- the Meghna are the major rivers of Bangladesh and this rivers system built this Bengal one of the largest delta in the world. The river system of this delta has evolved through various changes and these changes are interlinked with each other. In line with the evolution of the river system, the rivers during the last 250 years have changed their respective courses several times. The rivers abandoned their courses and subsequently, occupied several other new courses. In most of the cases, delta building processes, together with tectonics and natural hazards, like earthquake played the main role for frequent avulsion and shifting processes of the rivers. Due to sediment starvation, most of the large deltas of the world are suffering from net erosion, while net accretion is the dominating morphological process in the Bengal Delta. Huge sediment generated by the earthquake has expedited the delta building process through delta progradation, which is also responsible for floodplain and tidal plain development through river morphology adjustment process. In general, avulsion of the Brahmaputra River, tectonic activities (like 1950 Assam earthquake, subsidence), deltaic subsidence, and human interventions, along with delta progradation are the main drivers which have influenced the overall river characteristics of Bangladesh in different scale.

A very high rate of erosion and accretion process is prevailing in the estuary area since the last several years. Out of several tens of km^2/y erosion and accretion, net accretion is the dominating morphological processes. Very high rate of net accretion ($< 40\ km^2/y$) during 1940s to 1960s was mainly due to the entrance of fine sediment, immediate after the 1950 Assam earthquake. A major part of the 45 billion cubic meter debris was poured into the Brahmaputra River. This process, however, was expedited by the construction of two Noakhali Cross Dams in the late 1950s and early 1960s. Net volume of depositing sediment in 1950 to 1973 is about $7{,}360\times106\ m^3$. The sediment generated by 1950 Assam earthquake is considered to have immense effect on this delta building process, especially on the topography of the estuary (Brammer, 2004). Moreover, erosion of the Himalayas, highland boundaries, avulsion of Brahmaputra has influenced the process. This active delta building process has impact on accelerating the dynamics of rivers and Meghna estuary of this region (Sarker, 2013). The overall river system of this region was flowing eastward previously. But the rivers are now flowing westward due to the adjustment with the delta building process.

BDP 2100 formulated strategy on earthquake as follows:

Strategies

- Strengthen the earthquake management and enhance the capacity to cope with earthquakes;
- Design earthquake-proof structures including barrages, regulators, sluices, embankments, cross-dams, roads, bridges, buildings in conformity with the Bangladesh National Building codes or any other approved standards;
- Formulate a proper land use plan for building construction in municipal areas;
- Conduct a detailed study on identification of faults and epicentres.

Chapter 7
Sustainable Land Use and Spatial Planning across the Dynamic Delta

Chapter 7 : Sustainable Land Use and Spatial Planning across the Dynamic Delta

7.1 Introduction

Bangladesh's economy is characterized by rice-based agriculture dominated landscapes, within the largest delta in the world. The vast plain land is washed by the mighty rivers-the Meghna, the Padma, the Jamuna and the Karnaphuli and their numerous tributaries. The total area of Bangladesh is about 1,47,570 km^2 with population over 160 million, which makes Bangladesh a densely populated country and land-person ratio is lowest in the world, which is estimated to be 0.06 ha per person. The main landforms in Bangladesh are ridges, basins, char lands, hills, terraces, rivers, and valleys. 80% of it is floodplain, 12% is hilly and the remaining 8% is under uplifted blocks (terraces) (IUCN, 2002). Vast areas of these floodplain lands get inundated during monsoon season and become intractable for cultivation. In the summer, the swamp areas dry up and come under cultivation. These swamps are also sources of fish resources. The hilly tract is used for plantation of tea, rubber, pineapples and terrace cultivation.

Land is a finite resource, and with requirements for human needs ever expanding from diverse social and economic activities. These have also been placing ever-increasing pressure on land resources. There is competing demand for land use; and because of its scarcity there is speculative land pricing in an otherwise a very inefficiently functioning land market. Land resources are the major asset contributing to wealth and livelihood in both urban and rural areas. It is deemed as the safest asset to hold and pass on for inheritance, and also the fastest way for appreciating the wealth of a person. This wealth aspect has also been the source of conflicts and clogging up of the court system by cases that are land related. All these results in suboptimal use of both land and land related resources. While there had been land reforms limiting holding sizes, land inequality continues to remain a problem in Bangladesh and is exacerbated by elite land grabs and the inadequate capacity to execute legislation on land ownership ceilings. This, in the context of the land accretion and erosion in the Bangladesh delta region, is even more of a problem.

7.2 Necessity for Integrated Spatial Planning in Bangladesh

The importance of spatial planning as an instrument to guide development in Bangladesh has already been underlined in several policy documents including the 7th FYP and the draft Urban Sector Policy (USP). In the context of ADM in general and the BDP 2100 in particular, spatial planning is an essential tool to provide a consistent direction in cross-sector development. Hence the concept is adopted in the preferred strategy for the urban areas hotspot. Integrated planning can be employed to achieve the following goals:

- to identify the appropriate locations for economic and urban development through integrated planning. Bangladesh's ambitions in the planning of economic zones and urban areas should be developed in coherence with typical BDP 2100 aspects such as flood risk management, fresh water availability, waterway and road infrastructure connections, sustainability and land reclamation.
- to coordinate efforts in environmental protection and the improvement of liveability of urban areas. Environmental degradation is a typical cross-sector issue, produced by contradictory interests converging in one area. Bangladesh's largest cities are facing the consequences of

soil, water and air pollution, and lack qualitative living environments. Urban strategies for green-blue structures and mobility are absent. Spatial planning and the implementation of such plans provides a means of addressing these problems.

- to provide vision and strategic assessment of not only what is desirable, but also of what is possible in various scenarios.
- to formulate spatial strategies at national, regional and local levels to deliver priorities for investment and development.

Lack of coordination between different departments responsible for preparation and maintenance of Record of Rights (ROR) that often leads to confusion, conflicts and many instances of litigation causing suffering of the people especially the small and marginal farmers. To mitigate this problem, the Ministry of Land has already undertaken projects to conduct digital surveys and introduce e-governance. Land records will be computerized and land mutation will be made automatic. There is articulation of the need for necessary measures to be initiated for ensuring sound coordination of the activities undertaken by department of registration, AC (Land) and DLRS offices. Through appropriate delineation of supervisory responsibility of settlement activities, better coordination of the two offices in dealing with the preparation and maintenance of land records at the Upazilla level will have to be achieved. The Directorate of Registration will have to remove inconsistency in land records management, and also measures need to be taken for immediate updating of land titles.

The goals of the land resource management strategy, therefore, should aim at achieving sustainable and optimal land use, which in turn should support better spatial planning across the dynamic Delta while being supportive of the broader development goals of the country. These can be summarized as follows:

- Ensuring food security for the growing population;
- Ensuring housing and shelter for the growing population;
- Achieving 8% GDP growth by 2020 for higher levels of job creation and accelerated poverty reduction through higher levels of growth in the manufacturing sector with its increased share in GDP;
- Ensuring multi-modal transportation system using land and water in an integrated approach;
- Ensuring land use management and risk sensitive land use/spatial planning.

Land resource management is integrally linked to water resource management given the close link between the silt carrying rivers and the accompanying land erosion and accretion. These resources also impact on all aspects of livelihood and habitation within the Delta. Therefore, all strategies and actions have been planned and designed in ways that ensures efficient integration and proper interaction between land and water use aspects. Any land resource management would be able to help mainstream the inter-connected resources functions (drainage, navigation, land accretion, erosion, etc.) and link it to the broader strategic development goal of Bangladesh, as mentioned in the 7th FYP, of industry becoming the engine for achieving 8% growth of GDP by FY2020. A comprehensive land resources management and spatial plan is therefore urgently needed to meet the present and future demands in a suitable way for successful implementation of BDP 2100.

7.3 Aspects of Integrated Spatial Planning

Integrated spatial planning goes further than weighing and combining the elements of sectoral plans. The interdependencies between system layers and scales are defined in the drafting of an integrated spatial strategy or plan. In the following sections three different scale levels are discussed, which employ different aspects of planning and design; the national scale level, regional scale level and the city ('settlement') scale level. The following sections handle the three scale levels and the relevant aspects they hold for integrated spatial planning in Bangladesh.

An important concept in integrated planning is the 'triple layer framework', which is instrumental in understanding the natural delta system, and the relation between spatial interventions. In this model three layers are identified:

- The occupation layer (the layer of human occupation, e.g. rural and urban settlements, characterised by a relatively short development rate of 25-50 years);
- The network layer (the layer of the infrastructural networks, e.g. roads and embankments, characterised by a relatively development rate of 50-100 years);
- The subsoil (the natural layer of the subsoil in which physical changes take centuries).

7.3.1 Key Aspects in Integrated Land Use and Flood Risk Management

In both spatial planning as well as in water management and flood risk management the relation between different scales and interventions is essential. Flood risk interventions at three scales (regional, local, building scale) have relation between four basic choices with regards to flood risk protection:

- letting the water in (and dealing with floods on other scales or with insurance/evacuation);
- elevating grounds;
- dikes or polders to protect land;
- barriers to divert or block the water from the area.

The different measures at different scales can complement one another, as the scales and interventions are interchangeable to some degree. For instance, letting the water into an inhabited area in order to optimize the flow capacity of the river will mean that on a lower scale level of the building one can provide flood protection by taking measures to flood proof buildings.

Integrated Flood Risk Management at National Scale

A strategy that relates water management interventions to the location of growth centres and urban development at national scale is essential. Within this national strategy the choice for development locations can be related to the way the country will be protected from floods or provided with water. Of course water management is not the only relevant factor: on this scale for instance the economic development of regions, the existing or potential transport network of the country and large development projects also influence the development opportunities for certain regions.

The interdependency of flood risk interventions and spatial development

Often flood risk protection measures are necessary to protect urbanised or inhabited areas from flooding. However the flood risk protection measure itself can become a driver for development. This can lead to different future obligations, and start a spiral of interdependency where the development behind a flood risk protection measure can heighten the economic value of the protected value hence the need for improved flood risk protection. Taking probabilistic reduction measures in areas that will remain challenging to defend against natural disasters in the long term can become an ongoing costly protection obligation, due to the increase of occupation and economic activities resulting from the initial protection measure.

Guiding population and development by infrastructure

Infrastructure can be a driver for urbanisation since it can improve the connection to markets or amenities and development often originates around it. It can therefore be used as an instrument for directing future development. The distribution of the population can be guided by infrastructure investments (and other services and amenities) in three ways:

- Keeping inhabitants in areas one does not want them to migrate from (for instance rural settlements) by providing jobs, services and infrastructure in centres that one would like to retain people;
- Prevent sprawl by guiding people to new settlements where basic services such as infrastructure, electricity and sewers are provided so that they are drawn to settle in this area;
- Intensify existing settlements by increasing the density. This can only be done in a qualitative way if the amount of infrastructure and amenities are improved simultaneously to serve the growing population.

Integrated Flood Risk Management at Urban Scale

Different flexibility of reservation areas for future development

Planning of reservation zones are necessary in order to guarantee the availability of space for certain functions on the long term. These functions can include space for widening roads or rail tracks, extending airports or harbours or for flood risk protection or fresh water reserves expected to be needed in the future. The reason these areas are reserved is that buying out land owners in the future will be too expensive and projects can become unfeasible.

Designing for different return periods

Designing for flood risk does not mean that the protection needs to be the same for every flood recurrence and that flooding is unacceptable in every situation. It can be that a minor flood occurring every once in a while can actually benefit agriculture for instance, but also contribute to the people's awareness of living in a flood risk area. This awareness can be important for people to be aware of the risks and for building flood proof houses as well as be an incentive for not occupying floodplains.

Change of values with growing prosperity

With growing prosperity come new values and expectations of the (urban) living environment. This is important with regard to integrated water management strategies as well as developing urban plans in general.

Alleviating Land Scarcity through Integrated Design

Multifunctional land use

This principle is based on using a single area for multiple uses. For instance combining open water surfaces or flood plains with houses on stilts or floating houses so that the area has a double use; water storage/ flood plain and housing. Another example are green roofs that make it possible to overlap a building designation with ecology, urban agriculture, or water retention on the roof. This way one can increase the available surface and with that create more space for other necessary functions.

Land reclamation

An often practised way of addressing land scarcity is the creation of extra land from rivers, estuaries and the sea. The reclaimed land can be use for increasing agricultural area or for creating space for industries, harbours or urban development. With planning new reclamations, future development scenarios should be taken into consideration with regards to long term planning.

Increasing density

By building in higher densities, the pressure on the available land from an occupation perspective can decrease. For cities, it is essential to maintain the liveability while increasing its density. For agriculture the 'density' can be improved by using high production agriculture techniques.

7.3.2 Key Aspects for Spatial Strategies at City/ Settlement Scale

The following aspects are suggested for spatial policy on city/settlement scale. Further details for urban water management are provided in **Chapter 10**.

Integrated Urban Planning

In Bangladesh, the urban areas are developing in an unsustainable way resulting in poor liveability. A strong vision on liveability of cities can help set targets on growth management and sustainable interventions for aspects such as mobility, green and blue recreational spaces, urban drainage, water supply and sanitation, density and (national) urban growth management and general measures and concepts for developing liveable neighbourhoods. This includes providing open and green spaces, pedestrian areas, mixed neighbourhoods, diversified and sufficient amenities. An example for improving existing drainage system through integrated planning is shown **Figure 7.1**.

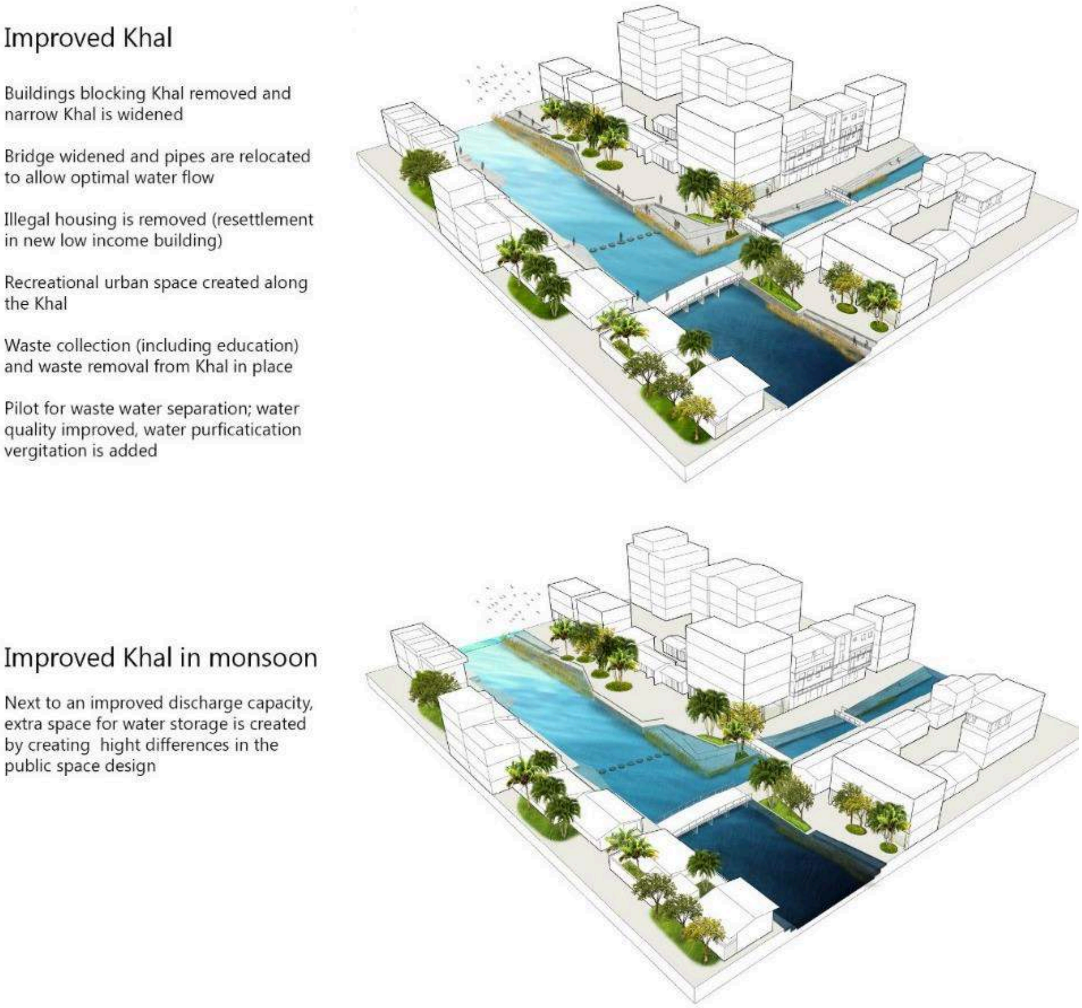


Figure 7.1: Improving existing drainage systems in an integrated approach

Specific Planning Issues for Metropolises

Bangladesh's metropolises currently experience the large negative consequences of rapid and informal urban development. A vision on restructuring in metropolises can provide guidelines to raise the quality of life in informal development in Dhaka and Chattogram. Restructuring of the high density informal development areas is to be anticipated in the short to medium term. New urban water management concepts (specifically aimed at sanitation solutions and urban drainage) are much needed in these areas.

Preservation of Wetlands and other Water Bodies

To effectively protect wetlands in and around urban areas, it is important to know the value of water bodies to urban drainage. When the ecological and hydrological (retention and discharge capacity) values are established, targets for water retention and ecological value can be set. In the short term, measures are introduced to protect wetlands from unwanted development. Wetlands in the urban fringe that experience high spatial pressure (due to high land prices and land grabbing) are developed in Public-Private-Partnerships. This allows the development agencies to guard essential functional design elements including the provision of sanitation infrastructure, open-area ratios and retention capacity (see **Figure 7.2** and **Figure 7.3**).

Figure 7.2: New development during normal water level

Source: BDP 2100 Technical Team, GED, 2015

Figure 7.3: New development in monsoon

Source: BDP 2100 Technical Team, GED, 2015

Sustainable Urban Floodplain Development through Public-Private Partnerships

Currently the capacity for water storage areas in urban areas is organized by reserving large areas as floodplains. In these areas there is a restrictive building policy, however due to the major pressure on land and the growth of urban population the wetland areas are being developed illegally both by developers as well as by informal urban sprawl, resulting in the loss of water storage capacity and unsustainable, low quality development (since the road structure and facilities such as sewerage are not planned).

7.3.3 Key Aspects for Spatial Strategies at Neighbourhood Scale

In light of BDP 2100, the following aspects are suggested for spatial policy at the neighbourhood scale, which have been applied in the strategies for the Urban Area Hotspot.

Flood Risk Protection and Riverfront Development/Embankments

With this strategy the urban embankments will have to be enforced in time to make the flood risk protection level grow in time together with the increase of the population and the economic value behind the embankment. Embankments are natural attractions to settlement, which can make it difficult to extend the infrastructure in the future. Also the embankments and the river view are attractive places for recreation. In order to make the future elevation of the levee possible it is best to keep it open, either by assigning a placeholder function (like a public waterfront) or by only allowing flexible functions that can easily be removed when needed. Examples of the public space are the Sylhet waterfront development and the hard point area, that both function as a public recreational space. Examples of flexible functions can be the Dhaka Buriganga waterfront where small market spaces occupy the river bank. The public space placeholders can also help preventing sprawl of the floodplain since they are both a placeholder for the space needed for the future enforcement of the levee as well as the floodplain space needed for optimal river discharge.

Which option is favourable will depend on future developments. With a growth of GDP and the request for qualitative living standards (as per Productive and Resilient scenarios), the public space along the river will be preferable. With lower GDP growth and less opportunities for qualitative public space (as per Moderate and Active scenarios), the river banks could still be good investments for public space, however the flexible functions (markets with small scale flexible buildings) could be a better alternative **(see Figure 7.4).**

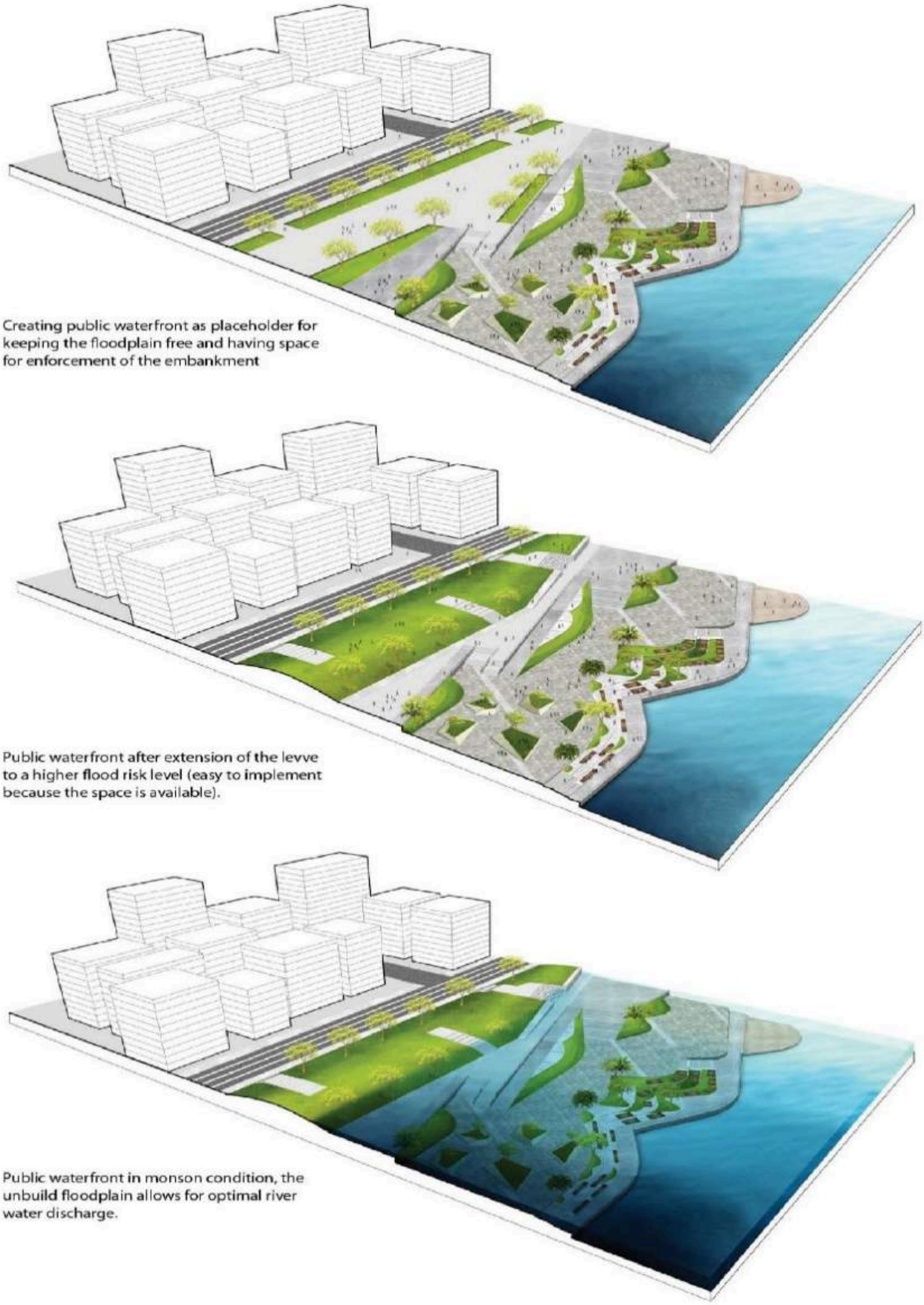


Figure 7.4: Public waterfront development as a placeholder for future expansion of embankment

Source: BDP 2100 Technical Team, GED, 2015

7.4 Constraints and Challenges of Land Resources Management

The main challenges for land resources management of the Bangladesh Delta relate to optimizing land use so that the integrity of life-support systems and their productive capacities are maintained. At the same time, another challenge is to support the growing population needs by taking measures to increase the land area of the country along the rivers and coasts through accretion and reclamation while ensuring the integrity of existing river channels. A key challenge for optimum land use will be to come up with a long term sustainable healthy balance between land needs for agriculture and food security and that for urbanization, industry and rural settlements. A challenge and an opportunity will be to have implementable zoning laws and also optimizing on value-added use of newly accreted land and reclaimed land. Land zoning can also be an efficient tool for protecting critical environmental areas such as wetlands and restricting development in hazard prone areas.

The higher temperature, and changing rainfalls by time and amount, rising salinity in the coastal belt, and droughts are likely to impact future land use management of the country. The area of soil salinity is expanding due to reduction of upstream flows mainly due to human interventions and also due to rising sea levels caused by climate change. In the southwestern region, water and soil salinity is a severe problem with respect to crop production and fresh water fisheries. Soil and water salinity generally increases with dryness and reaches maximum in the month of April and May and then tend to decrease due to onset of monsoon rainfall. It is expected that the sea level rise is likely to significantly impact coastal river salinity in Bangladesh by 2050.

If sea level rise is higher than currently expected and coastal polders are not strengthened and/or new ones are not built, then it is projected that six to eight million people could be displaced by 2050.

With population growth and declining per capita availability of land Bangladesh also faces land degradation. Deforestation, cultivation on steep slopes, shifting cultivation, over-exploitation of groundwater, unbalanced use of fertilizers and improper crop rotations are responsible for land degradation induced by humans. Lands are also degraded by soil erosion, both in floodplains and in hilly areas, as well as salinization, acidification, fertility depletion, water –logging/ drainage congestion, heavy metal pollution and industrial effluents from urban and industrial areas.

Land resource management will therefore require innovations and adaptations that will support both food security as well as land for urban, non-farm activities, industry, and infrastructure needs, and will be interlinked with all aspects of water resource management within the six hotspots of BDP 2100.

Constraints and Challenges in River Systems and Estuaries

The hydrological characteristics of the Ganges- the Brahmaputra- the Meghna basins is influenced by climate change impacts like temperature rise, which affect the timing and snow melting in upper Himalayan ridges. This change tends to raise the average water level of lower riparian rivers and causes serious flooding. Through Bangladesh Delta, 93% of the Ganges- the Brahmaputra- the Meghna basin is drained to the Bay of Bengal, though it accounts for only 7% of the total area of the three Basins. Every year, these river systems are carrying one trillion cubic meter of water with more than one billion tonnes of sediments from beyond the Bangladesh border to the Bay of

Bengal. Therefore, effective management of upstream water flow as well as sediments is one of the major concerns for the Bangladesh Delta.

Constraints and Challenges in Haor and Flash Flood Areas

The haors and wetlands, characterized by unique physical and hydrological settings, are considered one of the potential economic zones of the country. The key identified constraints relating to optimizing land resource management in the haor and flash flood areas are as follows:

- Early flash flood destroys maturing Boro, young Aus and deepwater B. Aman.
- Heavy rainfall hampers harvesting, drying and storage of crops.
- Slow drainage of basin centres.
- Consierable amounts of large land ownership (and absentee owners).
- Conflict between fisheries and crop production interests for use of the water remaining in haors after rainy season.

Constraints and Challenges in Coastal Zone

Coastal livelihoods are also largely dependent on agricultural crops, mainly rice. At present, Coastal Zone contributes approximately 16% of the total rice production of the country. In coastal districts rain-fed monsoon paddy is the dominant crop, covering about 70% of the total paddy cropped area. The entire area is almost traditionally mono-cropped during monsoon under rain-fed condition with local rice having moderate to poor yields; though the Coastal Zone also produces a relatively high proportion of pulses, oilseeds, betel nuts and leaves, winter vegetables and potatoes, and the three coastal districts — Gopalganj, Pirojpur and Barishal — have a history of practicing a cropping system called floating agriculture. The coastal lands of the southern delta are generally low and flat and vulnerable to different hazards such as flood, riverbank erosion, and inundation by high tides, salinity intrusion, droughts, cyclones and associated tidal surges, drainage congestion, water logging, and lack of quality irrigation water. These also affect coastal land use for agriculture in the Coastal Zone.

Floods are annual phenomena with the most severe occurring during the months of July and August, with regular river floods affecting 20% of the country increasing up to 68% in extreme years. There is the added problem of water-logging and drainage congestion of soils. The entire river system of the southwest delta of Bangladesh is vulnerable to excessive sedimentation by incoming silts. After polderization in the early 1970s, and decrease of flushing fresh water flow from upstream during last few decades, the rivers in this part started to silt up. As a result of this continuous siltation process over the years, the conveyance of the peripheral rivers of the coastal polders reduced significantly leading to large-scale water logging problems inside the polders. The waterlogged soils become strongly acidic upon drying with heavy soil texture and deficient in nutrients, which create unfavorable environment for crop production. Inundation of land for long periods is harmful even for wetland crops, especially if the standing water is stagnant. Water logging is also common in the beels, jheels, haors and baors.

Besides crop agriculture, one of the main economic activities in the coastal zone is aquaculture. This provides a big opportunity of diversifying agriculture practices while taking into account the water related challenges. The significance of shrimp farming has grown rapidly over the last 30 years with shrimp exports an important foreign exchange earner. Land devoted to shrimp farming has increased remarkably over the last decade and is still increasing. The EEZ in the Bay of Bengal also supports marine fisheries and opens new opportunities that will support the Government's desired development strategy.

Any land resource management strategy needs to take into account the above challenges and opportunities from food security point of view. There have been efforts in that direction and for a long time construction of polders along the coasts have been part of the strategy of safeguarding from water related hazards as well as providing opportunities for reclamation of land. However, the construction of costal polders that de-linked the floodplains from the rivers, and diminished upstream flow during the dry season deteriorated the sedimentation problem in this region. While polders and dykes have been built along with afforestation programs to reduce different risks listed above, and new salinity resistant crop varieties are being developed and introduced, better water system management will be required along with value added use of reclaimed land. This is particularly important from urban, rural settlement and industry demand's point of view. Spatial planning that links land resource management to water resource management will be key to achieving value added needs.

The challenge for optimizing land resource management will be to ensure that the river flows are better managed and drained through the historic channels with better silt carrying capacity. This optimization can have value added use in land accretion and reclamation and also reduce water-logging, salinity and encroachment related problems.

Constraints and Challenges in Barind and Drought Prone Areas

The greater part of the Barind tract (approximately 7,700 km^2) is almost plain and crisscrossed by only a few minor rivers. The area is considered an ecologically fragile ecosystem with extremely low vegetation cover. Here the soil, which is flooded in the rainy season, becomes very parched in the dry season. Consequently, the area suffers from frequent droughts and water scarcity in addition to low organic matter content and low fertility of the soil. Inadequate surface and groundwater limits irrigation. Ownership of large land parcels (generally absentee) also makes it difficult to organize activities, e.g. maintenance of irrigation/drainage channels, IPM, etc. Key constraints in these areas are as follows:

- Soils which are flooded in the rainy season become very dry, specially in the dry season;
- Low organic matter content and low soil fertility;
- Uncertain groundwater supplies in some areas;
- Poor rural road communication, especially in the rainy season;
- Unreliable pre-monsoon and post-monsoon rainfall, as well as occasional dry periods within the rainy season;
- Soils poorly drained in rainy season;
- Large land ownership (generally absentee);
- Generally inadequate surface water and in some places groundwater also;
- Large–scale irrigation would be difficult to provide as the high lift required from the adjoining perennial rivers (Ganges, Mahananda) due to undulated topography.

Constraints and Challenges in Chattogram Hill Tracts

This Hotspot is confined within the districts of Khagrachari, Rangamati and Bandarban. The region experiences cyclonic rainfall, flash floods and landslides during the monsoon and water shortage during the dry season both for domestic and agriculture purposes. Ownership issue is a big challenge to land resource management in this Hotspot. Key constraints include:

- Steep sloped land;
- Roads are expensive to build because of long, linear, hill ranges with steep slopes;
- Very strongly acidic soils;
- Fertilizer nitrogen is rapidly leached during heavy monsoon rainfall;
- Area exposed to cyclones;
- Prominent flash floods;
- Hill areas are vulnerable due to its soft soil formation and cause landslides with incessant rainfall and unplanned settlements;
- Remoteness of areas;
- Complexity in land ownership.

Constraints and Challenges in Urban Areas

The challeneges in Urban Areas are a bit different from the other Hotspots. The growing population and the concomitant demand for land for housing, infrastructure development, and industrial needs will continue to be a challenge for land resources management in Urban Areas. This Hotspot also experiences floods, drainage congestion, water logging, water shortage, environmental degradation as well as high incidences of water, air, soil, noise and thermal pollution. The challenge here is that of undertaking integrated spatial planning and also identifying new areas for urbanization that minimizes encroachment into prime agricultural lands.

7.4.1 Land Use Issues and Practices

A land use strategy that takes into account the challenges of the different Hotspots as well as adequately responds to the competing land needs of food security, urbanization and industrialiaztion in the long term is the key to an optimal land resource management. Land use in Bangladesh is generally determined by physiography, climate and land levels (Brammer, 2002). Together, they constitute a highly complex environment characterized by five main land types related to the depth of seasonal flooding. As evident, about 60% of the land is seasonally inundated to a depth of 30 centimeters or more.

While land use pattern would be dependent on the various land types, to get a proper measurement of land based on its various usages and also its impact on ecosystems, land use classification is required. There are classifications made on the basis of physical appearance (land cover classification), the purpose of its use, and agro-climatic/ agro-ecological classifications. A very comprehensive classification has been done as part of Land Resources Appraisal of Bangladesh for agricultural development; where Bangladesh has been subdivided into 30 agro-ecological regions and 88 sub regions (Brammer, 2002). The major components of these regions and sub-regions are physiography, soil properties, soil salinity, depth and duration of flooding which are relevant for land use and for the assessment of present and future agricultural potential.

Each of these agro-ecological zones is characterized with differences in soils, climate and hydrology and with varying degrees of risk apropos disastrous floods, drought and cyclones.

The agro-ecological regions and the 88 sub-regions are more attuned to agriculture and may not be reflective enough for other type of land use, particularly the growing land demand for urban and industrial needs. Any land use related strategic planning that primarily focuses on agriculture and rural usages without adequately taking into the demographic needs of creating jobs will not be able to fulfill the Government's strategic objective of inclusive growth as stated in the 6th FYP and 7th FYP's as well as in its Vision 2021. A more comprehensive and standardized land use classification is, therefore, required for a more integrated land use planning and optimal land resource management. The land use could be classified under three broad headings.

a) Areas of conservation (natural resource protection areas with environmental concerns like wetlands, watersheds, rivers, hills, disaster prone areas, etc.);
b) Areas for agriculture and forestry production (includes agricultural land, forest areas, other production oriented resources and rural homesteads);
c) Developed areas and areas needed for future development for residential, commercial, industrial and other urban areas.

Land Utilization Pattern

Based on a study by the Soil Resource Development Institute (SRDI) the Baseline Study on Land Resource Management for BDP 2100 has elaborated on the technicalities relating to Land Utilization and the entire area has been investigated to know the present status of land coverage/ land utilization that includes forest, herb/ shrubs, fallow/ agricultural land, river and water bodies, settlements, and hill shades. Agriculture accounts for 82% of about 14,840,000 ha of land with non-agriculture land being about 18%. Agriculture land includes cropland, which is about 59% with cropping intensity of 190% in single, double and triple cropped areas. Rural settlements account for 11.9% of the total land area while urban and industrial land accounts for only 0.6% (see **Table 7.1**).

According to the BBS, urban area includes areas under city corporations, paurashavas, Upazilla headquarters and cantonment areas. The BBS data shows that the total amount of urban land in 2011 was about 8,867 km^2, which is 8,86,700 ha contrary to 87,616 ha by the SRDI 2013 report. However, even with the differences in methodology of data collection, it is clear that in both cases land use from urbanization and industry is increasing at a fast pace. While urbanization and industrial challenges to land use will continue to increase, the main challenge from land resource management point of view will be to limit land use for rural settlements and spatial planning will be critical in this context. Land utilization pattern is presented in **Table 7.1** below.

Table 7.1: Land Utilization/Land Cover of Bangladesh (2010)

Land Use / Land Cover	Gross Area (ha)	% of Total
Agricultural land	12,176,904	82.1
Crop land	8,751,937	59.0
Forest	1,434,136	9.7
Mangrove forest	441,455	3.0
River	939,073	6.3
Lake	51,739	0.3
Beel and haor	250,727	1.7
Aquaculture	175,663	1.2
Tea estate	96,152	0.6
Salt pan	36,022	0.2
Non-agricultural land	2,663,096	17.9
Rural settlement	1,766,123	11.9
Urban & Industrial	87,616	0.6
Accreted land	547,128	3.7
Others (unidentified)	262,229	1.8
Total	***14,840,000***	***100.0***

Source: SRDI, 2013

Changing Land Use Trends

Given the scarcity of land, large working age population, and the path of development being pursued by Bangladesh, land use pattern has been changing with declining share of agriculture land. As depicted in **Figure 7.5**, the area under agricultural land was 133,03,654 ha, which was about 91.83% of the country in 1976. This agricultural land has since decreased to 127,42,274 ha in 2000; that is there has been a total decline of 561,380 ha in 24 years or an average annual decline of 23,391 ha/yr during this period.

Keeping pace with growing share of industry and manufacturing sectors in its GDP, the land available for agriculture declined further but also at an accelerated rate, and it reached to 121,76,904 ha in 2010. This meant a decline of 565,370 ha in a ten year period at an annual average decline of 56,537 ha/yr, which is more than 142% decline in latter 10 years compared to previous 24 years. The average annual loss of agricultural land during the period (1976-2010) was 33,140 ha/yr.

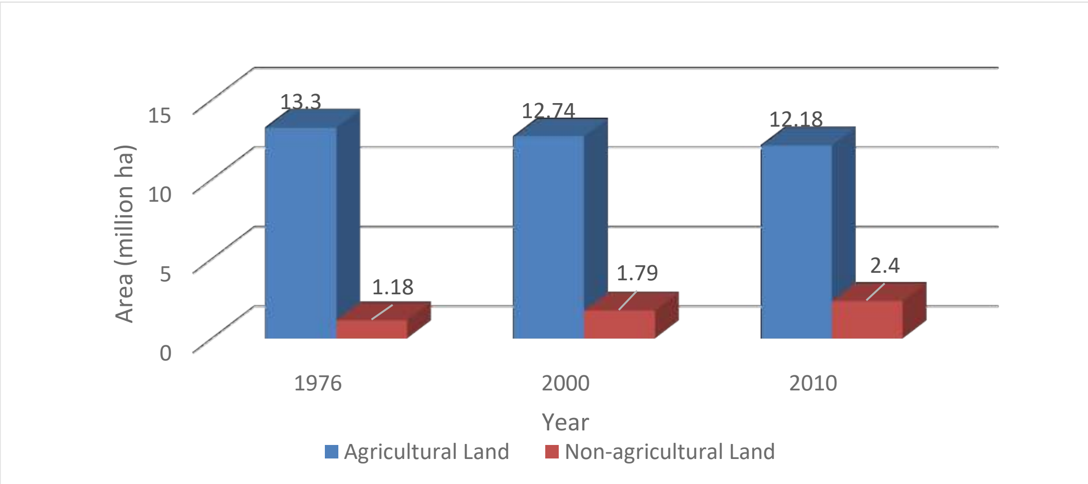


Figure 7.5: Trends of Agricultural and Non-agricultural Land Cover during 1976 -2010

Source: SRDI, 2013

Agricultural Land Use Changes over Time

In order to get a better understanding of the above trends, changes in areas of sub-categories for agriculture and non-agriculture land uses have been analysed (**Table 7.2**). The biggest decline in agriculture land resulted from decline in cropland. While it declined at an annual average rate of 0.14%/yr between 1976 and 2000, the decline accelerated to 0.73%/yr between 2000 and 2010. While there had also been initial decline (0.13%/yr) in forest area between 1976 and 2000, there was reversal with annual average growth of forest land growing by 0.08%/yr between 2000 and 2010. Mangrove forests, on the other hand, grew between 1976-2000, but again declined between 2000 and 2010.

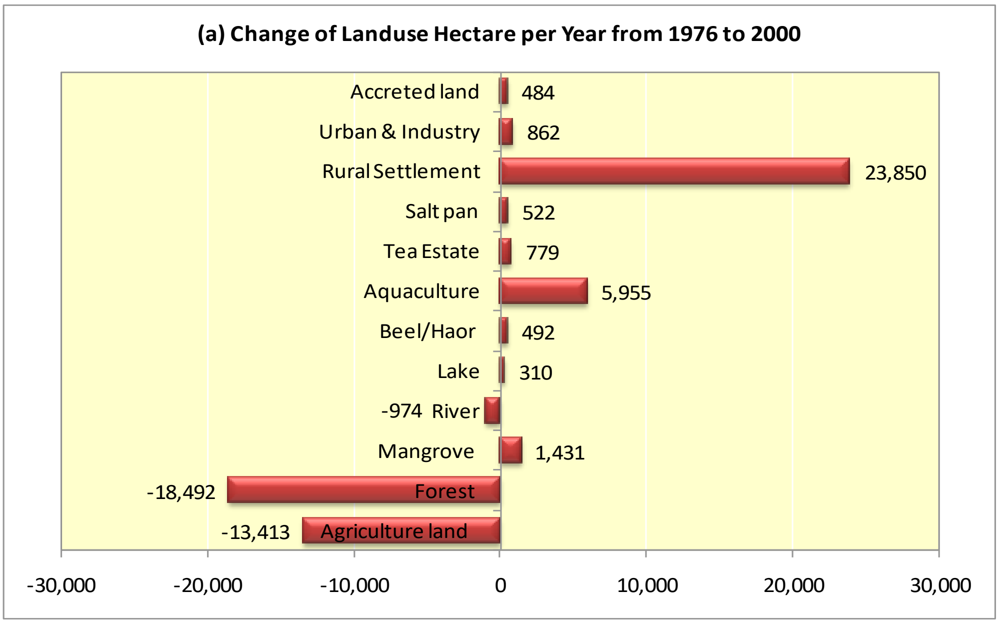
Table 7.2: Area and Average Annual Change in Land Use Acreage (%)

Land Use / Land Cover	Year 1976	Year 2000	Year 2010	Annual change by area (ha)			Average annual changes (%)		
	Area (ha)	Area (ha)	Area (ha)	1976-2000	2000-2010	1976-2010	1976-2000	2000-2010	1976-2010
Agricultural land	13,303,654	12,742,274	12,176,904	-23,391	- 56,537	- 33,140	-0.176	- 0.444	-0.249
Crop land	9,761,453	9,439,541	8,751,937	-13,413	- 68,760	- 29,692	-0.137	-0.728	-0.304
Forest	1,754,917	1,311,121	1,434,136	- 18,492	12,302	-9,435	-1.054	0.938	-0.538
Mangrove forest	452,444	486,791	441,455	1,431	-4,534	-323	0.316	-0.931	-0.071
River	911,819	888,441	939,073	-974	5,063	802	-0.107	0.570	0.088
Lake	50,829	58,261	51,739	310	-652	27	0.609	-1.119	0.053
Beel and Haor	239,977	251,774	250,724	492	-105	316	0.205	- 0.042	0.132
Aquaculture	582	143,506	175,663	5,955	3,216	5,149	1,023.2	2.241	884.78
Tea estate	119,847	138,533	96,152	779	-4,238	-697	0.652	- 3.059	-0.582
Salt pan	11,789	24,306	36,022	522	1,172	713	4.424	4.820	6.046
Non-agric. land	1,183,605	1,788,307	2,400,867	25,196	61,256	35,802	2.129	3.425	3.025
Rural settlement	885,637	1,458,031	1,766,123	23,850	30,809	25,897	2.693	2.113	2.924
Urban & Industrial	26,799	47,495	87,616	862	4,012	1,789	3.218	8.447	6.675
Accreted land	271,169	282,781	547,128	484	26,435	8,116	0.178	9.348	2.993
Total	***14,487,259***	***14,530,581***	***14,577,771***	-	-	-	-	-	-

Source: SDRI, 2013

Non-agriculture Land Use over Time

Non-agricultural land includes rural settlement, urban and industrial area as wel as accreted land. As discussed before and also evident from **Table 7.2**, **Figure 7.6** and **Figure 7.7**, non-agriculture land increased substantially between 1976 and 2010 reducing land available for agriculture use. This has happened both because of growing population density and also the pursuit of an economic development path that is conducive for creating new jobs for an ever-increasing working age population. So the additional land use has been not only for catering to urban and industrial land needs, but also the growing rural settlement needs for a growing population.



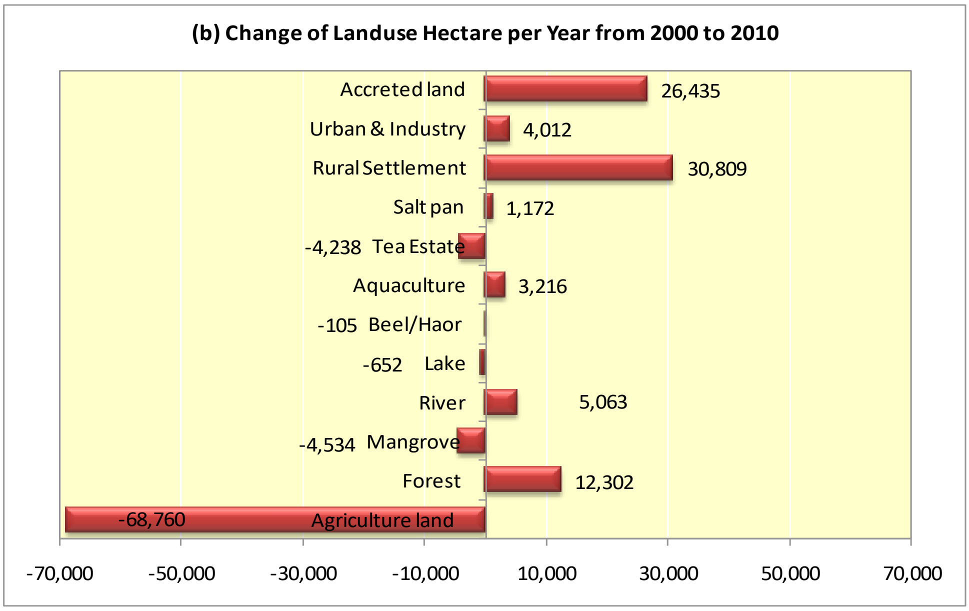


Figure 7.6: Annual Net Land Loss and Land Gain by Use

Source: SRDI, 2013

Even though cropland declined, a very positive factor was that the crop production trebled during the period and continues to grow. So, more crops are being produced on lesser land, thanks to the successful adoption of green revolution technology. Technological evolution, farmer's ability to adopt technology and good use of markets along with road infrastructure development has been key to the success of crop agriculture. While adaptation of technology has played its part in increasing crop productivity, in the future higher agricultural productivity and food security will also require proper management of land resources for agriculture practices, agricultural production, agriculture land use planning, and scope of agro-ecological planning. Improved knowledge of land or crop suitability will also help in this regard.

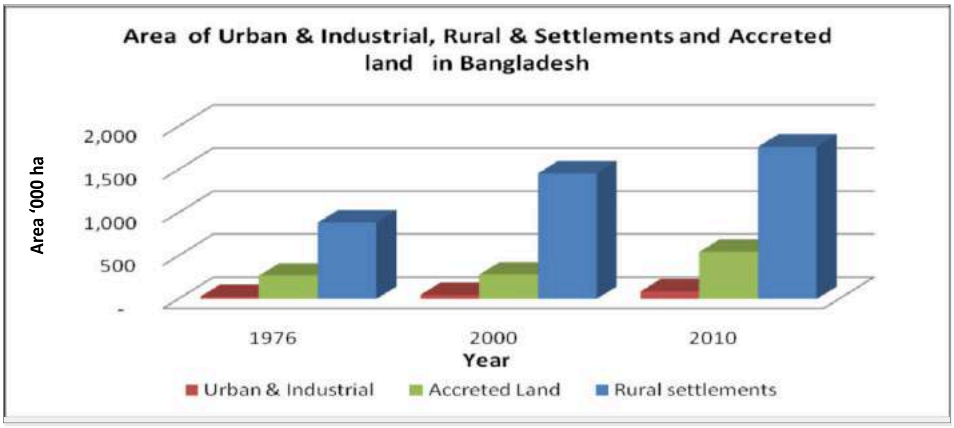


Figure 7.7: Change in Land Cover by Use, 1976 -2010 (Area '000' ha)

Source: SRDI, 2013 and BDP 2100 Baseline Study Report: Land Resource Management.

Trend of Urbanization and Industrial Areas: Bangladesh is a densely populated country with urban and rural settlements continuing to grow over time. The urban areas have expanded more rapidly due to rural to urban migration as job seekers have been flooding to cities and towns seeking better income opportunities. Besides, people losing assets from river erosions and becoming destitute have moved to urban areas seeking work, shelter in slums and public places and also bettwe livelihood opportunities. Given that most economic opportunities are in Dhaka and Chattogram, the migration has been most pronounced in these two cities, though migration is also seen in other urban areas. The growth of urban centers has moved parallel with growth of industry. This has been driven in particular by the spectacular growth of labor intensive RMG industry, and also service sectors, particularly banking and financial institutions that creates jobs and also caters to the need of the industry sector as a whole. This industrial expansion has of course been at the cost of agriculture land.

While urban expansion has been catalyzed by the related economic needs, there has also been transformation happening in the rural areas not only because of growing population, but also people increasingly getting into non-farm business activities in the rural and settlement areas. This has also been triggered by inflow of remittances and also people in rural areas increasingly responding to rising market demand and supply for goods and services. Rural settlement land use expansion is the principal cause of diversion of land out of agriculture use.

Growth of Megacities, Metropolis, other Cities and Towns

The fastest growth in land use happened in urban areas, including growth of megacities and metropolises. This occurred especially between 2000 and 2010, when urban areas and settlements grew at a rate of 8.5% annually, causing decline in the availability of cropland area. This loss of cropland, however, was more than compensated by higher crop yields from adaptation of advanced agricultural technologies.

Dhaka is the only megacity in the country. There are 3 metropolises: Chattogram, Khulna and Rajshahi. Together with Dhaka, the three accounted for about 56% of the country's total urban population in 2001. The percentage of urban population has decreased and come down to 23.30% in 2011 as against 23.53% in 2001, due to change in definition of Statistical Metropolitan Area by BBS for the 2011 Population Census. If the same areas would have been used, the percentage of urban population would be 28.00% in 2011.

It can be observed that the number of urban centers had increased until 1991 and have held steady at 522 since then. What has happened is that between 1991 and 2001 there has been transformation in sizes with decline in number of small towns and increase in number of medium towns and Cities. As per BBS data, while in 2001 there were 116 medium towns, the number increased to 222 in 2011. There was also a sharp increase in number of cities from 17 in 2001 to 39 in 2011. The number of metropolises increased to 04 in 2011 from 03 in 2001 and there is still 01 megacity (Dhaka) since 2001. The growth in size as well as number of urban areas over time has happened because of internal rural to urban migration, catalyzed by growth of industry and the service sectors.

Population growth and the ongoing process of urbanization will further increase the pressure on land, requiring better policies, regulatory enforcements, and proper implementation of zoning laws and regulation. As a result, the urbanization process should be streamlined in a way that it both addresses the urban related demand on land resources as well as delineating land in an optimal way to meet the competing demands for food security on the one hand and the need for creation of quality jobs for a continuously growing labor market.

Trends in Rural Settlement

About 72% of the country is under rural areas. There are three main types of rural settlement: linear, clustered (or nucleated) and scattered. These patterns were originally related to the different physiographic characteristics. In the Hill tract area near Chattogram it is different, and settlements are scarcely found in a linear pattern. This is because the unique topography of the hills and green vegetation. Rural settlement includes homesteads, homestead gardens and ponds.

Area of Rural settlements was estimated at 8,85,637 ha in 1976 occupying 6.11% of the total area of the country. Rural settlement area consistently increased since then at a faster rate and became 12.12% in 2010. The average annual rates of increasing rural settlement area were 2.69% and 2.11% during 1976-2000 and 2000-2010, respectively. Therefore, it is apparent that rapid growth of rural settlements has been the main driver of declining agricultural land, especially crop land. It is estimated that annually on an average 23,850 ha/yr of land went to rural settlement during the period 1976 to 2000 compared to 30,809 ha/yr between 2000 and 2010.

7.4.2 Erosion and Accretion of Land

Riverbank erosion and accretion of land, except some hilly areas in the southeast and the northeast of the country, are common in Bangladesh (**Chapter 1**). Every year, a significant area of fertile lands and settlements are lost due to riverbank erosion. While river erosion is a big challenge, there is also opportunity for value added land getting reclaimed through accretion, if properly managed. This can provide some degree of flexibility in long term land resource management and optimum land use policy that would support the inclusive growth and sustainable development strategic agenda of the perspective plan and the five-year plans.

Char Lands

Char lands occur along the major river systems and have complex topography. The main problems are instability of land, coarse soil texture, and low water holding capacity along with low nutrient availability, riverbank erosion, and flooding. About 0.72 million ha of char land exits mainly in Kurigram, Lalmonirhat, Sirajganj, Pabna, Jamalpur, Manikganj, Faridpur, Shariatpur, Madaripur, Chandpur, and Bhola Districts. Coarse soil textures, low water holding capacity, and low fertility are responsible for poor crop yields. These chars, of which many are inhabited, "move with the flow" and are extremely sensitive to changes in the river conditions.

Formations of new chars are not necessarily favorable for land use management. Burial of standing crops by fresh sediments of sandy deposits (sand carpeting) also destroys crops. Addition of organic matter through green manuring with Dhancha/ leguminous crop might help to improve physical and chemical properties of the char lands. Rabi crops, especially groundnuts, pulses, mustard, etc. may be practiced. Of course, large chars may be protected for development of settlements / industrial areas by taking measures against river bank erosion, as demand for industrial and land grows with economic development. These may be extended in newly accreted char lands, dredged spoils platform areas, preferably in non-agricultural fallow lands taking necessary steps for the protection from riverbank erosion. This will require major physical investments and so should be undertaken on the basis of sound feasibility studies.

Erosion And Accretion along the Major Rivers

Different Districts along each of the major rivers are affected in different magnitudes from the erosion and accretion process. The main net gainers of land are Nawabganj and Patuakhali. Pabna and Bhola have gained moderately. All other Districts are net losers of land owing to the heavy incidence of river bank erosion. The biggest losers are Kurigram, Gaibandha, Sirajganj, Manikganj and Kushtia.

During 1973-2013, a total of approximately 249,452 ha of land have been eroded, whereas total area of accreted lands was approximately 152,271 ha in the same period along the Ganges, Jamuna, Padma, and Meghna rivers. The erosion, therefore, was more than that of accretion in the Ganges, Jamuna and Padma rivers areas, while it was opposite in the case of the Meghna Estuaries areas. Detailed erosion and accretion in the above-mentioned rivers during this period are presented in **Table 7.3**.

Table 7.3: Distribution of Erosion & Accretion (3 Major Rivers of Bangladesh, 1973-2013)

Name of River	Erosion in ha (1973-2013)	Accretion in ha (1973-2013)
Ganges	30,100	25,712
Jamuna	87,713	16,444
Padma	41,650	7,212
Lower Meghna	90,079	103,003
Total	***249,542***	***152,271***

Source: CEGIS, 2014.

Land accretion has been most pronounced in the Meghna estuaries as evident from different CEGIS estimates. It has been estimated that the areas of accretion and erosion in the Meghna Estuaries were 3,219.5 km^2 and 2,734.36 km^2 respectively during 1973-2010. Net accretion area has been about 485.13 km^2 during last 37 years and overall rate of accretion was about 13.11 km^2/year. It is assumed that land development may be possible in the Meghna Estuaries of the Coastal Zone.

Land Reclamation and Development in the River systems and Estuaries and Coastal Zone

Beyond the erosion and accretion process discussed above it is also possible to reclaim land given the huge amount of silt that is regularly carried by the rivers to the sea. Land reclamation, itself, is the process to create new land from sea, riverbeds, canals, or lakes for human activities, and a spatial planning process in this regard would be very useful, especially for a growing economy like Bangladesh. This is more so because land is scarce in Bangladesh and issues like food security, housing, infrastructure building, industrial development mostly depend on it.

While there has been decline in crop land area with growing coverage of rural settlements, there has also been ongoing land reclamation process, and a significant area has already been reclaimed from the sea in the Coastal Zone. Land reclamation from sea can be continued to increase land area. It can be done through appropriate selection of spots for reclamation in various places in the coastal belt and substantial new amount of land can be reclaimed from the sea and added to the existing land mass. In the Coastal Zone, especially in the Meghna Estuaries, land has continuously been reclaimed on a limited scale. Bangladesh has experienced stabilization of newly accreted lands from tidal and storm surges through afforestation and polderization.

Optimizing Use of Coastal Land

Land use in the coast is diverse, competitive and often conflicting. Coastal land use comprises agriculture, shrimp and fish farming, forestry, urban development and other settlement needs. There is continuous demand for expansion of current land use, while the need for new exploitation is also emerging. Land is also degrading due to increased salinity and water logging. Since the 1960s, measures to address these problems have been polderization, land reclamation and coastal afforestation. Protection from recurring storm surges is an important issue in coastal land management. Polders are mainly designed to provide protection against tidal intrusion with the main objective of increasing agricultural production; however, they also provide protection against floods and storm surges. Drainage in these polders is provided at low tide by means of flap gates mounted in sluice structures, usually located where natural drainage channels (khals) cross the embankment alignments. The objective to increase agricultural productivity was achieved with great success until 1980s, after which drainage congestion became serious in some areas. As a result, the Coastal Embankment Rehabilitation Project started to incorporate elements of internal water management, land use management inside the polder, and social use of the embankment and foreshore. Despite drainage problems, the polders have resulted in higher agricultural returns by excluding saline tidal flooding. Communications have also improved. Polderization has contributed considerably to altered and new land use in coastal Bangladesh.

Acceleration of land accretion process and optimum use of these coastal lands, including reclaimed land, would significantly contribute to the regional economy and wellbeing of the local people. Land zoning is one instrument that could optimize the use of coastal lands – e.g. the Coastal Zone may be utilized through identification of zones such as agriculture, shrimp (brackish water), shrimp (sweet water), salt pans, forest, mangrove, tourism zones, Special Economic Zones (SEZs) for industry and urban settlements. A program of participatory approach of mangrove plantation, involving nearby coastal communities, which has proved successful in other countries, could be a sustainable mechanism to protect mangrove forests. This mechanism is being actively considered within the Forest Department. Recently, lands reclaimed through construction of embankment at Undarchar (newly accreted land) were developed by plantation of a green belt in the Patuakhali District. This process needs further expansion for sustainable land reclamation.

Land accretion/reclamation and land erosion generate socio-economic anomalies and issues. These lead to displacement of people, land capture and illegal settlements are prevalent in areas where the coast is accreting. These newly accreted land resources need careful management with institutional and regulatory framework being put in place to avoid illegal capture and also to use it optimally where feasible for industry, urban, settlements, and agriculture. However, the political economy of land reclamation in land scarce country like Bangladesh can be very complex not only from engineering point of view but also social and political angles, and will require proper governance structure and land management.

7.5 Governance Structure of Land Management

Land in Bangladesh is owned either by private individuals and entities or the state. Individuals acquire ownership-rights to land through purchase, inheritance, or gift. Titling and registration of land ownership is set out in the Transfer of Property Act 1882 and Registration Act of 1908. Under formal law, land sales, leases of a year or more, and land received through inheritance must be registered. Article 42 of Bangladesh's Constitution provides that land can be acquired, nationalized, or requisitioned upon authority of law and with compensation. The Acquisition and Requisition of Immovable Property Ordinance, 1982, permits government land-acquisitions as needed for any public purpose. Here the compensation is linked to the price in the market.

Land ownership (farm size) is very important for the land use management. So, land ownership pattern, in case of agriculture, will help farmers plan on land use pattern as per Mauza maps. However, in Mauza maps, actual ownership may not be updated with the change in ownerships. There are many big landowners in Bangladesh, especially in the Haor and Coastal Zone. The big landowners are not interested in improving farming practices because of the huge investments required. Most of them appoint sharecroppers or tenants. The tenants or sharecroppers are not generally so solvent to meet the expenditure of labor, fertilizers, and other inputs. This situation is not favorable for improved land use in respect of crop production.

Regulatory and Institutional Setting

In Bangladesh, the land administration moves in a parallel way among three institutions– the Director of Surveys through the Settlement Officer, the Director of Land Records thorough Deputy Commissioner and Assistant Commissioner (AC Land), and Inspector General of Registration through the District Registrar and the Sub-Registrar. Land related complications arise because the Land records may be updated through (i) land surveys (via the Settlement Officer); (ii) (via the sub-registrar's office) registering of deeds of sale; and (iii) inheritance (through AC land office).

The issues can be further unbundled by analyzing the processes involved in land transfer and those in updating the land titles. The diversity of ways in which land records may be updated, and the problems associated with each give rise to numerous disputes and also proliferation of land related civil and criminal cases.

Land Transfer and Registration Process

Land Transfer is undertaken through a process by which the land gets registered and the registration document gets handed over to the new owner. World Bank's Doing Business Indicators shows that there are several steps and around 100 days needed to complete the registration process (**Table 7.4**). While the number of steps is comparable with other countries, the big difference is in the number of days it takes to complete the process even compared to India, Pakistan, and Sri Lanka, and enhance there are scopes for improvement.

Table 7.4: Summary of Time, Costs and Procedures for Registering Property in Bangladesh

No.	Procedure	Time to Complete	Cost
1.	Verify the record of rights from the Land Office (also known as Land Revenue Office) Agency: Land Office or Land Revenue Office	30 days (simultaneous with procedures 2 and 3)	BDT 3,000-6,000
2.	Conduct BS Mutation on property Agency: Assistant Commissioner of Lands (Tahsil)	30 days (procedures 1 and 3)	BDT 15,000
3.	Obtain inspection for BS Mutation Agency: Assistant Commissioner of Lands (Tahsil)	30 days (procedures 1 and 2)	BDT 15,000
4.	Obtain the non-encumbrance certificate from the relevant Sub-registry office. Agency: Sub-registry and Land Revenue Office	30 days	BDT 2,500
5.	Prepare deed of transfer and pay stamp duty Agency: Registry Office and Designated Bank	1 day	3% of property value (Stamp duty)

Source: World Bank, Doing Business, 2015

The land transfer process involves the necessity of the buyer to crosscheck the authenticity of the entitlement with AC Land office before registration of transfer. The Registration process could become faster if the AC Land/Tehsil office work is better synchronized with the work of the Registration office. Also, the record on the land transfer is not updated in the AC Land office immediately after deed registration due to delay in sending the registration information.

Land Survey: Land survey is an important ingredient in updating of land records. The survey, which leads to Settlement, is seen as a temporary process where only certain parts of the country are covered at particular points of time. A very important regulatory process is preparing khatian (record of rights), the form assigning plot numbers, i.e. the khatian number, classification of land (that affects land revenue), area, crops grown, name of owner, agricultural practices along with a Mouza map.

The survey process itself could take anywhere between 6 months to 2 years, depending on whether a re-survey is ordered. There is definitely scope for improvement here if necessary regulatory steps and institutional changes are brought in backed up by use of technology. Similarly the scope for reducing Appeal time and procedures need to be looked into. There is process for review and rectification but the appeal process could take a long time and also be too costly for poor people.

One factor that becomes apparent is that the links between the three key institutions, the Survey, the AC Land, and the Sub-Registrar's office, are very weak as accountability mechanisms only move vertically in each of the institutions. For an efficient and transparent system there needs to be well synchronized linkages across the three institutions. The issue gets further complicated as two of the agencies report to MoL where as the Registry is within the jurisdiction of Ministry of Law and Justice (MOLJ). So there has to be good synchronization between the two ministries also.

There are policy and regulatory challenges to land resource management, which need to be addressed. In the short and medium term, the regulatory and institutional challenge will be in bridging the gaps across the institutions as well as improving efficiency within each agency. It will be particularly important to reduce time for undertaking surveys, simplifying the appeal process, reducing the number of days in the registration process. Ultimate aim is to have a system up with a more dependable and readily available certificate of title that is protected from abuse.

7.6 Land Management related Laws and Regulations

Bangladesh has several policies in place relating to land management. While the policies provide scope to ensure better utilization of land through land zoning, practically these seldom gets fully implemented. This indicates that there are gaps in the policies as well as institutional arrangements for implementing such policies. The important following policies are discussed in this section along with some of the gaps that may need to be addressed.

7.6.1 Regulations relating to Land Erosion and Accretion – Alluvion and Diluvion

In the context of land accretion and land loss through alluvion and diluvion process, its rules of usage were given statutory shape for the first time by promulgation of the Bengal Alluvion and Diluvion Regulation 1825. This regulation covered two broad categories of land re-formation: in situ and new accretions. The right to land once diluviated and subsequently re-formed in the old site and the right to new accretion were identified as two distinct rights. The right of ownership of land re-formed in situ was considered to be incidental to one's title to a tangible property. This ownership principal of alluvion and diluvion was further established through the tenancy law, as contained in sections 17 and 18 of the Bengal Rent Act 1859.

7.6.2 Khas Land Management Policies

A critical concern on a more efficient land resource management is the management of khas lands. The principal instruments governing khas land management are the: Bengal Regulation XI 1825, Bengal Alluvion Act 1868, Government Estates Manual 1919, Bengal Crown Estates Manual 1932, East Bengal Acquisition and Tenancy Act 1950, The Bangladesh State Acquisition and Tenancy (Fourth Amendment) Order 1972 (PO 135), Bangladesh Landholding Limitation Order 1972 (PO 98), President's Order LXI 1975, Land Reform Action Program 1987, Agriculture Khas Land Management and Settlement Policy 1997.

There are two khas land management policies: (i) Agricultural Khas Land Management Policy 1997, and (ii) Non-agricultural Khas Land Management Policy 1995.

Agriculture Khas Land Management and Settlement Policy 1997 clearly states that khas land will be distributed to households that are dependent on agriculture and have no homestead or cultivable land or with a homestead smaller than 10 decimals. There are, however, gaps particularly for non-agricultural khas land. The Policy does not provide clear guidelines on recovery procedure for grabbed land from powerful elites as well as how to distribute non-agricultural khas land to urban poor or landless. Similar gaps exist for newly accreting land or reclaimed land. So khas land related policies need to be reviewed and revised for better land resource management. The following points may be considered during review and revision of khas land policies:

- Local level khas land management and distribution committees should have representatives from landless people– women and men. They can be executive committee members of local level development projects;
- Involvement of poor people (women and men) of the locality in the identification, selection and utilization of khas land should be strengthened;

- Ministry of Land should arrange awareness-raising activities for women and men about their rights and procedures to get khas land including land settlement procedures. Training on filling out application forms to get khas land is a real necessity. Gender Focal Point and Climate Change Focal Point of the concerned Ministries could implement specific programmes;
- Displaced population (male and female) due to river bank erosion should be rehabilitated on the newly accreted chars and khas lands. Legal procedures in these situations should be gender-friendly;
- Women should be recognized as 'farmers' considering their huge involvement in farms;
- Property inheritance right should be established considering equality of women and men and for establishing women's rights;
- Ensuring ownership of land in the name of women even though they do not have a mature son; and for enforcing this, necessary policy revision is important (Reference- Agricultural Khas Land Management and Settlement Policy 1997).

7.6.3 Administration of the Accreting Land - the Char Land

The Bengal Alluvial Lands Act 1920 was enacted 'to prevent disputes concerning the possession of certain lands in Bengal gained by alluvion or by dereliction of a river on the sea'. On 4 August 1972, President's Order No. 135 was promulgated to provide that in case of diluvion the rent of the holding shall be abated and the tenant's right of ownership shall be extinguished. On reappearance, the land shall vest in the government, except the land in respect of which the tenant's right to repossession was finally recognized by the court or competent authority before in situ.

The position was again changed through The State Acquisition and Tenancy (Amendment) Act 1994. Provision was made for abatement of rent in the case of land lost by Diluvion and subsistence of the right to land re-formed in situ for 30 years, subject to the ceiling of 60 bighas. The present legal position is that all chars other than those re-formed in situ within 30 years of diluvion are the property of the state, which the government may settle in accordance with the rules.

There may be need to take a fresh look into the laws and administrative process, because there will be new reclaimed land for value added use during implementation of the BDP 2100.

7.6.4 Land Acquisition Related Policies

A very difficult issue is that related to land acquisition, which become necessary for development purposes and which also increases use of land for non-agriculture needs. The compulsory acquisition of land has historically been a difficult and delicate issue for Governments in Bangladesh. Therefore, land acquisition and the concomitant smooth resettlement process are always a challenge. In addition to micro-level conflicts relating to implementation of specific projects and the communities impacted by those, land acquisition processes generate disputes at a higher level when associated with possible differential uses of lands.

Laws in Bangladesh do not distinguish between processes governing the acquisition of farm land and urban lands. The instrument of current legal aid for expropriating lands for public purposes is the Land Acquisition and Requisition of Immovable Property Ordinance, 1982. The 1982 Ordinance has roots in the British colonial Land Acquisition Act of 1894 that laid the basis for the practice of land acquisition in South Asia during the colonial and post-colonial periods. As it stands, the 1982 Ordinance presents significant challenges in its application, as it is based on compensation rationale only. As such it monetizes productive (for ex: land) or important assets (houses) that are not based on market valuations and it provides affected people with a promise of a payment later for an asset foregone today. Therefore, a comprehensive and modern technique of resettlement needs to be adopted for acquiring of land.

7.6.5 National Land Use Policy (2001)

The National Land Use Policy (NLUP), 2001 was promulgated with the objective to help ensure criteria based uses of land and to provide guidelines for usage of land for the purpose of agriculture (crop production, fish cultivation and rearing of ducks and chickens), housing, afforestation, commercial and industrial establishments, rail and highway infrastructures and for tea and rubber gardens. This policy mainly identifies limitation of land use and management of limited land resources of the country. The key targets to help achieve the objectives of the Policy are:

- reform the present land administration system by introducing Certificate of Land Ownership (CLO) which records all lands of each household in a single document;
- zoning of land for commercial and other purposes;
- prevent wasteful use of acquired land;
- increase crop intensity through optimal use of available agricultural land;
- update different laws related to proposed land administration reform;
- prevent loss of agricultural land, which is needed to meet the food demand of the population;
- protect state-owned (khas) land which can be used to meet the needs of development projects;
- prevent soil degradation;
- establish a data bank (Management Information System –MIS) for khas land, fallow land, acquired land, char land, etc. for ensuring proper use.

Subsequently, draft National Zoning Act and Village Improvement Act was prepared in 2010 in line with the Land Use Policy. However, these are yet to be adopted officially. However, the preparation of a nation-wide Land Zoning Map is ongoing under a project implemented by the Ministry of Land. Mapping of about 100 Upazillas have been completed to date.

The existing policy has been found falling short of providing guidance as to how cross-sectoral interests and plans relating to land should be coordinated. To overcome the existing limitations of NLUP, a revision of the national Land Policy is desirable during the 7th FYP period by outlaying guiding principles on appropriate and sustainable use of specific types of land, sectoral and cross-sectoral land use and environmental management.

The policy must take inputs from the ongoing land zoning maps, particularly the problems associated with multi-sectoral nature of land use, unabated frictions among different sectors due to competing uses and negative environmental effects on land. For a conclusive Certificate of Ownership, it is important to rationalize the existing institutional framework for recording or registration of property rights and avoid mandates that are either overlapping or difficult to coordinate. The cross-sectoral policies of the National Agricultural Policy 1999, National Fisheries Policy 1998, Jalmahal Management Policy 2009, National Rural Development Policy 2001, National Forest Policy 1994, National Water Policy 1999 and Coastal Zone Policy 2005 need to be aligned and harmonized in order to prepare a comprehensive land use policy.

7.6.6 *Economic Zone Act (2010)*

To help optimize land usage, the Government enacted Economic Zone Act in 2010, which would ease land-related problems faced by potential investors. The Act provides legal basis for the establishment of economic zones in all potential areas including underdeveloped regions with a view to encouraging rapid economic development through industrialization. The development of Economic Zones is expected to help investors through providing a place with various facilities that are conducive for industrial development. The Act promotes Economic Zones in the Private sector, Government led EZs or combination of the two. In this connection, Bangladesh Economic Zone Authority (BEZA) has been established. The mandate of BEZA is to identify local potential zones, acquire lands and build the zones with necessary facilities. BEZA may seek public-Private Partnership (PPP) to build and facilitate effective utilization of such zones. While Economic Zone Act 2010 provides a more organized use of land for industry and urban growth, it also provides an opportunity to bring a better balance with agriculture land use. This is done by restricting Economic Zones in areas that are less suitable for agriculture.

7.7 Strategies for Sustainable Land Use and Spatial Planning

Planning, managing and developing strategies for land resources are integral parts of BDP 2100. Land use strategy encompasss natural areas for agriculture, forests and watercourses as well as areas for urban and industrial needs. The utilization of land includes both for agricultural and non-agricultural land use, for which making spatial planning an integral part of land use management will be important. Key strategic elements include land zoning, prevention of soil and land loss through improved agronomic practices and river training works, land reclamation in the coast, restoration of soil fertility, and checking salinity intrusion in the Coastal Zone and desertification, especially in the northwest region.

The Land Management strategies are stated below according to BDP 2100 Goals:

Goal 1: Ensure Safety from Floods and Climate Change related Disasters

Strategy 1.1: Preserve/conserve agricultural land from floods or erosion to sustain food grain production

Beyond the strategy of zoning the whole country, there are specific strategic priorities for the agriculture sector that could be undertaken that would support optimal land resource management. This will be particularly conducive from food security point of view. The suggested priorities and strategic interventions include the following:

- Coastal Zone, Sylhet region, char areas and drought prone areas must receive priority in crop sector development and intensification plans encouraging private sector involvement;
- Prioritize protection of agricultural land from inundation, river erosion;
- In order to meet the growing demand of additional food for the increasing population, emphasis should be given in utilizing the hoar lands of the northeast part of Bangladesh;
- Strategy, policy and action should be formulated to convert the single crop land into double crop land, double crop land to triple crop land where feasible;
- Land reclamation in Coastal Zone and rehabilitation of cultivable land in water logging areas
- Emphasize intensive cultivation of saline tolerant varieties particularly in Rabi season;
- In order to maintain soil fertility use of organic fertilizer should be encouraged.

Strategy 1.2: Prevention of salinity intrusion and desertification

Provisions need to be established to increase upstream fresh water flow to prevent salinity intrusion in the Coastal Zone. Vegetation in the Barind and Drought Prone Areas need to be increased. Finally, stress on water resources system should be reduced.

Goal 3: Ensure Sustainable and Integrated River Systems and Estuaries Management

Strategy 3.1: Management of newly accreted land in the Meghna Estuary

The land loss due to sea level rise and river bank erosion may be overcome by new land formation towards the sea through land reclamation, construction of closures and cross dams, which may be accelerated with natural techniques for stabilization through protection of pioneer (mangrove) vegetation. Acceleration of the land accretion process and optimum use of these coastal lands would significantly contribute to the regional economy and wellbeing of the local people. TRM could be one of the policy options for land reclamation which might develop new land type in the low-lying beels of the Coastal Zone through sedimentation. This might enable double/triple cropping pattern and can also increase the availability of land for settlements. Land zoning is one instrument that could help optimize the use of accreted coastal lands. Besides, all accreted and reclaimed land should be put to value added used particularly for urban and industrial needs with necessary infrastructure like dikes, high quality roads, rails, water transport mode connection, and with adequate power and energy supply. The actual choice of such value added sites should be on the basis of feasibility studies and where appropriate PPP options should be sought.

Goal 4: Conserve and Preserve Wetlands and Ecosystems and Promote their Wise Use

Strategy 4.1: Sustainable coastal land management for enhancing agriculture and non-agriculture land

In Bangladesh, there are about 2.83 million ha of coastal area of which different levels of soil salinity affect one million hectares of land. The wetlands and ecosystems of the Coastal Zone will have to be managed in a manner that will not only ensure their sustainability but will also secure access to the poor for meeting their livelihood requirements. The soils of the Coastal Zone are mostly mono-cropped with low yield rice produced during the rainy season. The cultivation of winter crops is very limited due to the accumulation of salts in the surface soil and lack of fresh water irrigation during dry season. A number of crop production technologies have been developed and there are encouraging results that could mitigate the challenge and help in the food security front. This effort should continue.

As part of its coastal land management strategy, Bangladesh has used coastal afforestation and polderization to stabilize and protect newly accreted lands from tidal and storm surges. This strategy should continue under proper legislative framework for optimal land utilization. Dense forests can attenuate wave velocity. In 1966, the Forest Department began a mangrove plantation program outside the protective coastal embankments in order to better protect life in Coastal Zone from cyclones and tidal surges. A program of participatory mangrove plantation involving nearby coastal communities, which has proved successful in other countries, could be a sustainable mechanism to protect mangrove ecosystems. This mechanism is being actively considered within the Forest Department. Recently, lands are reclaimed through construction of embankment and developed by plantation of green belt in Patuakhali district.

More broadly, the strategies to mitigate the challenges of coastal land resource management are estuary and coastal ecosystem management, coastal land zoning, integrated management of coastal water infrastructures, socially and environmentally responsible shrimp farming, and development of coastal and marine environment. While coastal land management will also require large scale physical investments over time, one of the key issues will be putting in place an effective land governance structure with appropriate institutions so that the small/ marginal farmers and the poor (including women) can be safeguarded.

Goal 5: Develop Effective Institutions and Equitable Governance for In-Country and TransBoundary Water Resources Management

Strategy 5.1: Development of Land Information System (LIS) for Land Administration and Management

At present the responsible ministries and agencies involved for land management and administration work independently with little coordination among them. The whole process is manual, laborious and time intensive. Conventional methods of land survey, preparation and upgradation of land records, maintenance of all related data for each parcel of land makes land administration and management incomplete and inefficient. Moreover, distortion of land records at various stages (i.e. plot-to-plot survey, preparation of records and drawing of maps through conventional methods, objections, printing, etc.) hinders land development control and property tax collection. Computerized Land Management System should be developed for access to Land and Property Rights to all Citizens, to prepare digital Mouza maps and khatian using modern equipment, to create and maintain authentic land records, etc.

There is an ongoing effort of computerization of some of the processes in each of the three key institutions (agencies), but it is mainly on individual Ministry basis. This needs to be a priority goal for the government, and a single strategy for implementation of all land related computerization should be undertaken. Effective and well-coordinated computerization of each of the agencies under the two Ministries should be able to bridge the existing gaps and provide more readily available reliable information to citizens, businesses, financial institutions and to the courts. This will definitely help the improve business environment in the country while also reducing scope of inefficiencies at different levels.

There will also be need to undertake a full mapping of the country to determine which land will be exclusively kept for agriculture and which for industry, housing, roads and there should proper zoning laws with institutional enforcement in place. Even Government's future infrastructure and urban related investments should be built in a way that it caters to desired zoning needs of the country. Early adoption of spatial planning (SP) for land use management could help optimally distribute land resources for different uses.

Strategy 5.2: Development of Digital Land Resource Management System

Some of the suggested institutional and policy related priority interventions that could potentially lead to a more optimal land resource management that supports the growth strategy of the Government, in a sustainable manner are as follows:

- Computerization of the processes and use of technology in AC Land, the sub-registrar's office, and the land survey under the e-Government program should be of highest priority. The target should be accessibility of information to citizens and reducing unnecessary steps. However, it needs to be ensured that there are clear links between the different agencies so that desired results can be obtained;

- Undertaking a comprehensive public sector reform initiative involving Ministries/ Institutions involved in land governance. These should help in evolving a regulatory and institutional framework that could make the land market more efficient;
- Modernization of land management through Digital Land Management System (DLMS) will have to be implemented with the following objectives:
    - Facilitate implementation of land use policy, ensuring delivery of land related services to the people through modernized and efficient land administration.
    - Strengthening Access to Land and Property Rights to all Citizens of Bangladesh through development of Digital Information System (DIS) to ensure proper, planned and wise land use.
    - Development of digital techniques for the preparation of maps and khatian using modern equipment (GPS, data recorders, computers, map processors and softwares, plotters, printers, etc.)
    - Strengthening governance management for land resources;
    - Computerization of existing Mouza maps and khatian;
    - Creating authentic land records through joint venture between AC (Land), settlements and Sub-register offices.

Strategy 5.3: Improvement/formulation of new National Land Use Policy

Ministry of Land is in the process of formulating a new National Land Use Policy, Agricultural Land Protection Act and National Land Policy. Particular importance needs to be given to effective communications across the institutions, especially to ensure that information can get automatically updated. The updated Land Use Policy should explicitly recognize competing demands of land by different sectors for achieving food security and alleviating poverty, creating jobs, providing housing and infrastructure requirements. In this context, the following need to be addressed in the new Land Use Policy:

- Policy should support value added use of accreted land along major rivers as well as reclaimed land along the Coastal Zone that can effectively meet long term urban, infrastructure and industry needs;
- Growth center based development activities to be included in the land use policy of the rural areas for optimal utilization of land;
- Consider the case for introducing some sort of land ceiling for homestead in both urban and rural areas, particularly through compact township;
- Land use policy should ensure proper management of saltmahal, jalmahal, balumahal and other mahals for poverty reduction. On the other hand it should ensure protection and conservation of wetlands, hilly areas, tea gardens, heritage sites, rubber gardens and coastal lands;
- Policy should include a provision to ensure environmental protection and safeguards from the adverse effects of climate change;
- Policy should also focus on development and management of protected areas such as eco-parks, botanical gardens and safari parks under a reformed legal framework.

Strategy 5.4: Reviewing and updating/enactment of Laws/Regulations relating to Alluvion and Diluvion to improve efficiency of land administration of accreting and reclaimed land

It is important that along with the updated laws and regulations, there should also be reforms in the processes of land administration, particularly in ensuring faster surveys of accreting lands. The reformed laws should support zoning of the land based on optimizing and value added use of the accreted land.

Strategy 5.5: Formulation of necessary laws and acts to form Land Zoning

Land Zoning is the demarcation of geographic areas with specific combinations of properties or features used as per designated criteria only. The land zoning could be considered as one of the tools to help government in integrated planning and sustainable management of land and water resources of the country. Land zoning process including formulation of necessary laws and acts need to be accelerated. The Government has enacted the Economic Zones Act 2010 to facilitate use of land for industry and services. However, a more articulated policy is required which would lead to zoning of the entire country so that the land use gets distributed optimally to meet the competing and sometimes complementary needs. Local government institutions also will have to be strengthened to implement land zoning. More specifically the zoning objectives should be based on optimal utilization of available and also accruing and reclaimed land resources; and the following segments may be considered for land zoning that should also include coastal zone strategies.

Zones for manufacturing, service industry and new urban centres:

- Implement new Special Economic Zones for industries and related urbanization in areas where there is single cropland and also newly accreting land and land reclaimed in coastal zones, with proper infrastructure development to support setting up of those zones;
- Develop zones for tourism.

For coastal agriculture:

- Shrimp (brackish water) Zone; Shrimp (sweet water) Zone; Salt – Shrimp Zone; Forest Zone; Mangrove Zone need to be delineated.

Strategy 5.6: Increase climate change adaptation capacity for land management

Increase farmers' capabilities in adaption to climate variability. This can be through change in crops or varieties, choosing different harvest and sowing dates, alter land management, and employing improved water efficiency techniques. Long term climate change farmers should be dependent on land resources, and so at the national and international levels, governments and development agencies play a fundamental role in building the capacity of farmers to cope with and adapt to a changing environment.

Strategy 5.7: Ensure gender equitability for land ownership

Land ownership and entitlement to land, signify economic, as well as social identity and reflect empowerment and dignity. Control over income and assets like land, etc. are an indicator of empowerment of women and men.

Goal 6: Achieve Optimal and Integrated Use of Land and Water Resources

Strategy 6.1: Sustainable land utilization for achieving food security

There is a vast potential to scale up the improved management of land and water resources as an integral component of agricultural development strategies. Proper agriculture practices and production depends on effective utilization of agriculture land use planning.

It is important to take into account the need for optimal water resource management as a means for achieving land use management efficiency. The improved land and water management practices will help increase crop yields through sustainable management of land resources. Besides, land management efficiency will be better achieved if land can be safeguarded from degradation. Many smallholder farmers must deal with low and unpredictable crop yields and incomes, as well as chronic food insecurity. These challenges are particularly acute where land degradation, depleted soil fertility, water stress, and high costs for fertilizers contribute to low crop yields and associated poverty.

Farmers and scientists have identified a wide range of land and water management practices that can address land degradation and increase long term agricultural productivity. The benefits of these improved land and water management practices to farmers and rural economies, include higher crop yields, increased supplies of other valuable goods such as firewood and fodder, increased income and employment opportunities, and increased resilience to climate change. These benefits occur because these improved land and water management practices help increase soil organic matter, improve soil structure, reduce soil erosion, increase water filtration or permeability, increase efficiency of water use, replenish soil nutrients, and increase the efficiency of nutrient uptake.

In this context, the productivity of degraded agricultural lands can be better restored and crop yields boosted if smallholder farmers could be leveraged through policies and appropriate financial intermediation to invest in their lands and also undertake appropriate water management practices. This could be catalysed through institutional and policy reforms, particularly for strengthening property rights, particularly involving community-based organizations (CBOs).

Strategy 6.2: Spatial land use planning for urbanization

Land utilization for urbanization and settlements related strategy should be grounded on the Government's desired strategic goals and the inclusive growth strategy of job creation in the manufacturing, services, and off-farm sectors. Rapid urbanization and continuous expansion of rural settlements and industrialization leads to many issues in relation to land use management, which creates negative externalities for cities, as well as reduction of cropland in the rural areas. Informal expansion of slums further engraves the already dire living conditions, striking the marginalized population (landless households, the unemployed, and women) the hardest. The ill-equipped urban governance and planning system will face enormous challenges to sustainably guide the growing cities towards 2100. This is very serious threat to proper land use management.

As part of a mitigation strategy for the challenges and constraints of rapid urbanization, land use management should act as a tool to keep reservations for future developments, and keep enough open space for water storage and flood plain management. The water areas can, provided the water quality can also come to an acceptable level, serve as ecological and recreational areas within cities. For urban and non-agricultural needs, land resources management should be linked through a spatial planning mechanism. As discussed earlier, Bangladesh needs to adopt spatial planning for optimizing land resource management including land use. A spatial planning mechanism in relation to urban land use policies, land use zoning, land use management systems that relate to the development of urban and rural settlements themselves (regional/township planning), as well as the development of cities, rural areas, and industrial areas, need to be addressed for proper land use management.

While undertaking spatial planning, the focus should also be in using the provisions of the Special Economic Zone (SEZ) Act 2010 to set up new urban industrial and urban centers in the newly accreted land. As an example, the accreting and reclaimed land along Jamuna, Padma, and Meghna rivers or any other major river should be protected and used as part of spatial planning in making value added land use by setting up of new SEZs. This sort of action will not only require major physical investments, but adopting appropriate land use policies, zoning laws, and institutional land governance arrangements. Efforts need to be made in exploring possibility of such development works undertaken through Public-Private Partnerships (PPPs), thus providing the opportunity for both leveraging private investments for spatial development and also have in place institutions that that can have implementation efficiency. A national comprehensive physical plan would be an effective instrument to guide landuse plan and urbanization of the country in the long term. This plan can be prepared under the overall guidance of the Planning Commission in close cooperation with LGED, UDD, MoL and MoA.

Strategy 6.3: Optimization of Land Use

For an optimal land use plan as well as design and implementation of any zoning strategy, a study and projection is needed for different time horizons by a multi-discipline team consisting of land use planner, urbanization developer, agricultural experts, socio-economic specialists and morphologists. The following indicative categories may be considered for land zoning, including Coastal Zone to help government in planning for rational land use: Shrimp (brackish water) Zone, Shrimp (sweet water) Zone, Salt – Shrimp Zone, Forest Zone, Mangrove Zone, Urban and Commercial Zone (Industrial, Port, EPZs and Ship breaking yards), Tourism Zone and Agriculture Zone. Accelerated vertical expansion of settlements including schools, hospitals, industries, roads, etc should also be seriously considered to optimize available land. This should be done taking into consideration the long term vision and development goals and should cover areas that include food security, urban and rural settlements, industrialization, infrastructure needs, etc. In this situation, tipping points relating to different Hotspots and the agro-ecological regions need to be considered.

Strategy 6.4: Formulation of Spatial Planning and Land Resource Management Act

Bangladesh needs to consider giving legal coverage to spatial planning by putting in place a "Spatial Planning and Land Resource Management Act". Given the scarcity of land resources, its intrinsic links to river flows and water bodies and also its challenging diverse demands, having in place such a Spatial Planning Act will be a rational way of addressing the land use related challenges. Spatial Planning Act will allow focus on spatial pattern/distribution of land-uses/resources, which will better help in achieving the strategic objectives of food security, accelerated job creation, rapid urbanization, and also addressing climate change challenges.

Strategy 6.5: Management and protection of Marine land

Bangladesh won a landmark verdict at the International Tribunal on Law of the Sea, which sustained its claims to 200-nautical-mile exclusive economic and territorial rights in the Bay of Bengal. The verdict of the tribunal gave Bangladesh a substantial share of the outer continental shelf beyond 200 nautical miles, which would open up possibilities for peacefully exploiting immense resources (gas, oil, fish and others). The tribunal also awarded Bangladesh a full 12-nautical mile territorial sea around St Martin's Island. Integrated management is needed for marine resources. Capacity building and research is needed for exploring marine resources. It is also important to keep the exploitation of the marine resources within sustainable limits by following major regional and international conservation programs.

Strategy 6.6: Enhance afforestation and plantation in the coastal zone for stabilizing land

The existing coastal afforestation and enrichment plantation projects need to continue. Newly accreted lands need to be stabilized through plantation of mangrove. To prevent the extent of damage by cyclones and tidal surges, Coastal Green Belt needs be created and seedling will be raised and distributed in the Coastal Zone. The reedlands of Sylhet have long been lying unutilized, which needs to be brought under afforestation. The protected area of forests would be increased to 25% of the total forest land.

Strategy 6.7: Restoration and protection of soil health

The intensive cultivation of HYV rice without organic recycling and rapid mineralization is causing depletion of organic matter and other plant nutrients. Intensive cultivation would also be required to meet the additional food requirement, which would further deplete nutrient status of the soil. Intrusion of salinity, gradual increasing of shrimp culture, soil erosion, river bank erosion, water logging, industrial pollution and indiscriminate use of agro-chemicals are contributing to the overall deterioration of soil health. Protection against saline water intrusion can be achieved through the rehabilitation of existing polders and construction of new polders. Another measure for southwest region includes increasing supply of upstream fresh water by water storage in the proposed Padma barrage. Other measures include Tidal River Management (TRM) for reducing water logging problems in the Coastal Zone as well as promoting and implementing organic farming and IPNS (Integrated Plant Nutrient Management System) for maintaining land productivity. Furthermore, programmes to popularize production and application of bio-fertilizer/green manure need to be undertaken. Promotion of ICM and IPM to reduce agro-chemical use is also an important part of this strategy. Also, farmers need to be motivated to apply site specific soil test based fertilizers and other farm management techniques, including crop rotation and crop diversification.

Strategy 6.8: Reducing soil erosion and land loss

Prevent soil erosion by promoting and adopting improved tillage and irrigation practices wherever feasible. Undulated hilly areas may be brought under afforestation programmes. Adoption of proper river training works is also required to reduce land loss to river bank erosion.

Strategy 6.9: Integrated management of coastal water infrastructures to protect land

The polders should be managed in an integrated manner in respect of embankment maintenance with foreshore afforestation and fisheries and agricultural development. Water logging problem in the southwest region need to be relieved permanently through appropriate management of polders.

7.8 Recommendations for Improved Urban Governance

The capacity of local urban government needs to be strengthened in the short term to achieve a more effective delivery of urban services and local infrastructure development in urban areas. To implement the aspects and plans that follow the integrated spatial planning approach, a strong institutional framework for land management along with inter-ministerial coordination for spatial planning is required. The institutional role of spatial planning and sustainable land use management as instruments in integrated water resources management should also be considered. This section sets out various recommendations for the improvement of urban governance.

Decentralization

In line with the recommendation to develop a national spatial strategic vision, functional decentralization supports a more even distribution of the growing urban population. The distribution of the population in urban centres can be balanced throughout the country and the various regions, by allowing selected smaller urban centres to be developed into compact townships, which can provide higher order services (including physical planning). This requires adequate capacity building for the selected administrations, focussed on urban growth management, building control, and other key issues in town planning. In time, authority from the national agencies can be devolved to the local government authorities.

The need is most pressing in the divisional towns, and can later be expanded in accordance with the priority development centres as designated in a national strategic vision for spatial development. Local government should be enabled to have autonomy in providing higher order services to its population by raising local taxes and (community infrastructure) levies. Finally, investment should be made in local infrastructure that is essential for local economic growth in underdeveloped regions.

Local Governance and Resources

Local infrastructure is best planned and implemented at the local level (following the principle of 'subsidiarity' in spatial planning). This requires investments and new revenue streams for local governments. Some technical forms of resource regeneration that are directly linked to infrastructure development could support in building acceptance and willingness to pay by the citizens (service users). Charging new developments through betterment levies or a community infrastructure levy can provide additional funds that can be used to develop local infrastructure. Part of the costs of investment in public infrastructure could be covered by obligating land owners to contribute part of the land-value profits. Land readjustment schemes could contribute to lower the costs of physical restructuring and upgrading in metropolises.

Urban Service Delivery

The uncoordinated development and deficient urban service provision in urban areas need to be addressed. There is potential for inclusion of informal governance sector to overcome short term capacity gaps. Additionally, the national government should develop new incentives in the city corporations to regain control in physical planning. Building control through land regulations remains a point of attention that has many connections to water management and general spatial quality. Too many agencies and urban service providers are now involved in physical planning and have the mandate to intervene in the physical environment. Therefore it is advised to re-establish coordination and update the accompanying mandates.

Inclusive Planning

Community participation can have a positive impact on planning, for social acceptance and to improve transparency. Therefore, inclusive planning should be encouraged as much as possible.

Land Related Institutions and Need for Reforms

The links between the three key land related institutions (the Survey, the AC Land, and the Sub-Registrar's office) are weak as accountability mechanisms only move vertically in each of the organizations. For an efficient and transparent system there needs to well synchronized linkages across the three institutions.

In the short and medium term, the regulatory and institutional challenge will be in bridging these gaps across the institutions as well as brining efficiency within each agency. It will be particularly important to reduce time for undertaking surveys, simplifying the appeal process, reducing the number of days in the registration process and finally coming up with a more dependable and readily available certificate of title that is protected from abuse.

Chapter 8
Sustainable Agriculture, Food Security, Nutrition and Livelihoods

Chapter 8: Sustainable Agriculture, Food Security, Nutrition and Livelihoods

8.1 Climate Change and Food Security

Chapter 3 provided strong evidence that climate change will become a major threat to Bangladesh's aspirations to ensure food security, poverty alleviation and sustainable development. Agriculture, including horticulture, forestry, livestock and fisheries, is the most climate-sensitive sector. Therefore this sector must adapt to the impacts of climate change to improve the resilience of food production systems in order to feed a growing population. Since water is critical to agriculture, managing water resources and addressing the vagaries of climate change will have to be co-integrated national strategies. That remains a major long term challenge of Bangladesh agriculture sector and must be addressed as an integral part of the overall development agenda and under BDP 2100.

In the moderate scenario posited by the Inter Governmental Panel for Climate Change (IPCC), global temperatures are expected to rise by 2°C by 2050 and another 3 - 4°C by the end of this century. Even under the moderate scenario, the Bangladesh Delta, and particularly its agriculture, faces severe challenges of falling crop yields, loss of agricultural land, decreasing quality of aquifer, loss of biodiversity and extreme weather events. The combined effects of these challenges could seriously threaten livelihoods of people dependent on agriculture and related occupations.

In the cooler regions of the world, it is possible that global warming initially may have some favorable impacts on crop yields, and declining yields kick in only after warming exceeds 2°C, beyond 2050. For Bangladesh, which lies in the tropical regions of the world, this is not the case (

Figure 8.1). According to the Stern Review, one of the ways to depict production impacts of Climate Change on agriculture is through an inverse parabolic function where countries in the tropics fall on the right side of the hump in the curve. Bangladesh, being in the tropics, is likely to be point A of the curve, a point where crop yields start declining as global warming sets in. In cooler regions, low levels of warming may improve conditions for crop growth (extended growing season and new areas opened up for production), but further warming will have increasingly negative impacts as critical temperature thresholds are crossed more often. Tropical regions may already be past the peak. The shape and location of the curve depend on crop variety and local conditions.

Inverse parabolic ("hill function") $y = -x^2$

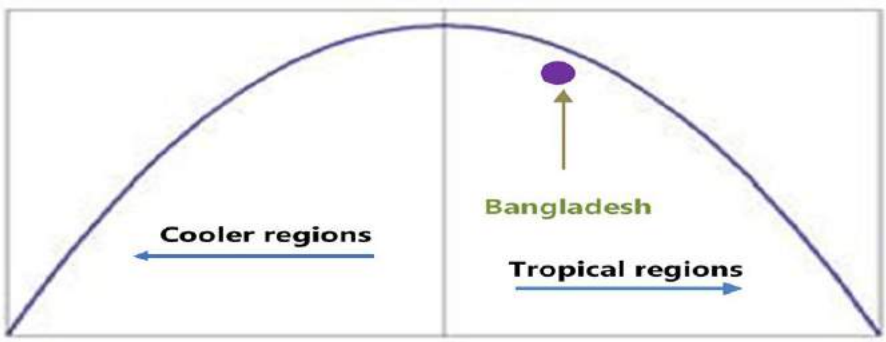


Figure 8.1: Physical impacts of Climate Change on Agricultural production

Source: Adapted from Stern, 2007

This Chapter focuses on both the direct and economy-wide impacts of climate change on agriculture, food security, nutrition and livelihoods from a full range of climate risks, including droughts, floods, sea level rise, warmer temperatures, and increased CO_2 concentrations. The importance of agriculture, forestry and fishing for rural livelihoods and poverty reduction will vary by the geography of the Hotspots. The strategies and solutions for sustainable agriculture, forestry, livestock and fisheries will also vary by the nature of the Hotspots. In this chapter, a detailed review of these activities and emerging challenges to livelihoods, nutrition, poverty reduction, and food security in the context of the Hotspots and oncoming climate change impacts are provided. The underlying water, land, climate change and environmental factors and their implications for the agriculture, forestry, livestock and fishery activities and the associated threats are analyzed. Strategic approaches to address climate change impacts in terms of adaptation and mitigation are then articulated as key ingredients of development planning.

8.2 Opportunities and Challenges in Agriculture

The Bangladesh Delta presents tremendous opportunities for agriculture but also many challenges. The land is fertile and the availability of abundant water on aggregate through many rivers, rainfall and groundwater helps sustain a very productive agriculture in the wet season. Bangladesh has done well in increasing food production. River fishery and increasingly sea fishery based on the open access to sea are increasingly an important source of employment and income. Both have contributed to substantial progress on food security from the supply side. The accretion of new land from the river system has increased substantially over the 1973-2013 period, estimated at 152,271 ha in the major river systems. This is an important resource for the land-constrained economy of Bangladesh. Yet, these sources of livelihood for the rural poor and food security for the country as a whole face many challenges.

Water-related hazards could be exacerbated by the emerging climate change developments. The various water-related hazards, impinging on agricultural activity, are listed in **Table 8.1**.

Table 8.1: Delta Implications for Agriculture

Water-Related Hazards	Risk Factors	Opportunities
Delta location	Exposed to Coastal Hazards	Plentiful of water supply; rich soil fertility; strong potential for fishery.
Floods	Damages to crops and physical assets as well as loss of lives in extreme cases	Flooding recharges groundwater and improves soil fertility
Cyclones	Loss of human lives, damages to crops, forestry, storm surge, etc.	None
Sea Level Rise	Causes loss of available land for cultivation and human habitation by increasing soil salinity	Salinity creates opportunities for shrimp farming and mining of sea-salt.
Water Logging	Crop damage	Floating agriculture
Siltation	Creates river flow barriers leading to river flooding, navigation problems and flow reduction (cutoff) during dry season	Creates opportunity for land accretion
Land Erosion	Loss of usable land	None
Drought Prone Areas	Low water recharge causing non-sustainable water use for agriculture	None

Source: BDP 2100 Technical Team Analysis, GED, 2015

Floods are a recurring feature in Bangladesh, often causing heavy loss of crops, cattle, and homestead and prolong sufferings to affected people. Cyclones happen periodically, sometimes proving deadly with tremendous cost in terms of loss of output, human lives and property. Sea water encroachment in the coastal belt creates problems of salinity, posing challenge to cropping and productivity. Soil erosion from river movements causes losses of land resulting in substantial loss of homestead and livelihood. Water logging due to poor drainage creates challenges for land use and agricultural production. In parts of the Bangladesh Delta, drought and water shortages can challenge agricultural production, inflicting crop losses and loss of income for the poor and vulnerable.

Maintaining the ecological balance across the Bangladesh Delta is also at risk. Forestry cover is threatened by cyclones and human activities. Degradation of wetlands owing to human interference has caused several problems, including extinction and reduction of wildlife, extinction of many indigenous wild and domesticated rice varieties, loss of many indigenous aquatic plants, herbs, shrubs and weeds, loss of natural soil nutrients, loss of natural water reservoirs and of their resultant benefits, increase in the occurrence of flooding and degeneration of wetland based ecosystems as well as associated livelihoods. Land degradation from salinity and water-logging creates problems for agricultural sustainability. In general, sustainable uses of land, water and forest cover are major issues for the Delta Region and poses serious challenges for sustainable agricultural development.

These issues have prevailed for a long time and the population has adapted in a variety of ways. Government policies and programmes and supportive investments have also helped. However, occasionally the solutions have also presented new challenges. Traditional forms of irrigation have given way to mechanized large-scale irrigation. Protection of Coastal Zone from tidal waves has led to construction of polders. Such large scale irrigation, drainage and flood control infrastructure have benefitted the population but also created their own dynamics owing to poor operation and maintenance as well as damages caused by large scale floods and cyclones.

8.2.1 Progress in Crop Production

The agriculture sector has contributed considerably to the development of Bangladesh. During the time of independence, Bangladesh was a poor agrarian economy. Agriculture accounted for over 78% of total employment and more than 50% of value-added. Between 75-80% of the population was poor, with most depending on peasant agriculture for livelihood. The situation changed rapidly after independence. Strong focus on agriculture based on the adoption of seed, fertilizer and water technology of the 1970s-1990s along with a very strong population control policy rapidly changed the rural scenario. Rapid gains were achieved in food productivity that enabled Bangladesh to achieve food self-sufficiency. The poverty incidence was more than halved. By 2000, the national poverty rate had fallen to 49% and rural poverty had come down to 52%, down from the 80% level in the early 1970s. Subsequent progress in agriculture and the strengthening of economic transformation during 2000-2015 period saw national and rural poverty decline further to 24% and 30% respectively by 2015.

Although the share of agriculture in Gross Domestic Product (GDP) declined to 17% in FY2015, compared to 50% in FY1973, it still remains the predominant sector in terms of employment and livelihood. About 44% of Bangladesh's workforce is engaged in agriculture sector as the principal occupation. Agriculture is the principal source of food and nutrition. Agriculture and agro-processed products also contributes significantly to export earnings of Bangladesh and agricultural output is used as an important source of raw materials of many industries. For example, agriculture and agro-product exports amounted to US$ 2.4 billion in FY2015. Therefore, the importance of agriculture sector in generating employment, alleviating poverty and fostering growth remains substantial.

The decline in share of the agricultural sector is largely due to the transformation of the Bangladeshi economy from a pre-dominantly agrarian economy towards a manufacturing and service-based economy. This is a natural phenomenon observed for all fast growing countries. Within agriculture there has been a substantial structural change. The share of the crop sector has fallen while forestry and fishery activities have gained momentum (**Table 8.2**).

Table 8.2: Agricultural Production Value Added in Bangladesh (% Constant Prices)

Farm Produce	Value Added 1977/78	Value Added 2007/08	Value Added 2012/13	Value Added 2013/14
Crops	80.9	58.3	56.5	55.8
Rice	(57.8)	(36.2)	(34.3)	(33.6)
Others	(23.1)	(19.9)	(20.5)	(22.2)
Livestock	6.9	11.7	11.0	10.9
Forestry	3.6	10.3	10.5	10.7
Fishery	8.6	20.3	22.0	22.6
Total Agriculture	***100.0***	***100.0***	***100.0***	***100.0***
Agriculture/GDP	***53.4***	***18.5***	***16.8***	***16.3***

Source: BBS, 2015

The main reason for the declining share of crops is the fall in the share of rice in value-added terms. Thus, the share of crops in agriculture fell from 81% in FY1978 to 56% in FY2014; the commensurate shares of fishery and forestry grew from 9% and 4% respectively to 23% and 11% respectively. Livestock also gained some momentum, rising from 7% to 11%.

The growth performance has been variable by decades. In the early years after independence, crops took the lead in farm production. Forestry sector grew slowly, while fishery collapsed with strong negative growth. The picture changed since the 1980s. Fishery and forestry gained momentum while crops lost ground. Most recently, during the FY2011-15 period, fishing and forestry have continued to gain momentum, growing rapidly, while crop sector growth has slowed considerably. Livestock showed considerable progress during FY2001-10, but slowed down in FY2011-15.

Table 8.3: Growth Performance of Agriculture and Sub-sectors, FY1972-15 (%/year)

Type	FY1972-80	FY1981-90	FY1991-00	FY2001-10	FY2011-15
Agriculture and Forestry	2.43	2.58	2.08	3.69	2.73
Crops & horticulture	2.51	2.69	1.83	3.34	2.25
Livestock	2.23	2.10	2.51	4.52	2.79
Forestry	1.63	2.74	3.62	5.03	5.34
Fisheries	-3.87	2.35	8.21	2.72	6.19

Source: National Accounts, BBS, 2015

Despite the challenging physiography and extreme climate variability, enormous success has been achieved in the last several decades, with the country largely food self-sufficient. The crop sector provides staple food such as rice and wheat, and other daily necessities like pulses, oil, sugar, vegetables, spices, and fruits. Bangladesh made steady progress in crop agriculture in the post-independence period. In fact, the entire growth in crop production was due to the growth in foodgrain production, particularly rice, which rose from 11 million tonnes in 1971 to 34 million tonnes in 2015. The major driver of crop production has been development and diffusion of improved farm technology in the form of improved seeds, fertilizers and more effective water management, particularly expansion of irrigation infrastructure (mostly mechanized tube wells). Available data suggest that Bangladesh has achieved self-sufficiency in rice production in years of normal climatic environment. This milestone has also been supported by sharp reduction in fertility and changing consumption habits away from rice. The production of potatoes and vegetables has also increased (**Table 8.4**). Yield of other non-cereal crops such as pulses and oilseeds almost stagnated, while that of wheat increased only marginally. The total jute production has declined due to decline in acreage over time but due to introduction of improved varities and modern techonlogies, the productivity has increased. Cotton is another fibre crop, which is second to jute, has potential to grow in char lands, Barind, saline and hilly areas. It has huge demand as basic raw material in textile sector. Livestock and diary production has gained ground contributing to a more balanced and nutritious food mix for the Bangladeshi population.

Table 8.4: Average Annual Production of Major Crops and Livestock ('000 MT)

Type	FY1970-79	FY1980-89	FY1990-99	FY2000-09	FY2010-13
Rice	17,645.2	22,517.4	28,031.8	26,308.4	33,309.8
Potatoes	831.1	1,098.6	1,528.7	3,858.9	7,498.8
Roots	1,591.3	1,754.4	1,966.8	4,701.2	8,545.5
Pulses	512.2	536.1	506.2	302.9	257.9
Jute	993.8	1,037.6	873.4	728.0	1,322.5
Vegetables	1,079.7	1,173.8	1,490.1	2,491.7	3,992.6
Eggs	37.0	42.7	93.2	160.0	228.3
Meat (chicken)	41.0	48.4	79.0	126.4	168.5
Meat (cattle)	148.4	129.5	151.0	181.4	192.0
Milk	757.2	744.8	763.1	803.8	833.7

Source: FAOSTAT; BBS, 2013

Gradual adoption of improved varieties by replacing low-yielding traditional varieties have contributed to increase in yield, reduction in per unit cost of production, and increased profitability in farming. The growth in rice productivity has been remarkable, expanding by nearly four-fold between 1974 and 2014, which is about 1.5% per year (**Figure 8.2**). The technological progress has been supported by public and private investment for the infrastructure for irrigation; flood control and drainage, because the optimum exploitation of the yield potential of improved varieties depend on good irrigation management. The area irrigated has expanded rapidly since 1989 with the liberalization in the import of diesel engines and reduction in import duties and withdrawal of restrictions on standardization of irrigation equipment. This has facilitated the cultivation of dry season irrigated rice farming known as Boro rice.

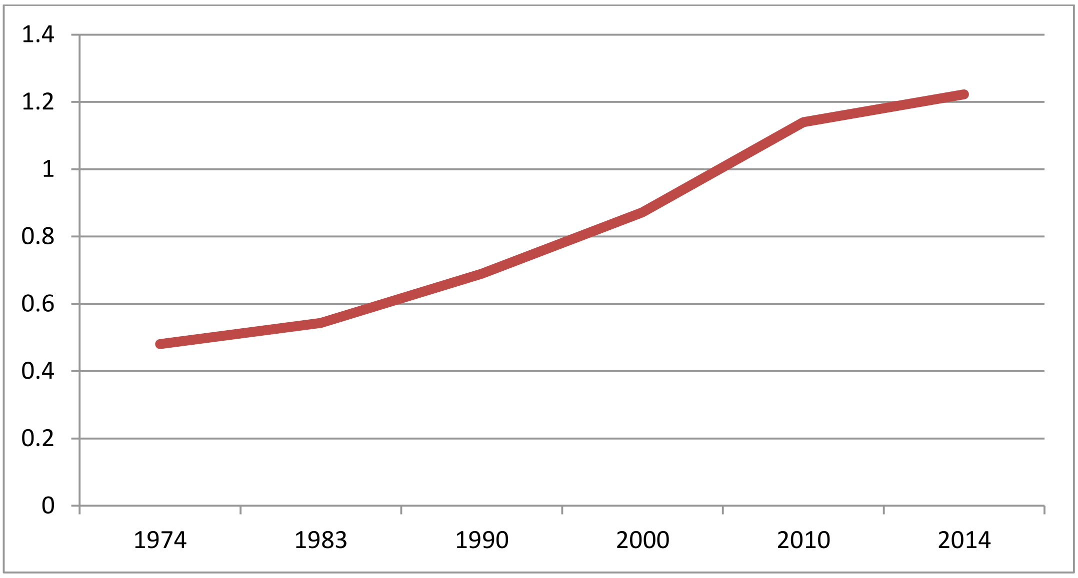


Figure 8.2: Trend in Rice Productivity (MT/acre)

Source: BBS, 2015

During the 1960s, the focus of FCD projects of BWDB was to protect the crops, mainly Aman, from the river floods as well as tidal floods and that of FCDI projects was to provide supplementary irrigation to Aman and Aus crops. This decade witnessed the introduction of the high yielding variety rice for the first time. Initially, the response of the farmers to it was unenthusiastic. However, due to untiring efforts by BWDB, with assistance from the Department of Agriculture, slowly and steadily, the cropping area under HYV rice was on the rise and during 1970s, this variety became predominant. This was possible because of FCD and FCDI projects by creating an enabling flood-free environment for rice to grow and provide irrigation during Kharif I and II seasons. An overview of pre-project and post-project production of some selected irrigation projects is an example of how the food production increased due to creation of these projects. Food production is characterized by considerable regional variations, including factors such as tendency to natural disasters as well as distribution and quality of agricultural land. So far, a total of 6.3 million ha of agricultural land has been provided with flood control and drainage facilities, thereby facilitating the production of additional food grain amounting to about 6.3 million tonnes (BDP 2100 Water Resources Baseline Study). In addition, 1.6 million ha land in 114 projects has been provided with irrigation facilities and thereby producing about of 2.8 million tonnes of food grain. The total additional food grain production from the completed FCD and FCDI projects is about 9.1 million tonnes annually. This additional production is about 25% of the total food grain production of the country. Because of the flood control facilities, the production of Aman crop is on increase as evident from the graph shown in **Figure** 8.3. In this connection, rapid rise of High Yield Varity of crops helped to produce more crops for the burgeoning population.

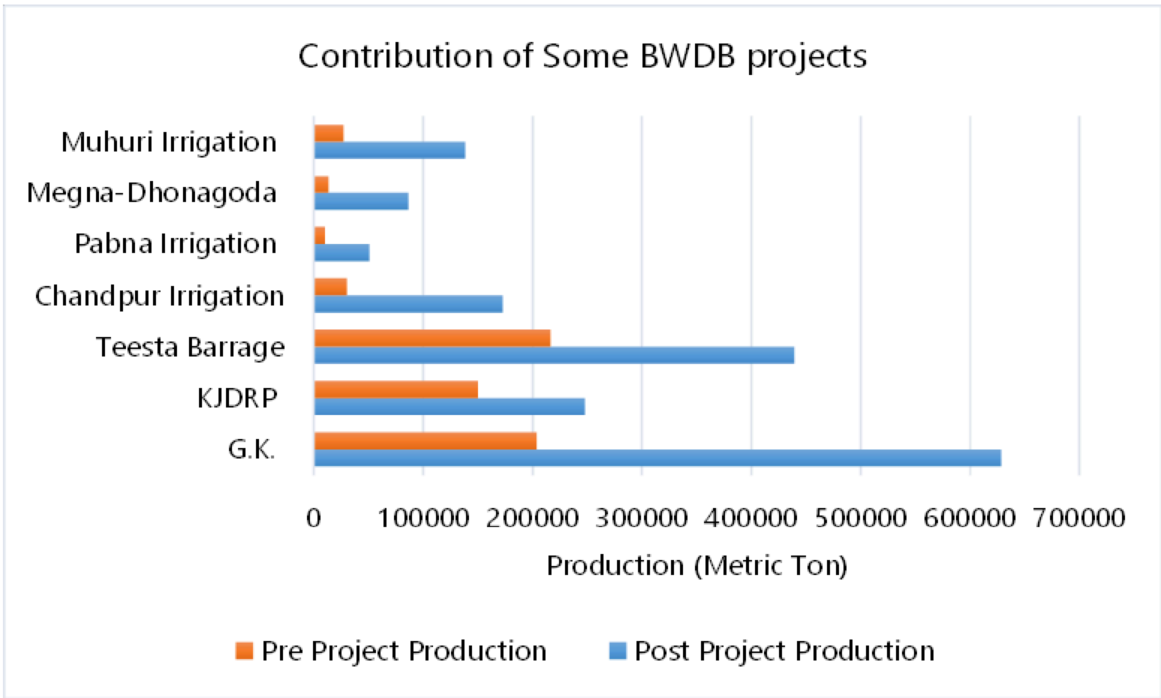


Figure 8.3: Contribution of BWDB projects to enhance food security

Source: BDP 2100 Baseline Study Report: Sixty Years of Water Resource Development in Bangladesh, 2015

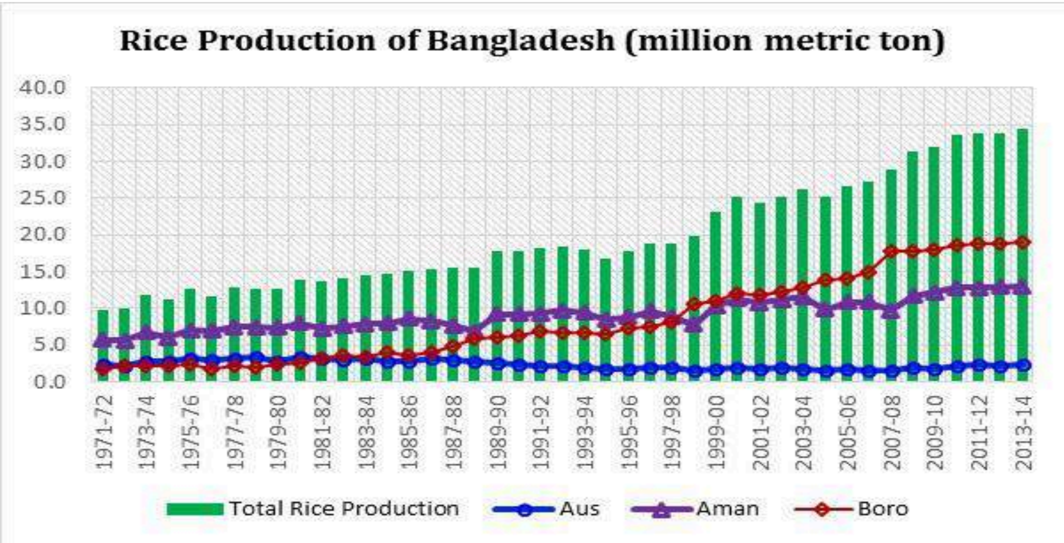


Figure 8.4 Graph showing the gradual increase of rice production (1971-2014)

Source: BDP 2100 Baseline Study Report: Sixty Years of Water Resource Development in Bangladesh, 2015

8.2.2 Progress in Fisheries Production

The coastal polders have also opened up the opportunity for shrimp culture. During the period from 1985 to 1992, the IDA-aided Shrimp Culture Project was implemented in the coastal polders. In Khulna, an area of 1,430 ha was developed under Polders 20 and 20/1 while in Cox's Bazar an area of 5,594 ha under Polders 66/3, 66/4 and 70 was developed. The polder infrastructure were modified and built for introducing salt water within these polders. During 1994-1999, under IDA-aided Third Fisheries Project, an area of 10,454 ha of privately owned land was brought under shrimp culture by constructing 150 new structures in Polders 5, 23, 31 and 32 in Khulna and Satkhira

Districts. In polder 23, an area of 3824 ha was developed as an area which was suitable for shrimp culture alternating with paddy cultivation within the same year. In polder 5, high intensity type shrimp culture could be practiced for a 9-month period and therefore an area of 1686 ha was developed for the purpose. During 2000-06, IDA-aided Fourth Fisheries Project was implemented. This project was a community based fisheries project working in the coastal polder areas seeking to promote sustainable growth in fish shrimp production. The project activities included setting up of fish sanctuaries, habitat restoration through reexcavation of canals and beels, and construction of fish passes and fish friendly regulators to ease riverfloodplain migration of fish. Lately, BWDB's activities with regard to fisheries development have contributed positively in the growth of fisheries production. In 1983-84, the total fish production was around 0.8 million ton, while in 2013-14, it reached to around 3.6 million tons. From Figure 8.5, it is observed that the production of culture is increasing, however, the production of capture fish is decreasing as the quantity of open water bodies are shrinking because of sharp rise in pollution of water bodies and rivers by industrial and household wastes.

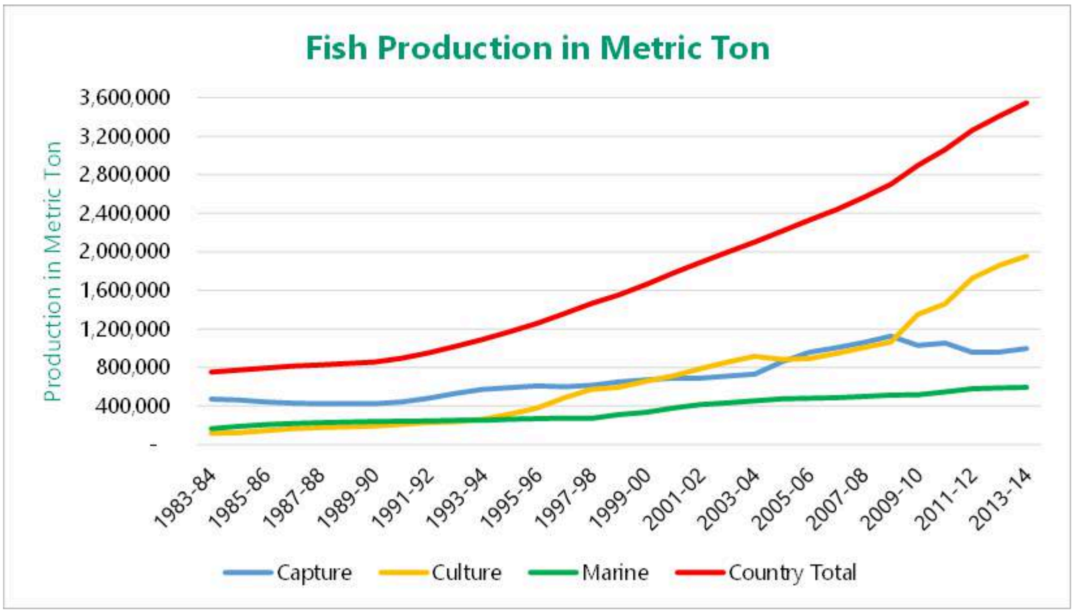


Figure 8.5: The increasing trend of fish production, FRSS, DoF (1983)

Source: BDP 2100 Baseline Study Report: Sixty Years of Water Resource Development in Bangladesh, 2015

Non-crop agriculture (livestock, fisheries and forestry) have gained substantial ground and now plays a significant role in terms of employment generation and contribution to GDP. Although livestock accounts for 10% of agricultural GDP (less than 2% of total GDP), it is very labor intensive. Livestock sub-sector contributes output for both production and consumption. However there exists a gap between the demand for livestock products and their current levels of production. This gap is expected to widen further due to increase in per capita income and change in food consumption pattern. This is a missed opportunity that needs major policy attention.

A major breakthrough that has happened in post-independence Bangladesh is the growing importance of fisheries. As noted in **Table 8.2**, its share in agricultural production climbed up from less than 9% in the 1970s to 23% in FY2014. As a result, fisheries sector now contributes to 4.4% of total GDP and employs about 13% of rural labor force. There has been a major transformation in the fisheries sector (**Table 8.5**). The small-scale open water capture fisheries which was dominant in the 1970s has given way to close water culture fisheries, which is now playing an important role in the development of the sub-sector. Thus, the share of inland open capture fishing has fallen from 63% in FY73 to only 28% in FY14; correspondingly, the share of inland culture fishing has grown from 27% to 55%. Two other notable structural changes are the growing share of marine fishing, from 11% in FY73 to 17% in FY14, and the increasing share of shrimps, from 3% to 6% over the same periods. Since much of the shrimp catch is exported with considerably higher prices than domestic consumption fisheries, commercial value of the export-oriented shrimp production is changing the role of fisheries sector in value-added and incomes. The main driving forces for growth of aquaculture are high intensive technological management and improved fish breeds based on private investment. With growing domestic demand and a large export market, there is considerable further scope for enlarging the contribution of fisheries in the development of Bangladesh.

Table 8.5: Evolution of the Fisheries Sector by Source

Fishing Source	FY1973		FY1977	FY2013	FY2014	
	Tonnes	% share	Tonnes	Tonnes	Tonnes	% Share
Total	818,000	100	826,000	3,061,687	3,548,115	100
Inland	731,000	89	736,000	2,515,354	2,952,730	83
Inland (culture)	219,300	27	220,800	1,460,769	1,956,295	55
Inland (capture)	511,700	63	515,200	1,054,585	996,435	28
Marine	87,000	11	90,000	546,333	595,385	17
of which						
Inland water shrimps	24,000	3	26,000	206,235	216,447	6
Inland water fish	707,000	86	710,000	2,309,119	2,736,283	77
Marine fish	87,000	11	90,000	546,333	595,385	17
Total (excl. shrimps)	794,000	97	800,000	2,855,452	3,331,668	94

Source: BBS, 2015

Livestock contributed over 14.2% to agriculture GDP in FY2016 (DLS 2016). Numbers of buffalo, sheep, poultry have increased at a rate of 25-30% over the last decade (**Table 8.6**). Cattle and goats are the most important livestock holdings. Cattle are a typical part of a traditional cropping system as a source of power, transport, and manure, as are buffalo, which are fewer in numbers.

Table 8.6: National Livestock Production (in 000s)

Species	2006-2007	2012-13	2013-14	2014-15	2015-16	% of Change (2006 to 2016)
Buffalo	1,210	1,450	1,457	1,464	1,471	22
Cattle	22,870	23,341	23,488	23,636	23,785	4
Goats	20,750	25,277	25,439	25,602	25,766	24
Poultry	245,970	296,264	304,172	312,293	320,633	31
Sheep	2,680	3,143	3,206	3,270	3,335	24

Source: DLS, 2015-16

Meat and milk productivity are low due to weak genetics as the buffalo and cattle herd are primarily made up of local breeds which are heat tolerant and less prone to disease compared to pure breeds or pure breed crosses. Improved breeds are more common on government and privately owned dairy farms. Milk productivity averages 206 litres/head/year compared to 1,087 for India, 1,253 for Pakistan and 9,118 for the United States (FPMU 2013). Although there has been some cross breeding, a major selective breeding program will be required to boost the milk subsector. Egg production has grown at a 2.9% annual rate. Egg imports, which account for about 50% of consumption, are at 1.9 billion pieces per year and dried milk imports have reached 63,000 tonnes/yr (FAO, 2014).

Forestry sector contributes about 1.8% of the total GDP and also plays an important role in protecting watersheds, irrigation and hydraulic structures as well as coastal zone from natural calamities. The role of forest in protecting the environment from pollution and its contribution towards biodiversity is immense. In addition, the participatory social forestry contributes towards rural poverty reduction.

8.2.3 Progress in Food Security

All these success stories add to and translate into achievements in enhanced food security.

Pillar 1 of Food Security: Per capita availability

Agricultural (excluding forestry) GDP growth increased by 2.1 percentage points to reach 4.3% in 2013-14, mainly due to increased rice, animal and fish production. Rice import dependency, measured as an average for the period 2011/12-2013/14, has consequently dropped to 1% from 2.3% registered in 2012-13. Variability of rice production remained unchanged in 2013-14 from its lowest level of 2.9% registered in 2012-13, mainly due to the stability in rice production throughout all seasons. In 2013-14, price of rice was more stable than in the previous year although it remained on an increasing trend, while wheat price has been decreasing and remained more volatile over the same period. Although the agricultural trade deficit rose to US$ 6.9 billion in 2011, fishery exports improved (FPMU 2015).

Per capita availability of cereals (rice and wheat) has increased from 374 gm/day in 1994-95 to 647 gm/day in 2010-11 (**Table 8.7**). Sharp increase in per capita availability of potato and vegetables is seen in the last four years, while the per capita availability of pulses and oilseeds has remained stagnant or declined. Availability of meat, milk and egg has also increased. Per capita fish availability increased from 27 gm/day in 1994-95 to 56 gm/day in 2010-11.

Table 8.7: Per Capita Availability of Major Food Items (1994-2011)

Food Item	Availability (gm/capita/day)		
	1994-95	2004-05	2010-11
Cereals	374	464	647
Potato	32	108	153
Pulses	11	10	13
Oilseeds	10	10	15
Vegetables	21	108	207
Fruits	24	68	65
Fish	20.5	41	52
Meat	11	21	35
Milk (ml/day/head)	35	42	55
Egg (numbers/year/head)	19	41	41

Source: BDP 2100 Technical Team Analysis, GED, 2015

Pillar 2 of Food Security: Access to Food

An indicator often used to assess the capacity of the poor to access food from the market is the level and trend in real wages. This indicator shows that since the mid 1990s there has been a favourable trend in the income of the households who depend on selling labour in the market, such as agricultural wage labourers, transport operators and construction workers. The rice equivalent wage had increased from about three kg in 1990 to nearly 8.9 kg in 2013-14. The only low-income group who has not been able to increase its real income is industrial labourers, particularly the unskilled workers in the garment industry and the fixed wage earners in the public sector.

Despite the gains in food production, particularly rice, inadequate access to food and food insecurity remain major problems for a population segment, particularly during two seasonal lean periods, March and April prior to the boro harvest and in October and November prior to the Aman harvest. Limited off-farm employment combined with lack of food availability, particularly during these lean seasons, obviously worsens household food insecurity. In a 2011 survey, 74.4% of respondents reported that they had never faced any type of food shortage, while 25.6% reported that they sometimes or often faced food shortages (**Table 8.8**).

Table 8.8: Frequency of Household Food Shortages

Availability of Food	Urban (%)	Rural (%)	Total (%)
Never	77.9	72.9	74.4
Sometimes	11.9	15.4	14.4
Often	10.2	11.7	11.2
Total	***100.0***	***100.0***	***100.0***

Source: NIPORT, 2011

The government has given high priority to the social safety nets for ensuring food security. Currently nearly 2.2% of the GDP is allocated for safety nets and social protection.

Safety net programmes: A safety net programme is essential to insulate the poverty stricken population from chronic as well as temporary food insecurity that results from external shocks. A number of food safety net programmes are in operation in Bangladesh, each with its own specific objectives and target population. These include test relief, Vulnerable Group Feeding (VGF), Vulnerable Group Development (VGD), Food for Work, Employment Guarantee Scheme, etc. A number of social protection programmes such as VGF, allowance for destitute women, and old age pensions have also been introduced to support food security of the extremely needy people.

Pillar 3 of Food Security: Utilization of Food and Nutritional Security

The acceleration in economic and agricultural growth has had a positive impact on the diversity of food intake away from the rice and vegetable based diet in favour of more nutritous food. The change in per capita consumption of different items in the food basket for the rural and urban people, as estimated by the Household Income and Expenditure Surveys (HIES) of the BBS, is summarised in **Table 8.9**. It may be noted that the per capita consumption of rice and wheat has been declining, while the consumption of vegetables, fruits and fish and meat has been growing. For rural areas the consumption of rice has declined from 175 kg per person per year in 2000 to 161 kg in 2010, a decline of about 1.4 kg per year. For urban areas, the consumption of rice and wheat together has declined from 155 kg per person per year in 2000 to 140 kg in 2010, a decline 1.5 kg per year. During 2000 to 2010, the consumption of meat has increased by one-third for rural areas and by 40% in urban areas.

Table 8.9: Consumption of Different Food Items (gm/person/day)

Food Item	Normal for balanced nutrition	Rural Area				Urban Area			
		1984	2000	2005	2010	1984	2000	2005	2010
Rice	500	421	479	477	442	351	377	389	344
wheat	100	65	24	12	38	79	17	28	51
Vegetables	225	140	196	218	221	179	196	228	241
Pulses	30	26	15	13	13	22	19	19	17
Fruits	50	17	26	33	43	21	27	33	50
Fish	45	29	38	40	46	39	41	50	60
Meat & Egg	34	10	15	18	20	22	31	31	42
Milk	50	22	29	31	32	34	33	37	39

Source: Household Expenditure Survey Report of various years, Bangladesh National Nutrition Council for minimum food intake requirement

Bangladesh has made significant progress in reducing under-nutrition for children. The prevalence of underweight children for their age declined from 66% in 1990 to 32.5% (BDHS, 2014) which meets the required 50% reduction by 2015. Also, progress in reducing stunting, the indicator of chronic malnutrition, shows a positive picture. Children suffering from stunting fell from 51% in 2004 to 36.1% in 2014.

8.2.4 Other Issues and Challenges Facing Bangladesh Agriculture

All the successes, described above, could be short lived over a longer period of time. After achieving lower middle income country status, the challenge is not achieving food security but to sustain food security over medium and long term. Bangladesh aspires to become an upper middle income country and then on to become a developed country by 2041. This time frame unfortunately also coincides with onset of sea level rise potentially inundating parts of Bangladesh. Can Bangladesh sustain food security at that time? If not, will that threaten its aspiration to become developed country?

The main challenges to achieving and sustaining food security over the longer term include:

- Expanding urbanization
- Impacts of climate change and sea level rise
- Loss of agricultural land
- Uncertainty in water availability from upstream

Expanding urbanisation threatens food security. The total population of Bangladesh is set to increase from the present 160 million to a range of 209 to 224 million in 2061 (BBS, 2015). It is projected that by 2075 population will drop to 193 million and by 2100 population decrease to 170 million (UN, 2015). Bangladesh experienced faster urbanization than South Asia as a whole between 2000 and 2010. Over that period, the share of its population living in officially classified urban settlements increased by 1.69% per year. World Urbanization Prospects estimated that urban population will be 56% of total population of Bangladesh by 2050. Bangladesh's expanding urban populations presents it with a considerable affordable housing challenge. In the best case scenario in which urban population density remains constant, meeting this challenge will require expanding the amount of developable urban land by just over 7,000 km^2 or almost 45% – between 2010 and 2050 (World Bank, 2015). This will provide extreme stress on lands available for productive economic uses and threaten achieving food security.

Climate change and natural hazards will likely continue to worsen. Bangladesh ranks first in the 2014 Climate Change Vulnerability Index and it will likely suffer more from climate change by 2025 than any other country (Maplecroft, 2014). Rainfall is expected to increase by 10% to 15% during the monsoon seasons by 2030 and 27% by 2075; rising sea level is expected to inundate 120,000 km^2 by 2050; 14% more of the country may become extremely prone to floods by 2030; cyclones in the Bay of Bengal will occur more frequently due to increasing temperature, and the peak intensity of cyclones may increase by 5% to 10% (FPMU, 2013). Coastal salinity problems will likely worsen as changing rain patterns reduce the amount of dry season water supply from upstream river sources. Overall, crop production might be reduced by 30% by the end of the century, rice production could fall by 8%, and wheat production by 32% by 2050 (FPMU, 2013). Winter crop production would be seriously hampered due to a warmer and drier environment during non-monsoon seasons, while moisture stress might force farmers to reduce the area under irrigated rice cultivation.

Loss of agricultural land: Bangladesh is losing agriculture land at a rate of 0.5% per year due to various factors including urban encroachment of agriculture land, road infrastructure, water logging, depletion of groundwater and soil fertility, erosion, and salinity (Hasan, 2013). In the last three decades about 170,000 ha of agriculture land has been degraded by increased salinity (FAO, 2012). Soil fertility degradation results from imbalanced fertilizer use (overuse of subsidized nitrogen fertilizers), absence of micronutrient application, less use of manure for crops and more for fuel, and cropping intensification combined with the increase of mono culture rice without rotation. River bank erosion accounts for about 40% of land loss on about 1,200 km of riverbanks (primarily the Ganges, Jamuna, and Padma Rivers) that are seriously affected as topsoil is washed away and replaced by sand (Hasan, 2013). This problem is expected to intensify with increased climate change-induced sea level rise. This significant land loss when combined with population growth explains why the size of cultivated area per farm has decreased from 0.81 to 0.51 ha between 1984 and 2008 (FPMU, 2013).

Uncertainty in water availability from upstream. As Bangladesh is located in the low-lying delta of the Ganges- the Brahmaputra- the Meghna basin, upstream infrastructural developments both in India and possibly in China are expected to have a notable impact on the dry season flow in the country. Of particular interest for Bangladesh are the Indian proposals to construct 16 barrages on the Ganges River and the plans to divert water from the Ganges and the Brahmaputra rivers towards the south of India. In addition, India is planning to construct the Tipaimukh dam in the northeastern part of the country. These will impact the water availability in Bangladesh as well as the ecological condition of the rivers. Fisheries and agriculture activities within Bangladesh are expected to be impacted by these developments.

The other challenges can be succinctly outlined as:

- Land use change
- Land degradation and diminishing productivity of land
- Price volatility of food items in the domestic and global market,
- Disruptions in the food supply chain,
- Trade barriers and uncertainties in international trade,
- Labour shortage and high wage rate of agricultural labour, .
- Fossil fuel dependence
- Hybridization, genetic engineering and loss of diversity
- Seasonal variation of food supply
- Locational variation of food Supply
- High underemployment resulting in low accessibility to food
- Inequality of income in the society.

In fisheries, an important challenge is to address the factors that are adversely impacting on fish production. Factors responsible for open capture fish decline are siltation, channelization of river, unplanned construction of dams, embankments, roads, and diversion of water flows upstream in the transboundary major rivers. Degradation of inland water quality owing to discharge of untreated industrial effluents, domestic organic wastes and agro-chemicals are also causing substantial damage to fish resources. Shrimp cultivation presents its own challenge by contributing to soil salinity owing to inappropriate cultivation practices.

Regarding livestock, the major challenges are protecting them from natural hazards, providing fodder and veterinary services, improving quality of food chain processing, improving marketing and availability of credit and investment resources.

In forestry, while these resources are an important source of livelihood for the poor, unsustainable use of forest resources and illegal encroachments threaten the forest cover necessary to prevent land degradation and also provide essential protection from cyclones. Population pressure is causing a reduction in forest area by an estimated 13,000 ha annually. Considerable proportion of hill forests is barren due to harvesting and subsequently not bringing the area under vegetation cover. Denudation causes soil erosion, flood from runoff, siltation of river bed, and complicates management of watershed. As a result, services from the forest ecosystems are greatly reduced. In order to meet the growing need of wood, there has been introduction of exotic species. These plants have a destructive impact on natural habitats and wildlife population. Although considerable research findings are available that can help improve management of forests and increase production of the ecosystems, technology transfer and execution of research findings for higher return is lacking. Presently, there is no separate organization responsible for the extension of research achievements from the Bangladesh Forest Research Institute (BFoRI) to the community.

8.3 Climate Change, Agriculture, Food Security and Nutrition

The higher temperatures and changing rainfall patterns, coupled with increased flooding, rising salinity in the coastal belt and droughts are likely to reduce crop yields and crop production. IPCC estimates that, by 2050, rice production in Bangladesh could decline by 8% and wheat by 32% (against a base year of 1990). Increased river bank erosion and saline water intrusion in Coastal Zone are likely to displace thousands of people who will be forced to migrate, often to slums in Dhaka and other big cities. If sea level rise is higher than currently expected, and coastal polders are not strengthened and/or new ones built, six to eight million people could be displaced by 2050 and would have to be resettled.

Water use: Many of the impacts of climate change on agriculture will be mediated through water. The problem gets more aggravated by the fact that Bangladesh is a lower riparian country for its major river system and has minimal control over managing demand in the upper riparian country. Groundwater is an important source of water for irrigation and (safe) drinking water. Some 80% of irrigation, particularly of Boro rice, originates from groundwater. Due to intensive groundwater use the water table has fallen considerably, indicating that recharge does not keep up with abstraction.

Over time, the increasing human population will clearly add to the demand for water for non-agricultural and agricultural use, not only for staple crops but also in the production of livestock feed for rapidly increasing livestock populations. Although a warm world will result in more rainfall globally, the distribution of that rainfall, while uncertain, is likely to be highly variable. Being in the tropics and subtropics Bangladesh is likely to be particularly affected by reduced rainfall amounts. The impacts of changes in climate and climate variability on agricultural production will have substantial effects on smallholder and subsistence farmers, pastoralists, fishermen and much of the rural population in Bangladesh.

Land use: Future trends in land-use change may have enormous impacts on GHG emissions. Rapid conversion of forests and other natural habitats to cropland and pastures has occurred over the last 150 years. Reducing deforestation through agricultural intensification strategies that involve not only increased yields but also reduction of incentives for agricultural expansion offers considerable potential. In general, if a hectare of forest can be saved by yield gains or a hectare of land can be reforested because of yield gains; there would be large gains in carbon capture. Increasing yields through increases in fertilizer would reduce emissions substantially compared to the alternative of clearing more land to provide the same food.

8.3.1 Climate Change and Agricultural Challenges

Table 8.10 summarizes the major climate change factors that will have direct impact on agricultural production and livelihoods.

Being the most climate-sensitive sector, agriculture and rural livelihoods could be the most seriously impacted for the following reasons:

- Farmers could be potentially at risk of climate-driven heat stress, flooding, malnutrition and water related and vector borne diseases.
- Decline in crop yields from rising temperature and crop loss from flooding would result in falling farm incomes that will undercut poverty reduction efforts.
- Rising sea levels, salinity intrusion, drought, and other climate-driven changes would result in loss of farm land that could drive thousands of people to migrate out of the affected regions into urban centers putting additional pressure on already stretched urban infrastructure and services.

Table 8.10: Climate Change and Potential Impacts on Agriculture

Key Vulnerabilities	Outcomes	Impacts on Agriculture
Climate change may increase rainfall variability, i.e. heavier and more erratic rainfall	Higher river flows, causing over-topping and breaching of embankments; widespread flooding. River bank erosion resulting in loss of homes and agricultural land; Increased sedimentation in riverbeds leading to drainage congestion and waterlogging.	Reduced crop yield affects diet and nutrition; IPCC estimates that, by 2050, rice production in Bangladesh could decline by 8% and wheat by 32%, compared to 1990; Existing crop mixess are not sustainable under climate change in some areas.
Lower and more erratic rainfall	Increasing droughts, especially in drier northern and western regions	Livelihood activities in drought-prone areas will suffer as a result of increased impact of droughts due to climate change
Melting of the Himalayan glaciers	Higher river flows in the warmer months of the year, followed by	Lower agricultural yields due to decreased water availability

Key Vulnerabilities	Outcomes	Impacts on Agriculture
	lower river flows and increased saline intrusion after the glaciers have shrunk	
Sea level rise	Submergence of low- lying coastal areas and saline water intrusion up coastal rivers and into groundwater aquifers; reducing freshwater availability; damage to the Sundarbans mangrove forest; and drainage congestion inside coastal polders	Adverse effects on agriculture in the coastal zone.
Increasingly frequent and severe tropical cyclones	Higher wind speeds and storm surges.	More damage to crops in the Coastal Zone
Higher temperature and evaporation lead to excessive water use and water scarcity	Decline in surface water and groundwater resources; over exploitation of groundwater causes heavy metal contamination	Rise in temperature of 1°C–2°C reduces yields of high-yielding varieties of rice; Increased incidence of insect pests, diseases, and microorganisms. Low yields due to high temperature stress and water scarcity; By 2050, a reduction in 4.5 million tonnes of rice output compared to production in 2002.

Source: BDP 2100 Technical Team Analysis, GED, 2015

8.3.2 *Growth and Productivity Impact of Climate Change on Forestry*

Many aspects of projected climate change will likely affect forest growth and productivity. Climate Change implies the possible occurrence of (i) increases in carbon dioxide (CO_2), (ii) increases in temperature, and (iii) changes in precipitation.

- Higher future CO_2 levels could benefit forests with fertile soils in the Northeast. However, increased CO_2 may not be as effective in promoting growth in the West and Southeast, where water is limited.
- Warming temperatures could increase the length of the growing season. However, warming could also shift the geographic ranges of some tree species. Habitats of some types of trees are likely to move northward or to higher altitudes. Other species may be at risk locally or regionally if conditions in their current geographic range are no longer suitable.
- Climate change will likely increase the risk of drought in some areas and the risk of extreme precipitation and flooding in others. Although many trees are resilient to some degree of drought, increases in temperature could make future droughts more damaging than those experienced in the past. In addition, drought increases wildfire risk, since dry trees and shrubs provide fuel to fires. Drought also reduces trees' ability to produce sap, which protects them from destructive insects such as pine beetles.

8.3.3 *Some Quantitative Estimates of Adverse Impact of Climate Change on Agriculture*

Long term changes in temperatures and precipitation have direct implications on evaporative demands and consequently agriculture yields. However, climate change poses additional challenges to agriculture beyond the existing risks from current variability. Moreover, the changing hydro-characteristics (e.g. onset, duration, and magnitude) of extreme events may affect agriculture production significantly.

A recent ADB study (ADB, 2014) has provided some quantitative estimates of Climate Change impacts on the overall economy as well as some sectors like agriculture. Simulation studies predict about 17% decline in overall rice production and as high as 61% decline in wheat production compared with the baseline situation due to climate change. This translates to a reduction of 4.5 million tonnes of rice at the 2002 level of production. Bangladesh is projected to be vulnerable to increasing temperature and CO_2 level, which could result in a decline in rice yield of as much as 23% by 2080. The highest impact would be on wheat followed by Aus rice. Of the three seasonal rice crops grown in Bangladesh, Aus rice seems to be the most vulnerable. The decline in paddy yield due to climate change will bring a negative impact on real GDP of Bangladesh by 0.67% in 2050 and 0.93% in 2100 under the BAU scenario.

Dynamic biophysical crop models (i.e. the decision support system for agrotechnology transfer (DSSAT)) also validates the preceding findings. Simulations of changes in crop yield include impacts from climate only (CO_2 fertilization, temperature, and precipitation), mean changes in floods, and coastal inundation, both separately and in combination. Considering all these climate impacts, the median of all rice crop projections shows declining national production, with boro showing the largest median losses (DSSAT). Most GCM (General Circulation Model) projections estimate a potential decline in boro production with a median loss of 3% by the 2030s. Climate change exacerbates the negative impacts of existing climate variability by further reducing rice production by a projected cumulative total of 80 million tonnes over 2005–50 (about 3.9% each year), driven primarily by reduced boro crop production. This is equivalent to almost two years' worth of rice production lost over the next 45 years as a result of climate change. Various stipulations about climate change and possible impacts on agriculture are summarized in **Table 8.11**.

Table 8.11: Climate Change Factors and Impacts

CC Factors	Expected Changes	Possible Impacts	Projected by
Accelerated Sea Level Rise (ASLR)	1 m or more by 2100; increase in tidal flooding; with monsoonal rainfall and river discharge increase in flooded area; 37 to 75 cm for the RCP4.5 and 55 to 123 cm for RCP8.5	Inundation of additional 17%-21% of the total area of Bangladesh	Hardy, 1992; Choudhury 1997; IPCC (2001) report
	88cm SLR	11% of Coastal Zone and 3% of total area inundated	WARPO (2005)
	62cm SLR	16% inundation of over 5,000km^2	IWM (2008) and CEGIS (2010)
	Salinity ingress	Crop loss of 0.2 million tonnes;	Habibullah et al, 1998

CC Factors	Expected Changes	Possible Impacts	Projected by
		Bangladesh SLR expected to be slightly higher than the global average mean	
Temperatures	Increases in temperatures of up to 2.0 °C or more by 2100	17% reduction in rice yields; increase in pests and insects; extinction of some species; 61% reduction in wheat yields	The Geophysical Fluid Dynamics Laboratory model
Precipitation	Increase in rainfall by 800mm in NW region and 300mm in SW.	Higher monsoon flooding	IPCC AR5 and five General Circulation Models – GCM
	13% increase in precipitation over the Ganges- the Brahmaputra- the Meghna basins	22% increase in peak discharge—monsoon flooding.	IWM (2008)

Source: BDP 2100 Technical Team Analysis, GED, 2015

The southern and northwest regions are the most vulnerable. The south sits at the confluence of multiple climate risks. These areas experience the largest decline in rice production due to climate change. This is for three reasons. First, these regions already experience significant declines in Aus and Aman rice production due to climate variability, which is expected to worsen under climate change. Secondly, Boro yields are severely affected by the effects of changes in mean rainfall, temperature and mean shifts in the flood hydrographs. Thus, reductions in boro production limit the ability for these regions to compensate for lost aus and aman rice production during extreme events. The south is also affected the most by rising sea levels, which permanently reduces cultivable land. The largest percentage declines in per capita consumption are projected in these regions. Finally, the northwest is also vulnerable, as the lost consumption is a large fraction of existing household consumption. Adaptation measures should focus on these areas.

What is most disconcerting is the fact that the negative effects of climate change are projected to affect the populations with the least capacity to adjust, but with the greatest need for improved agricultural performance to achieve food security and reduce poverty. Bangladeshi population living on agriculture currently and in the future fits the classification of those with least capacity to adjust to climate change. Therefore, they are in the greatest need for transformation of the present agricultural systems in order to improve livelihoods and ensure food security. Achieving food security in the long term by mitigating adverse climate change effects becomes a long drawn out process of transforming agricultural systems that include cultivation of crops, rearing of livestock, modernizing aquaculture and fisheries, and preserving forestry resources. Raising productivity through technological adaptation and innovation is only one part of this adjustment. Other adjustments could include diversification of income sources by choosing off-farm activities that are not as sensitive to climate variation as rice cultivation, growing alternative crops between seasons, changing seedling techniques, and mechanization. The process of adjustment needs to start sooner rather than later as the costs of inaction today will simply raise the costs of adaptation and mitigation in future substantially.

8.4 Adaptation and Mitigation Measures in Agriculture, Food Security, Nutrition and Livelihoods

Adaptation and mitigation are the two strategic policy options available to Bangladesh's agriculture sector. Adaptation to climate change involves taking steps to build resilience and minimize costs. This is essential because it is no longer possible to prevent the climate change that will take place over the next two to three decades. However, it is still possible to protect Bangladesh agriculture from its impacts to some extent- for example, by providing better information, improved land and water management, and adopting more climate-resilient crops. Among others, it calls for substantial research into new crop varieties that will be more resilient to droughts and floods.

Bangladesh has experienced indiscriminate deforestation in the recent past. Action to reduce deforestation is another critical adaptation strategy. It has been estimated that the loss of natural forests around the world contributes more to global emissions each year than the transport sector. Curbing deforestation is a highly cost-effective way to reduce emissions. A major challenge awaits Bangladesh in curbing further deforestation thus making its own contribution to reducing local and global emissions.

Mitigation measures are required to address the long term challenge of climate change in agriculture- what needs to be done now to cope with the climate change impacts that could occur in the second half of this century. FAO has launched a Mitigation of Climate Change in Agriculture (MICCA) Programme to support developing countries cope with the emerging challenge. The focus of the MICCA program is on climate-smart agriculture (CSA). CSA integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. It is composed of three main pillars:

- sustainably increasing agricultural productivity and incomes;
- adapting and building resilience to climate change;
- reducing and/or removing greenhouse gases emissions, where possible.

Embracing these three pillars is essential for Bangladesh to achieve sustainable agricultural development for food security under climate change. The magnitude, immediacy and broad scope of the effects of climate change on Bangladesh agriculture create a compelling need to ensure comprehensive integration of these effects into national agricultural planning, investments and programs. Quite inevitably, it entails costs and places demands on the country's already scarce resources. However, the economics of adaptation and mitigation measures to address climate change impacts offers the clear determination that the benefits of strong, early action on climate change outweigh the costs.

Adaptation is the priority for Bangladesh in the short to medium term. The country is already a world leader in the research, design and implementation of adaptation strategies and this will continue. In the long term, however, climate resilience will require deep cuts in greenhouse gas emissions, led by the developed industrialized nations. Bangladesh will strive to achieve its own mitigation goals for low carbon growth while working with the global community to establish a fair and equitable post-Kyoto framework for developing countries. Bangladesh is committed to reducing greenhouse gas emissions from agriculture. Major sources of GHG emission in Bangladesh are methane from flooded rice fields. Raising irrigation and water use efficiency through improved agronomic practices is likely to lower emissions of methane. Bangladesh is developing climate change resilient cropping systems (e.g. agricultural research to develop crop varieties, which are tolerant of flooding, drought and salinity, and based on indigenous and other varieties suited to the needs of resource poor farmers), fisheries and livestock systems to ensure local and national food security. Furthermore, plans to expand the 'greenbelt' coastal afforestation programme with mangrove planting along the shoreline is under way.

8.4.1 On-going Interventions to Address Food Security

Since the World Food Summit of 1996, the Government of Bangladesh has undertaken an in-depth and consultative process of food security policy reform. This has provided the Government with a comprehensive food security policy framework (the National Food Policy) and programming document (the National Food Policy Plan of Action) as well as an investment plan for food security and nutrition (the Bangladesh Country Investment Plan).

The *National Food Policy 2006* is Bangladesh's main policy document on food security. It represents an important departure from the past by applying a comprehensive and integrated approach to food security, including the availability, access and utilization dimension of food security. The Policy represents an unprecedented effort to address food security in a comprehensive manner and fills the gaps of previous food and nutrition policy frameworks. The overarching goal of the National Food Policy is to ensure, in coordination with partner ministries, development partners and NGOs, "dependable and sustained food security for all people of Bangladesh at all times".

To provide programmatic guidance in implementing the National Food Policy, the Government formulated the National Food Policy Plan of Action (2008-2015). The Plan identified 26 strategic areas of intervention and priority actions that covered all dimensions of food security.

Responding to L'Aquila Initiative and in line with the 5 Principles agreed in the Rome Food Summit, the Country Investment Program - A road map towards investment in agriculture, food security and nutrition was approved in 2010 and revised in 2011 based on extensive consultations.

Of late, the GoB and FAO has developed 'Bangladesh Country Programming Framework: Towards Sustainable Agriculture and Improved Food Security & Nutrition (CPF 2014-2018). The CPF identifies and elaborates on 5 priority areas:

1. Reduce poverty and enhance food security and nutrition (access and utilization);
2. Enhance agricultural productivity through diversification/intensification, sustainable management of natural resources, use of quality inputs and mechanization;
3. Improve market linkages, value addition, and quality and safety of the food system;
4. Further improve technology generation and adaptation through better producer-extension-research linkages;
5. Increase resilience of communities to withstand 'shocks' such as natural disasters, health threats and other risks to livelihoods.

The Government is implementing many strategies and measures. These should be continued. Some of these are mentioned below.

Enhancement of Food Availability

A critical variable to increased food availability in Bangladesh is productivity growth. Food demand is expanding, driven by population growth, while food supply increases are being constrained by limited expansion potential for arable land and the offsetting losses of productive areas due to declining soil fertility, erosion and salinity intrusion, inadequate irrigation, increasing incidences of extreme weather events, and other climatic changes. The combination of these factors make a compelling argument that future food availability will be primarily influenced by improvements in reducing the yield gap, better management of water resources, and implementing new technologies involving seed varieties, and soil management and fertility, improving traditional technologies like floating agriculture. Significant progress has been made on improved seeds and planting material, but farmers often are unable to capitalize on the productive potential. Opportunities to address these evolving constraints include:

- Increased productivity for crops, livestock, and fish, whether on owned, rented, or share cropped land, could reduce lean seasons and offer more opportunities for sales of surplus production. This may include shifting some production area from cereals to in-demand high value fruits and vegetables.
- More emphasis on the market will be needed. Implementing a market-driven approach for poor smallholders will not be easy due to their lack of experience, limited assets and education, and the lack of land ownership by many.
- Another promising food access approach is to improve skills and thus off-farm employment opportunities which may also reduce the incentive for migration from rural to urban areas.

The answer to reducing the vulnerability of poor households is to improve their income earning capacity, but cultural, educational, financial and other constraints makes this a challenging task.

Sustainable Supply and Use of Improved Quality of Inputs

1) *Enhance availability of quality agricultural inputs:* The priority interventions are: expansion of both seed multiplication and processing farms and preservation facilities of BADC, NARS, DAE, and contract growers; capacity development of public laboratories and SCA for testing quality of inputs; strengthening participation of NGOs and private sector in seed distribution; capacity development of farmers for autonomous production of quality seeds; and establishment of mechanisms to ensure availability and reasonable prices of all quality and environmentally friendly agricultural inputs (i.e. seeds, planting materials, fertilizers, pesticides). Public-private partnerships are needed in order to strengthen capacities for the production of agricultural inputs, laboratories and the establishment of marketing networks in the country.

2) *Improve and increase sustainability of soil fertility management:* Restoring soil fertility is an important issue. The interventions are to promote efficient and balanced use of fertilizers. The main purpose is to strengthen environmentally safe fertility management practices. This will be done through facilitating application of fertilizers on the basis of soil tests, as well as strengthening of soil testing laboratories and promotion of improved soil health management practices. Additionally, awareness of Upazilla Nirdeshika (land and soil use guide) for location specific prescription of fertilizers by the grass root level extension workers should be strengthened.

3) *Facilitate access to credit and other financial services by smallholders and the rural poor:* There is a strong call for collateral-free bank loans/credit at low interest rates for crops, livestock and fishery

production for smallholders and the rural poor. There is a need to create specialized financial institutions for these sectors.

Improving Market Linkages and Development of Value Chains

1) *Improvement of infrastructure:* A number of priority investments have been identified that could form the programme of BDP 2100, including:

(i) Construction and adequate maintenance of rural roads to facilitate marketing of products and access to services in particular in remote areas;

(ii) Construction or rehabilitation of rural markets including the supply of potable water, drainage, and storage facilities to improve conditions.

(iii) Improvement and rehabilitation of wholesale markets in major cities;

(iv) Private storage facilities to reduce losses and increase value.

2) *Capacity building of value chain actors and market promotion:* A number of priority investments have been identified:

(i) Capacity building for group marketing at community level in the form of marketing groups and service cooperatives whose capacities should be developed and training provided;

(ii) Capacity development of farmers and market intermediaries through training in food quality and safety regulations and requirements, good agricultural practices so as to comply with market requirements;

(iii) Improved post-harvest management, value chain analysis and facilitation

(iv) Promote agro-processing

(v) Facilitate coordinated, market-based action, harnessing the productive capacity of agriculture to drive food security, environmental sustainability and economic opportunity.

3) *Establishment of export processing zones:* Harness opportunities to expand market linkages and agribusiness with establishment of export processing zones.

4) *Improving Food Safety and Quality for Consumer Health and Nutrition:* Food analytical laboratories at the central and regional level need to be established to facilitate support to food manufacturers, individuals and the enforcement of laws. There is no reliable surveillance data on food borne illnesses, impeding the understanding of the extent of disease burden and health and nutritional implications. Institute of Epidemiology, Disease Control and Research (IEDCR) of MoHFW has been working on the surveillance of food borne diseases. However, an effective surveillance on nutritional implications of food borne illnesses is necessary. It is also required to strengthen capacities of the existing institutions, strengthen consumer protection and build on on-going food safety activities.

Livelihood Improvement and Food Security

1. Developing programmes of alternative income generation and food security, reduce malnutrition of women, children and distressed population.
2. Developing Community Based Nutrition Activities through Livelihood Approaches: Home gardening, poultry raising and other community level nutrition-based agricultural activities

need to be included as food based nutrition approach and also complemented by integrated horticultural development, fish ponds, behaviour change communication or any other activities to increase demand. This strategy will include linking agriculture and food based nutrition to other nutrition efforts, including health.

3. Livelihoods improvement of population of char land, haor, coastal and CHT regions: All of these regions are not easily accessible and people are beset with problems and sufferings. Despite appalling conditions, a large number of families, due to abject poverty and lack of alternatives, are often forced to relocate to such lands battling precarious weather and adverse living conditions. As the families are often hard to reach through mainstream anti-poverty programmes, it drastically reduces opportunities to promote social and economic development within these communities.

Continue Supporting Technologies Already Innovated in Bangladesh:

The future challenge of increasing food production could be met through the introduction of modern biotechnology and an increase in investment in agricultural technology generation and transfer. **Table 8.12** presents information on technology generation and innovations in Bangladesh agriculture during 2004-14 and **Table 8.13** presents information on number of cultivars registered for notified crops, 2000-14.

Table 8.12: Technology Generation and Innovations in Bangladesh Agriculture, 2004-14

Product type	Examples of innovations
Seed	Rice cultivars, hybrid rice, hybrid maize, cultivars for potatoes, vegetables, jute seed, and other crops
Fertilizer	Biofertilizer from coconut dust, earthworm compost, and green manure
Pesticide	Pheromones, parasitoids, and phostoxin
Machinery	Jute ribboner, corn shellers, rippers, threshers, straw-bundle cutting machines, and seeders
Large-scale Crop-based production	Cultivars for gladiolas, strawberries, longum, grapes, guava, jujube, and durian
Processing Crop-based	Rubber rollers, color sorters, and graders for rice processing; and solvent extraction for oil seeds and rice bran

Source: Ministry of Agriculture (MoA), 2015

Table 8.13: Number of Cultivars Registered for Notified Crops, 2000–14

Species (Types of seed)	Cultivars submitted by private companies or NGOs	Cultivars submitted by public agencies	Total
Rice Varieties	0	41	41
Hybrid Rice Varieties	116	5	121
Wheat	0	10	10
Maize	44	8	52
Jute	0	6	6
Kenaf	0	1	1
Mesta	0	1	1
Potatoes	0	46	46
Sugarcane	0	15	15

Source: Ministry of Agriculture (MoA), 2015

For all non-notified crops, such as maize and vegetables, private companies have introduced hundreds of cultivars, but there is no centralized record of what has been introduced. For example, the National Seed Board (NSB) registered 52 maize cultivars during 2000-14.

Bangladesh Agricultural Research Institute (BARI) has introduced hydroponic system successfully using steel or plastic tray for cultivation of various crops and flower. High value vegetables like, tomato, cucumber, capsicum, lettuce and fruits can be cultivated in the hydroponic system in a controlled environment. Strawberry is perfect for hydroponic system because it can be rotten in a very short time with direct contact of soil. Therefore, it is indeed a big opportunity for small scale family farmers and traditional cultivators to grow different vegetables, fruits and flowers throughout the year. However, the only limitation is high initial installation cost. It can be a cost effective option for long term, since the system can be used for several years without further significant maintenance cost.

Water saving technology in rice farming: It takes 14 million litres of irrigation water to produce 6 tonnes of Boro rice on one hectare of typical farmland in Bangladesh. In other words, one needs 3,500 litres of water to produce a kg. of rice. A new farm technology has been developed where Boro will be grown as dry direct-seeded method instead of conventional puddle transplanted method, thereby halving the need of water. This has already received the attention of the MoA.

The future challenge of increasing food production could be met through the introduction of modern technology and its transfer to farmers. In this connection, farm level adoption of Conservation Agriculture (CA) technologies (such as, minimum tillage planter, crop residue retention, etc.) can play a crucial role in increasing crop productivity and farm profitability and also to reduce the inputs use, particularly water. Therefore, research on CA technology generation and dissimination should be emphasized.

Since the 1970s, the Government of Bangladesh, with the support of development partners, has invested in adaptation projects/schemes:

- flood management schemes to raise the agricultural productivity of many thousand hectares of low-lying rural areas and to protect them from extremely damaging severe floods;
- flood protection and drainage schemes to protect peri-urban agricultural areas from rainwater and river flooding during the monsoon season;
- coastal embankment projects, involving over 6,000 km of embankments and polder schemes, designed to raise agricultural productivity in Coastal Zone by preventing tidal flooding and incursion of saline water;
- over 2,000 cyclone shelters to provide refuges for communities and their livestock from storm surges caused by tropical cyclones and 200 shelters from river floods;
- comprehensive disaster management projects, involving community-based programmes and early warning systems for floods and cyclones;
- irrigation schemes to enable farmers to grow a dry season rice crop in areas subject to heavy monsoon flooding and in other parts of the country, including drought-prone areas;
- agricultural research programmes to develop saline, drought and flood-adapted high yielding varieties of rice and other crops, based on the traditional varieties evolved over centuries by Bangladeshi farmers;
- coastal 'greenbelt' projects, involving mangrove planting along nearly 9,000 km of the shoreline.

The following BCCSAP programmes are underway:

Building institutional capacity towards climate resilient cultivars: The impact of climate change on many food (e.g. potatoes) and non-food crops (e.g. jute) is largely unknown. Research is under way to understand these impacts and find out how to minimise adverse changes. It takes 7-8 years to breed new cultivars, certify them and release to the farmers. Following actions are underway:

- Collection and preservation of local cultivar varieties and documentation of their characteristics;
- Research to develop climate resilient varieties of rice (i.e. heat, drought, salinity and submergence- tolerant varieties);
- Research to develop climate resilient cultivars of wheat and other food and non-food crops, including vegetables;
- Field trials and dissemination to farmers of the local robust cultivars and the newly developed varieties, in partnership with the extension service and NGOs; and
- Strengthening the capacity of key research institutes and scientists.

Development of climate resilient cropping systems: Climate change will require farmers to modify their current cropping systems or change to alternative systems. Following actions are underway:

- Identify likely changes in agro-economic zones and probable climatic parameters;
- Develop climate resilient cropping patterns suited to different regions of the country;
- Field trials of climate resilient cropping patterns and associated water management systems; and
- Develop seed supply and extension mechanisms.

Adaptation-mitigation against drought: Climate change is likely to result in increasingly erratic rainfall patterns and droughts. Traditionally the main rice crop was Aman, which was planted in the monsoon and harvested in the post-monsoon period. It currently accounts for over 40% of rice production. Since Aman can suffer from drought stress, farmers developed indigenous methods of supplementary irrigation. Since Independence, major irrigation projects (e.g. the GK Project and Teesta Barrage) were developed to provide supplementary irrigation in the worst affected parts of the country. Farmers in these areas are currently reporting increasingly frequent drought events affecting the aman crop. Following actions are underway:

- Preparation of GIS maps of areas vulnerable to droughts; and
- Development and testing of adaptive measures in drought-prone areas by combining appropriate cultivars, cropping patterns and land and water management practices, and effective dissemination to farmers

Adaptation-mitigation in the fisheries sector: Climate change is likely to affect adversely the freshwater and marine fisheries (e.g. the spawning of freshwater species; water temperatures in ponds and inland fisheries are likely to increase; saline water is likely to extend further inland in the south of the country, which will change the aquatic ecosystem and production of fish in this zone; and turbulent and rough weather along the coast may prevail for longer durations adversely impacting on the livelihoods of fishermen). Following actions are underway:

- Assessment of potential threats to following sectors: 1) fish spawning and growth of fish in the freshwater fisheries sector 2) fish spawning and growth of fish in the Coastal Zone and brackish water sector 3) marine fish sector 4) shrimp sector.
- Development of adaptive measures based on the identified sectoral threats.
- Climate smart aquaculture technology are being adopted under ~~this program~~ which saline tolerant and drought smart varieties/species are being introduced

Beside these initiatives, establishment and maintenance of wetland fish sanctuaries are also needed. Good aquaculture practices particularly in shrimp farming in the Coastal Zone should be encouraged to avoid environmental degradation.

Adaptation-mitigation in livestock sector: Higher ambient temperatures, as well as floods and droughts, are likely to adversely affect poultry and livestock. Higher temperatures will limit the growth of chicken, broilers and other birds such as pigeons and ducks. Higher temperatures and humidity may affect animal health through the more rapid breeding of parasites and bacteria. Impacts of climate change on livestock and poultry production is mainly related to outbreak of different emerging and re-emerging diseases. Rising sea levels will inundate lands reducing grazing facilities. Intrusion of saline water in Coastal Zone will not be conducive for livestock rearing due to enhanced stress factors. Frequent tropical cyclones and tidal surges, and prolonged rainy seasons will affect livestock productivity.

Following actions are underway:

- Assessment of potential threats to the poultry sector and livestock sector, and develop adaptive measures and disseminate among farmers
- Strengthen veterinary services systems, including animal health measures in light of the likely increase in disease prevalence.

In 6th FYP, initial studies for ideas on adaptation were targeted but very little experience on adaptation process in livestock sector were identified as benchmark in the plan. Nevertheless, almost all of the preceding listed GoB investment projects relevant to address climate change adaptation are also appropriate for the livestock sector. For example: Flood management and protection schemes for agricultural productivity in low lying areas is also necessary for protecting livestock resources; Coastal embankment projects will help protecting livestock resources and help producing fodders in the region. GoB has also recognized the necessity of cyclone shelter for livestock resources. The 'Earthen-Killa' (Earthen platform/ village platform) programme is the best example of cyclone shelter for livestock resources. Comprehensive Disaster Management Programme and early warning system of natural disasters will help protect the livestock resources but must be complemented with community based programme on livestock protection. Climate change resilient irrigation schemes will help fodder production during dry seasons. Just as important are research programmes and institutional capacity building in the livestock sector.

8.4.2 Supply and Demand in Sustained Food Security

While the on-going efforts of the Government of Bangladesh are contributing to attaining food security, a quantitative analysis of supply and demand is a worthwhile consideration. With growing population, planning for future cereal production to meet food security challenges would require projections of future supply and demand for cereals. However, these analyses are almost non-existent for Bangladesh.

In 2012, Ganesh-Kumar et al. (2012) did a study with 2005 BBS data to provide forecasts of the demand and supply of cereals in Bangladesh for the period 2015–2030. Supply and demand projections are made for the years 2015, 2020, 2025, and 2030 under various scenarios. The total demand for rice in 2030 is expected to be in the range of 34.8 million and 52.5 million tonnes. The supply and demand projections for rice are then compared, to assess the likely surplus/deficit situation. The estimates show that Bangladesh can face either a surplus or a deficit in rice, depending upon the prevailing supply and demand scenario and intermediate demand requirements. The surplus in 2030 could be about 4.2 million tonnes, while the deficit could be as high as 13.7 million tonnes. The study also showed that surpluses, if any, could increase until 2020, after which they are likely to become smaller. In contrast, deficit projections show a steady rise over time, reflecting the sharp rise in demand under the high population growth scenario.

Amarsinghe et al. (2014) assessed the changing consumption patterns of rice in Bangladesh and its implications on water demand by 2030. Forecasts using time series models show rice demand for food consumption, which was 172 kg/person/ year in 2008, will have a negligible increase by 2 kg/person by 2030 (**Figure 8.6**). The demand for rice for feed will double with increasing animal products in the diet, which was only 4% of the calorie intake in 2008. Between 2000 and 2010, the total population and demand for rice increased by 15% and 22%, and these can increase further by 22% and 25%, respectively, over the next two decades. The demand for rice will be 35.4 million tonnes in 2020 and 38.7 in 2030. Forecasts of rice yield, area and production show that the country can meet the increasing demand for rice and can also have substantial production surpluses. However, the rice surpluses will come at a considerable environmental cost, because the demand for groundwater consumptive water use from irrigation alone could exceed the natural recharge in many locations. With the projected increases in area and yield, Bangladesh can even have substantial production surpluses of 14% of the demand in 2020, and 26% of the demand in 2030.

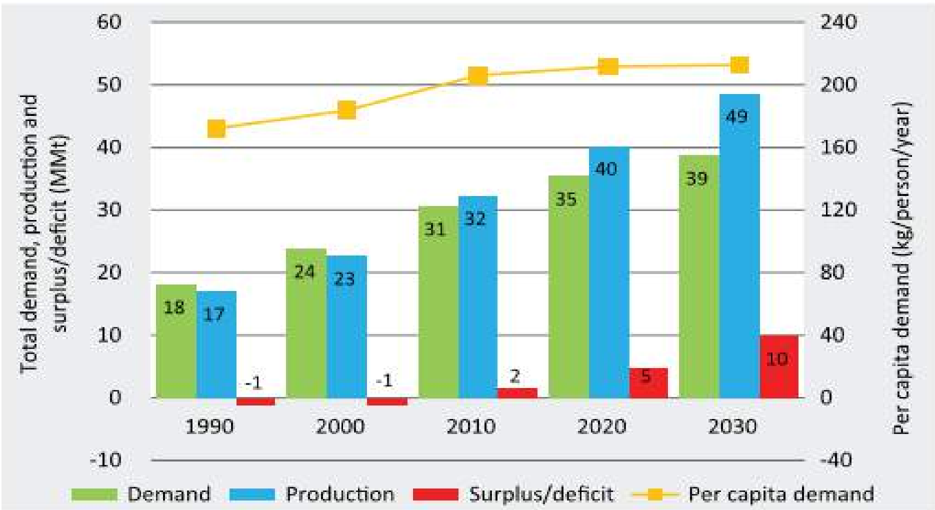


Figure 8.6: Rice Demand, Production and Surpluses/ Deficits

Source: Amarsinghe et al., 2014

Food security in Bangladesh, with particular reference to rice and wheat was investigated by examining trends in yields, area of cropping and overall production in recent decades (Mainuddin and Kirby, 2015). Prospects for continued increases in yield and area of the different rice crops and of wheat, considering the impact of climate change, suggest that continued large increases in production were likely. Demand for rice and other food will increase for many decades with the growing population. The range of projections was compared with recent population growth as well as the impacts of possible shifts in food preferences on the demand for rice and wheat. Demand for rice production in 2050 for a medium variant population projection is expected to be 14% less than the most conservative projection. Wheat production appears likely to remain less than demand by up to 76% in 2050, though it has the potential to increase sufficiently to meet demand.

All the available analyses indicate that food security can easily be sustained over a shorter time frame of 2-3 decades. The real question remains what happens in the long term. Attention has been drawn on to a recent study that has analysed the demand side for a time frame to 2100 (Rashid, CEGIS 2016, personal communication). The future food demand has been assessed considering two scenarios. These are: Demand 1-based on per capita consumption of HIES (Household Income Expenditure Survey), 2010 and Demand 2- based on per capita desirable intake of DDP (Desirable Dietary Pattern proposed by BIRDEM) 2013. Other assumptions in both scenarios include:

- Additional consumption of other forms of rice is 22 grams/capita.
- 12 % of loss for seed, feed & wastage and post-harvest losses for both rice and non- rice crops.

It has been concluded that, even with present-day technologies, rice production is not adequate enough under Demand 1 scenario (**Table 8.14**) after 2030 but adequate under Demand 2 scenario (**Table 8.15**) for all years up to 2100.

Table 8.14: Food Demand (million tonne) (Scenario 1)

Food items	Present consumption (grams/capita/day)	Demand					Availability
		2015	2030	2050	2070	2100	2015
Rice	416	28.3	34.0	38.5	36.1	32.6	34.71
Wheat	26	1.7	2.0	2.3	2.1	1.9	1.35
Pulses	14.3	0.9	1.1	1.3	1.2	1.1	0.73
Potato	70.3	4.5	5.5	6.2	5.8	5.2	9.25
Vegetables	166.1	10.7	12.9	14.6	13.7	12.4	5.92
Fruits	44.7	2.9	3.5	3.9	3.7	3.3	3.33

Source: HIES, 2010

Table 8.15: Food Demand (million tonne) (Scenario 2)

Food items	Desirable intake (grams/capita/da)	Demand					Availability
		2015	2030	2050	2070	2100	2015
Rice	350	25.7	31.2	32.7	30.7	27.7	34.71
Wheat	50	3.5	4.2	4.4	4.1	3.7	1.35
Pulses	50	3.5	4.2	4.4	4.1	3.7	0.73
Potato	100	6.9	8.4	8.8	8.2	7.4	9.25
Vegetables	300	20.7	25.1	26.3	24.7	22.3	5.92
Fruits	100	6.9	8.4	8.8	8.2	7.4	3.33

Source: DDP, 2013

FAO Bangladesh has initiated demand-supply analysis for projections towards 2050, 2075 and 2100. However, the findings have not been published yet and these should be considered in future updates of BDP 2100.

8.4.3 *Strengthening Responses to Climate Change Implications for Agriculture*

Building on the ongoing efforts, agriculture strategy and policies can be strengthened in several areas under the BDP 2100. The lessons of international experience provide some broad areas of intervention by the types of problem that have relevance for designing climate smart agricultural policies (**Table 8.16**). The specific implications of these lessons can be summarized as follows:

Negative impacts on food security can be reduced by development and poverty reduction approaches: Better infrastructure and market access help cope with production shocks. Well-functioning markets can help farmers cope with production shocks, although the ability to rely on markets depends on many socioeconomic conditions-especially institutional barriers (like trade barriers) and transportation costs. Rural road development offers a strong potential to lower transport costs and spur market activity. Greater access to all-weather roads in Bangladesh could be a game changer for farmers, as was the case in Ethiopia.

Table 8.16: Climate Change Risks, Impacts and Adaptation Practices

Climate Change Risks	Impact	Adaptation practice
Climate change may increase rainfall variability and cause longer dry spells making T. Aman and Rabi pulses face drought at various growth stages	Reduced crop yield affects diet and nutrition	Construction of mini ponds, shallow and deep tube wells
Climate change may increase dry spell lengths due to greater rainfall variability during early stages of T. Aman	Young transplanted seedlings affected by dry topsoil and reduced root proliferation may lead to reduced yields	Transplanting at deeper depths will lead to better root proliferation and facilitate moisture extraction during drought
Climate change may aggravate the complex, intense crop-weed competition	Intense competition for solar radiation, nutrients and moisture, weeds' smothering effect reduces yield	Manual controlling of weeds combined with closing soil cracks
More intense monsoon rainfall may lead to excessive loss of field water due to bund failures	Increased exposure to mid-season drought due to lack of water in the field	Strengthening field bunds to conserve more rain water
Increase in delayed onset of monsoon rainfall in June due to climate change	Delayed seedbed preparation and late planting; shortened growing period	Using dry seedbed method for T. Aman rice
Higher temperature and evaporation lead to excessive water use	Decline in surface water and groundwater resources; over exploitation of groundwater causes heavy metal contamination and conflicts with other sectors (e.g. domestic water demands)	Adoption of more intense rice cropping system
Low yield due to high temperature and water scarcity	Increased high temperature stress; more evaporation	System of direct sown rice using drum seeder
Local varieties of rice might be more sensitive to drought and high temperature	Excessive yield reduction	Drought- resistant, short duration varieties that fit in monsoon rainfall pattern
Improper water control structures and excessive rain water loss	Excessive run-off, soil erosion and uncontrolled water flow may cause localized inundation	Building of water control structures; check dams across the water ways

Climate Change Risks	Impact	Adaptation practice
Anticipated drought conditions would increase the seasonal famine conditions.	Reduced capacity for food production and community to absorb seasonal shocks	Growing famine reserve crops such as cassava and yam
Climate change models project increased temperature which will speed ripening of existing mango varieties	All varieties of mangoes will ripen at the same time causing price drop	Introduction of high-temperature tolerant mango and jujube (ber) varieties
Livelihood activities in drought-prone areas will suffer as a result of increased impact of drought due to climate change	Household income would be reduced	Enhancing facilities for cottage industries; engaging in homestead gardening
Existing crops are not sustainable under climate change	Yield reduction and decreased income	Adopting drought resistant mulberry intercropping in rice fields

Source: Selvaraju and Baas, 2007

Improved farm practices and technologies can mediate negative impacts: Climate-smart agricultural practices can increase productivity and make agricultural production more resilient. Being exposed to climate variability and change, disaster preparedness and resilient and diverse farming systems will be the long term strategic options in Bangladesh agriculture.

For instance, Vietnam is improving its water resource management to make its cropping and aquaculture regimes better adapted to increasing flood risk and salinity levels (ADB 2009). But more productive and more resilient practices require a more efficient use of land, water, soil nutrients, and genetic resources. Better technologies will also be needed to tackle future food security challenges. These might include improvements in crop varieties, smarter use of inputs, methods to strengthen crop resistance to pests and diseases, and reduction of postharvest losses. Improved crops and better use of water and soil can increase both farmers' incomes and their resilience to climate shocks.

Bangladesh's past experience has shown strong resilience and capacity to adopt new technology and adapt to natural hazards in crop production. As illustrated in **Figure 8.2**, average national rice productivity grew rapidly, since the adoption of new technology from the early 1980s, with average rice yields expanding 2.5 times between 1974 and 2014. This happened notwithstanding the adverse effects of natural hazards and climate change owing to supportive government policies on technology and water investments including flood control measures.

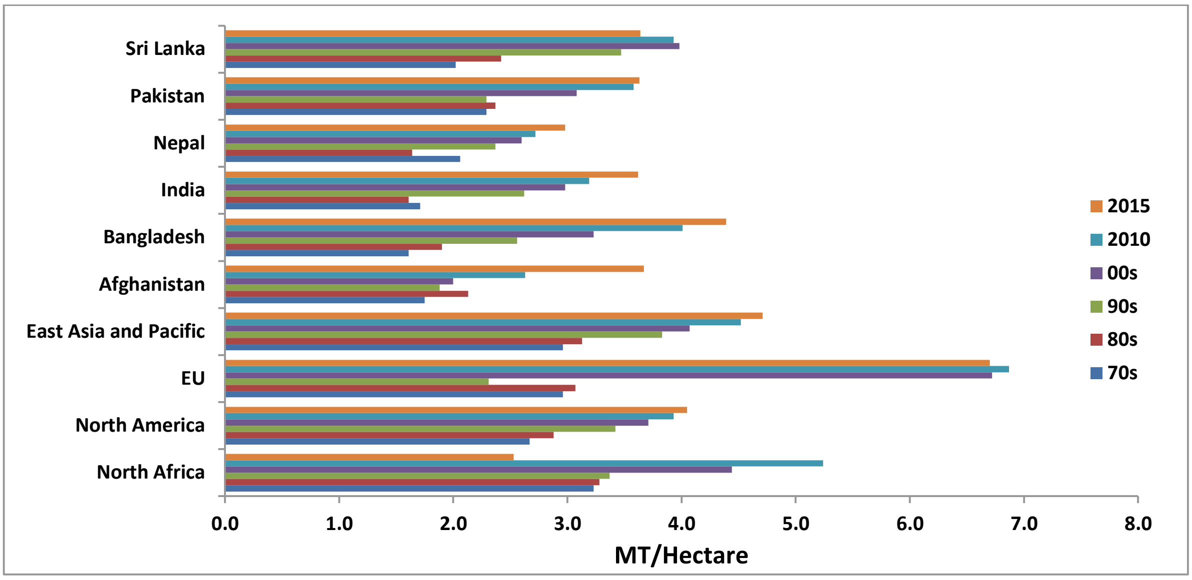


Figure 8.7: Rice Yields for Selected Countries and Regions

Source: USDA Database, 2015

The scope for productivity improvements remains large. This is suggested by the still prevailing productivity gap between Bangladesh and international rice productivity leaders in Europe (**Figure 8.7**). Adoption of climate smart technology will be an important element to achieve this higher productivity, especially because of the current productivity gap between the coastal districts (the most vulnerable districts from the crop productivity point of view) and the high-productivity districts of the Northern areas.

Conservation and adaptation to increase the resilience of ecosystems: Human activities can affect the vulnerability of ecosystems to climate change. For example, in countries with poorly regulated fisheries activities (such as Bangladesh, Cambodia, India, Indonesia, the Philippines Sri Lanka, and Vietnam), the fisheries sectors are particularly vulnerable to the combined impacts of climate change and over exploitation (Hallegatte et al., 2015). This linkage means that in order to enable ecosystems to continue supporting livelihoods, non-climate stresses need to be reduced, which will in turn make them adapt better to climate change. Thus, reducing or avoiding land or forest degradation, depletion of natural resource stocks (e.g. fish), or soil and water pollution can increase the resilience of poor people to climate change by protecting the ecosystems upon which their livelihoods depend.

Targeted measures to foster ecosystem based adaptation: There are critical ways to help ecosystems and poor people better prepare for climate change. They seek to strengthen ecosystem processes and services, as well as the human systems that maintain them, in order to make them more resilient to climate change.

Land-mitigation policies to benefit local incomes: Land-mitigation policies can be designed to avoid or at least minimize harmful impacts on agricultural production and food security and poor people. Careful land use planning such as using designated degraded or less-productive areas for storing and sequestrating carbon stocks - could minimize negative impacts on food production and even result in more productive landscapes. For example, African farmers that have adopted evergreen agriculture have reported yield increases of up to 30% (Hallegatte et al., 2015).

8.4.4 *Future Agriculture Policies and Approaches for Sustaining Food Security and Nutrition*

Notwithstanding past progress and ongoing measures, several additional initiatives are necessary to cope with the growing risk of climate change for agriculture, food security, and nutrition. Four strategic approaches are associated with addressing climate change impacts in agriculture:

1. Coping with Uncertainty in Developing Responses: There is still considerable uncertainty about the scale and eventual nature of adaptation needed to address climate change. Adaptations to climate change can be thought of as incremental changes to existing systems or more systemic changes that bring new components to (or remove old components from) systems, often with the goal of increasing diversification and hedging against new, unknown risks. These are part of a spectrum of levels of adaptation to climate changes. Transformational change in agriculture is not new: the planting of biofuel crops instead of food crops, the replacement of subsistence-based agriculture with modern, science-based agriculture, or migration in the face of extreme drought being a few examples among many. Therefore, an Adaptive Delta Madanagement approach has been adopted in BDP 2100 (section 5.2).

2. Sustainably Intensifying Agricultural Production Systems: A key defining principle for agricultural technologies and innovations to support food and nutrition security, as well as poverty reduction, is the need for sustainable agricultural intensification that could take on several approaches (Thornton and Lipper 2014):

- Although the causes of hunger and malnutrition are various and not a simple challenge of increasing supply, some increases in food output will be needed in coming years as populations grow and diets change.
- Increased production will need to be achieved mostly without bringing new land into agriculture. In many cases no land is available for agricultural expansion; furthermore, in the context of climate change, land-use conversion to agriculture is a major source of emissions (as well as loss of biodiversity).
- Increasing the stability of agricultural production systems requires much greater attention to building ecosystem services that increase resilience.
- Improving the efficiency of agricultural production systems, increasing sequestration, and reducing wastes are not only important forms of mitigation, they may also generate higher and more stable returns from farming investments.
- If yields are to increase sustainably, one needs to harness and develop the knowledge and insights gained from all current systems of agricultural production, including those based on organic principles, local indigenous knowledge, and innovative plant-breeding technologies.

3. Increasing Resilience of Agricultural Production Systems: The overall efficiency and resilience of crop and livestock production systems in the face of climate change can be enhanced through improving various components as follows:

- Appropriate soil and nutrient management, through composting manure and crop residues, more precise matching of nutrients with plant needs, controlled-release and deep-placement technologies, and using legumes for natural nitrogen fixation, can increase yields and resilience of crops, while reducing the need for often costly and inaccessible synthetic fertilizers (with the co-benefit of reducing the GHG emissions associated with their use) (Thornton and Lipper 2014).

- In situations with decreasing rainfall and increasing rainfall variability, there are many ways of improving water harvesting and retention (through the use of pools, dams, pits, retaining ridges, increasing soil organic matter to heighten the water retention capacity of soils) and water-use efficiency (irrigation systems).
- Climate change is already altering the distribution and intensity of weeds and animal and plant pests and diseases. There are considerable gaps in knowledge of systems interactions in relation to weeds, pests, and diseases, and increased understanding will lead to better ways to manage them in a changing climate.

4. Diversification in agricultural output and livelihoods: Agricultural diversification occurs when more species, plant varieties, or animal breeds are added to a given farm or farming community. It includes landscape diversification-different crops and cropping systems interspersed in space and time. Livelihood diversification implies that farming households are involved in different (nonagricultural) activities, for instance, by taking up a job in the city, setting up a shop, or starting to process farm products. Both agricultural and nonagricultural forms of diversification may be relevant for climate risk management, although the emphasis here is on agricultural diversification. Climate-related shocks, such as heat waves, frost, excessive rain or floods, or drought spells, have different and sometimes even opposite effects on different farming system components or economic activities. Diversification is an important element of climate change adaptation. Diversification can potentially reduce the impact of weather events on income, and it can also provide farmers with a broader range of options to address future change. Given the potential benefits, diversification is often recommended as a risk management strategy.

The Policy Priorities for the Future

Going forward, it is critical for policymakers to recognize that the future climate poses challenges outside historical experience. Building and improving adaptive capacity and taking technical and non-technical adaptation actions in key climate-sensitive sectors such as agriculture must be an urgent priority for Bangladesh. There is also the need for making strong efforts in taking adaptation actions in key related sectors including water resources, forestry, coastal and marine resources.

In the agriculture sector, the priority is to strengthen local adaptive capacity by providing public goods and services, such as better climate information, research and development on heat-resistant crop varieties and other techniques, early warning systems, and efficient irrigation systems; and explore innovative risk-sharing instruments such as index-based insurance schemes.

In water resources, the priority is to scale up existing good practices of water conservation and management, and apply more widely integrated water management, including flood control and prevention schemes, flood early warning systems, irrigation improvement, and demand- side management.

In the forestry sector, the priority is to implement effective public-private partnerships for reforestation and afforestation.

In the coastal and marine resources sector, the priority is to implement integrated coastal zone management plans, including mangrove conservation and plantation.

There exist "win-win" measures that address climate change and are also good sustainable development practices. The Government has a vital role to play in providing incentives and an effective policy framework for individuals and firms to adapt to climate change and to enhance their adaptive capacity.

There remains a need for enhancing policy and planning coordination across Ministries and different levels of government for climate change adaptation. There is also a need for adopting a more holistic approach to building the adaptive capacity of vulnerable groups and localities (e.g. in Coastal Zone Hotspot) to build their resilience to shocks, including developing their capability to diversify local economies, livelihoods, and coping strategies.

Livelihood protection in ecologically fragile areas

Strategies will be needed to help people in ecologically fragile regions to become climate resilient and ensure their economic and social well-being. Climate related disasters may destroy people's homes, and incomes and employment. Affected regions are likely to include the Coastal Zone, river chars, hilly areas (e.g. the Chattogram Hill Tracts) and inland wetland areas. The government needs to adopt a comprehensive and participatory planning and investment for climate resilience against reduction in income, employment and human health in coastal, char, hilly and wetland regions.

Livelihood protection of vulnerable socio-economic groups (agro-related)

Fisherman families, who will be affected by changes in freshwater and marine ecosystems; poor farmers, who will be at greater risk from crop failure will need special attention to protect them from income losses due to climate change. Therefore, a comprehensive and participatory planning and investment to protect the livelihoods (income, employment, health) of groups who will be especially severely impacted by climate change (e.g. marginal and small farmers, fishermen particularly those fisheries in estuaries and the seas) is necessary.

Monitoring of ecosystem and biodiversity changes and their impacts

Mangrove ecosystems which are already under serious stress will suffer heavily due to further increases in salinity. These could alter the entire ecosystem of the Sundarbans and cause the extinction of some species. Following actions are necessary:

- Set up a well-designed monitoring system to evaluate changes in ecosystem and biodiversity
- Develop participatory monitoring systems by involving local trained people
- Report changes in ecosystems and biodiversity and asses the implications

Lower emissions from agricultural land

Wet agricultural land produces methane (CH_4). Nitrogenous (N_2) fertilizers also contribute to the accumulation of methane. A major reason for methane emissions is that rice fields are kept continuously flooded, which scientists now say is unnecessary. A programme that aims to lower emissions through improved cropland management would include:

- Research and on-farm trials of new water management technology on crop land (including rice)
- Agricultural extension service for new water management techniques for rice production

Afforestation and reforestation

The afforestation and reforestation of degraded land contributes to food security by providing fruits and other edible products; energy security by providing fuel wood; livelihood security by employing people in forest plantations; harvesting and trade in forest products; and can protect land from soil erosion and landsides, particularly in hilly areas. Much of Government owned reserve forest land is largely without trees. Following actions are necessary:

- Provide support to existing and new coastal afforestation programmes taking into account the future rise in salinity levels due to sea level rise
- Develop a wetland afforestation programme to protect settlements against wave erosion
- Study the scope for carbon credits under REDD and invest in reforestation of degraded forests
- Provide support to existing and new homestead and social forestry programmes.
- Research on the suitability of various tree species for their carbon-locking properties for designing various forestry programmes.

Devise longer term adaptation mechanism against impacts of climate change and particularly of sea level rise on food security

Given the key challenges, approaches and actions for sustaining food security over a longer time frame require a different direction. Traditional food security approaches have to be gradually replaced by strategic needs of the future developed Bangladesh. The assumptions are:

- Bangladesh population peaks at 200 million in 2050 and then declines to 170 million in 2100, as projected.
- Rural urban divide will almost be non-existent.
- As aspired, per capita annual income of Bangladesh will need to grow from US$ 1,465 to 12,736 (high income economies) or more, thus enhancing per capita purchasing power.
- Rice will not be the only major food item.
- Sea food, as in developed countries, will be increasingly popular in daily diet.
- The concept of quantity of food intake will be replaced by quantity and quality of nutrition intake.
- Obesity itself is malnutrition and also will be one of major medical issues in the future.
- Bangladesh, as one of major climate related disaster prone country, needs to maintain reserve stock of food basket.

Proposed measures are:

- Implement climate smart agriculture;
- Expand cropped area with saline tolerant varieties for coastal area;
- Investigate into enhancement of productivity of traditional floating agriculture;
- Prevent SLR from affecting agricultural land by constructing heightened sea dykes.

Improved Delta Management including conjunctive use of surface and groundwater

BDP 2100is a long term plan to introduce ADM in Bangladesh through a number of strategies for flood risk management and freshwater, among other strategies. BDP 2100 is, thus, a water-centric, economic development plan.

Proposed measures are:

- Augmentation of surface water for irrigation through development of water reservoirs, recharge groundwater, and reduced use of groundwater. Key priority investment activities include:

(i) the development of small scale surface irrigation in the southern part of the country requiring new infrastructure and capacity building;

(ii) partially reduce reliance on deep well irrigation in the northern part of the country, reduce costs and mitigate the risk of depleting groundwater;

(iii) rehabilitate dykes and embankments particularly affected by previous cyclones to protect vulnerable households and production base against sea intrusion in the extreme south,

(iv) improved drainage, saline intrusion control and flood management; and

(vi) increasing river water flow towards the south, in particular involving major river dredging effort.

- Use water saving technology for improving efficiency of water and install facilities to reduce distribution losses. Activities include: reduce water losses in existing schemes through improved water management (capacity building of water management cooperatives); development of water saving techniques such as drip irrigation, buried pipe irrigation, 'fertigation'; or rehabilitation of existing schemes.
- Reduce impact of saline water intrusion in the south and enhance river water flow. The focused activities that emerged from the BDP 2100 consultations are: rehabilitation of polders and their management; dredging of rivers; enhanced surface water irrigation; and improved brackish water resource management practices.

Prevent encroachment of agricultural and forest lands from expanding urbanization

The UN (2004) projection for urban population of Bangladesh for 2030 was 86.5 million. Urban population would possibly cross the 50% mark by 2040 and the 60% mark by the year 2050 when the total urban population would rise above 100 million. Current urban population, 42 million, already poses a huge challenge. Indeed, the whole of Bangladesh is likely to transform itself into an urbanized country, only half of present land may remain for agriculture. In order to sustain food security from existing agricultural land, there is no alternative to improved land management and land zoning.

Proposed measures are:

- Promote Compact Township to reduce substitution of agricultural land for non-agricultural purposes.
- Improvement of land information, land administration and management: Bangladesh has a very high population density. Scarce land and the rapid increase of population of the country are creating high pressure over land-man ratio. As a result, it results in unplanned land development throughout the country. Therefore, it is important to establish a compatible land administration and management system for establishing a systematic approach for planned land development. This has already been outlined in **Chapter 7**.
- Land Zoning effort should be continued with strong enforcement. It is already evident that agricultural land once lost to urban development cannot be recovered.

Emphasis on enhancement of Blue Economy

The 7th FYP (2016-2020) emphasizes on the prospect of 'blue economy' (GoB 2015) as: Blue economy concept has ushered in a new horizon for economic development. The norms of Blue economy lend significant contribution towards eradication of poverty, contributing to food and nutrition security, and generation of sustainable and inclusive livelihoods.

Marine fisheries is an important component of the blue economy. As mentioned before, share of marine fisheries in the fisheries sector has increased from 11% in FY1973 to 17% in FY2014. Potentials are immense. There are 475 species of fish found in the EEZ compared to 250 species on land. Fish provides the much needed protein needs of the population. Hilsa (Tenualosa ilisha) is the largest and single most valuable species with annual catch of 340,000 MT, and generates employment and income for 2.5 million people valued at US$ 1.3 billion per year (BoBLME 2012, Hossain et al. 2014).

Bangladesh lacks almost no capabilities of catching demersal fishes below 50 m depth of water. Long lines fisheries are totally absent in deep waters. Harvesting of Maximum Sustainable Yield (MSY) of marine fishes is seen as a major element to sustain food security. It is true that marine fishes are not popular in Bangladesh. A national programme needs to be taken to popularise marine fish as part of the normal diet. This will also contribute to nutrition security.

Proposed measures are:

Marine fisheries

- Procurement of modern survey vessels
- Capacity building in survey works (science and techniques)
- Regional collaboration (BoBLME, FAO, India)
- Stock and maximum sustainable yield/total allowable catch (quota) must be determined thorough assessments on a regular basis.
- Digital Marine Fisheries Resource Mapping for the marine waters using digital cartography of the marine fisheries resources is an essential tool for efficient and sustainable harvesting of the marine resources. However, in all SAARC countries this is either absent or not in a state of art position. If a common DMFRM can be developed for the SAARC countries, that will be very useful to all the countries and at the same time will save the required investment in this respect.

Shallow and deep sea fishing

- Issue licenses for long line fisheries;
- Financial credit line to private sector, tax incentives;
- Introduction of Vessal Tracking and Monitoring System (VTMS);
- Capacity building in deep sea fisheries;
- Seek FDIs in building deep sea fisheries fleet;
- Simultaneous development of fish landing and processing facilities.

Fisheries in international waters

- Joint collaboration with regional and international countries
- Creation of 100% export oriented market mechanism.

Coastal aquaculture and mariculture

- Local capacity building;
- Small scale investment support;

Maintaining biodiversity to ensure long term fish availability

- Protecting and managing the fisheries for the present and the future generations
- Establish MPAs (marine protected areas) as breeding grounds
- Enforce ban on fisheries during breeding season
- Continue further research and study

Promote food diversification catering to the needs of a developed economy

Bangladesh's consumer class is swelling and dispersing. Although only some 7% of the country's current population can be classified as middle income or affluent, compared with 38% in Indonesia, this will account for around 17% of the population by 2025. Although the number of middle-class and affluent consumers (MAC) in Bangladesh remains small compared with those of other big emerging markets in Asia, Bangladesh is one of the fastest-growing markets worldwide. It is projected that, each year for the next decade, the annual income of around 2 million additional Bangladeshis will reach US$ 5,000 or more.

Affluent families tend to eat more meat and fish as well as dairy products, but less rice and cereal. Changed consumption basket will have implications on national food security situation.

Bangladesh, being a developing nation, still sees rampant 'childhood under-nutrition', especially amongst lower income classes. However, over the past few decades, there has also been a steep rise in childhood obesity and overweight complications, leading to a serious double burden of malnutrition. Childhood obesity is prevalent disproportionately among urban affluent families in Bangladesh; with higher incomes leading to greater purchasing power enabling children of these families to indulge in junk and calorie dense foods and live relaxed lifestyles, making them highly vulnerable to obesity and its associated risks and dangers. The ever dwindling playgrounds in urban areas, further exacerbates the problem. A survey conducted by the Centre for Control of Chronic Diseases of the ICDDR,B with support from the National Nutrition Services of Institute of Public-Health Nutrition says 10 out of every 100 children living in Bangladesh's urban areas, aged 5-18 are overweight, while 4% are obese (Abedin, 2015).

While reduction of poverty still remains the main focus, attention needs to be gradually given to cater to the needs of the growing MACs.

Proposed measures are:

- Emphasis on meat and milk production.
- Emphasis on improved marine fisheries and especially deep sea fishing
- Promotion of marine fish products among MACs;
- Promotion of existing 'Balanced Diet Guidelines';
- Promotion of conservation of small indigenous species viz. establishing fish sanctuary and culture of those species as well.

Support research and innovations

To sustain food and nutrition security, to meet challenges of growing population in reducing agricultural land situation, on-going mechanization and commercialization of agriculture will not be adequate. The emphasis should be more on tomorrow's technology. The Bangladesh Agricultural Research Council (BARC) and its network of research institutes should aim for tomorrow's technology. Many countries are adopting these. Some of them are described below in brief.

Vertical and/or floating farms: These condense the enormous resources and land area required for traditional farming into a single vertical structure, with crops being stacked on top of each other like the floors of a building. Singapore opened the world's first commercial vertical farm in 2012.

A major advantage of vertical farming is its sustainability. Most structures are primarily powered on site, using a combination of solar panels and wind turbines. Glass panels coated in titanium oxide cover the buildings, protecting the plants inside from any outside pollution or contaminants. These are also designed in accordance with the floor plan to maximise natural light. Any other necessary light can be provided artificially. The crops themselves are usually grown through hydroponics and aeroponics, substantially reducing the amount of space, soil, water and fertiliser required. Vertical and/or floating farms can be piloted near Gazipur or in chars of the Meghna River.

Specialised LED lighting to optimise photosynthesis: Sharp is growing strawberries in Dubai, while SONY, Toshiba and Fujitsu are all utilising former clean-room facilities at semiconductor plants across Japan for lettuce (Mcclelland, 2015). This no-wash, no-soil greens are cultivated by means of hydroponics and grown at more than twice the speed of normal field production using specialised LED lighting to optimise photosynthesis.

Aquaponics brings together fish and plant farming in one recirculating system (Mcclelland 2015). Vegetables and fish are grown together without chemicals or pesticides. The fish wastes provide nutrition to the plants, which in turn clean the water, allowing the water to be used for the fish again. This process can have considerable water savings compared to traditional horticulture farming.

Nanotechnology: while the food industry can be seen to be clearly benefiting from nanotechnology (in particular for food processing, distribution, packaging and functional food), its real contribution to the agricultural sector is still uncertain. Nanomaterials in agriculture aims in particular to reduce the amount of sprayed chemical products by smart delivery of active ingredients, minimise nutrient losses in fertilisation and increase yields through optimised water and nutrient management (Parisietal, 2014). Nanotechnology derived devices are also being explored in the field of plant breeding and genetic transformation.

8.5 Special Considerations for Agriculture and Rural Livelihoods by Hotspots

Chapter 1 identified the 6 hotspots that share broadly common hydrological and climate change pattern and risks. Many of the risks faced by agriculture are common to all hotspots. These include the risks from ecological imbalances; the risks to rice production; the risks to fisheries sector; and the risks to forestry resources. The magnitude of these risks, however, varies by regions. The strategies for sustainable agriculture as well as food and nutrition security from the supply side are similarly mostly applicable nationwide, with variations in investments and technology applications to address any unique risks in specific hotspots. These hotspot-specific special considerations for agriculture as well as food and nutrition security strategies are briefly noted in this section to supplement the national agricultural strategy discussed in previous sections.

Depending on location, the poorest in many of the districts of these hotspot regions will be directly affected by impacts on ecosystems. Poor consumers are highly vulnerable to food price hikes because they are net consumers and spend a large portion of their household budget on food. The poorest people will also be directly affected by climate change through its impacts on livelihood activities and subsistence needs. Many poor rural households depend on access to ecosystems.

They use them to produce or extract goods for self-consumption (like crops, timber, and fish) and to smooth income shocks (Hallegatte et al., 2015). *Rice Production:* Rice is a common crop for all hotspot areas. A large part of the natural hazard vulnerability of agriculture depends upon the adverse effects on rice production. **Table 8.17** provides a summary of rice production (Aus+Aman+Boro) for the most recent year for which district level data was available.

The data reveals that River Systems and Estuaries along with the Barind and Drought prone areas make up the predominant rice basket of the country, in terms of acreage under production, yield, and output. Not surprisingly, the floodplains of Bangladesh, which are spread all around the country along the river systems and estuaries and are the main beneficiaries of regular alluvial deposits, turn out to be the most productive region for food (8.8 million tonnes in 2013-14). The high productivity in the Barind and Drought Prone Areas reflects the spread of mechanized groundwater based irrigation. As a result, it is now also the most productive areas of the country, in terms of yield (3.3 tonnes/ha) and output (8.0 million tonnes). On the other hand, the Coastal Zone has low productivity owing to salinity problems. The aggregation, however, hides the productivity differentials by Districts. At the district level, rice productivity ranges from a low of 0.72 tonnes/acre for Patuakhali to 1.5 tonnes per acre in Naogaon.

Table 8.17: Rice Production by Hotspots 2013-2014

Hotspots	Area		Yield		Production (million tonne)
	Acres (million)	Hectare (million)	Per Acre (tonnes)	Per Hectare (tonnes)	
Haor and Flash Flood Areas	3.42	1.38	1.27	3.15	4.35
Coastal Zone	5.48	2.22	1.02	2.53	5.61
Chattogram Hill Tracts	0.21	0.08	1.11	2.91	0.23
Urban Areas	2.83	1.14	1.14	2.83	3.23
Barind and Drought Prone Areas	5.99	2.43	1.33	3.28	7.96
River Systems & Estuaries	6.93	2.81	1.27	3.14	8.82
RHF	3.25	1.31	1.28	3.18	4.16
Bangladesh	28.11	11.37	1.22	3.02	34.36

Source: BBS, 2015

Fisheries: **Table 8.18** presents a summary of fisheries production (2.2 million tonnes in 2013-14) across the various Delta Hotspots. Except for urban areas and CHT, fish is a major source of economic activity in the other 4 hotspot areas. The Coastal Zone accounts for some 35% of total fish production followed closely by the river systems and estuaries zone (34.1%). Most of the shrimp production (98%) happens in the Coastal Zone.

Table 8.18: Fisheries Production by Hotspots 2013-14 (tonnes)

Hotspots	River	Beel	Floodplain	Pond	Seasonal cultured water body	Shrimp Farm	Other	Total	Share (%)
Haor and Flash Flood Areas	4,153	42,682	17,4121	95,059	12,157	5	1,249	329,426	15.2
Coastal Zone	92,345	2,050	131,057	294,866	46,393	169,270	19,901	755,882	35.0

Hotspots	River	Beel	Floodplain	Pond	Seasonal cultured water body	Shrimp Farm	Other	Total	Share (%)
Chattogram Hill Tracts	222	94	136	5,192	72	14	8,181	13,911	0.6
Barind and Drought Prone Areas	6,648	10,882	89,470	202,210	13,467	30	2,079	324,786	15.0
River Systems & Estuaries	32,167	13,221	210,183	395,864	76,233	3,392	7,015	738,075	34.1
Total	***135,535***	***68,929***	***604,967***	***993,191***	***148,322***	***172,711***	***38,425***	***2,162,080***	***100.0***

Source: BDP 2100 Estimates (GED 2015) based on BBS data

Forestry: In Bangladesh, the forests are distributed on the eastern hills, central and north western terraces and the mangroves facing the Bay of Bengal. Thus concentration of forest cover is to be found in the Coastal Zone and Chattogram Hill Tracts, with modest spread in the Haor and Flash Flood Areas of Sylhet.

Forests provide immense services to agriculture and livelihoods through protection from storm surges, stability of environment, reduction of earthquake damages, and development of healthy microclimate, watershed management and eco-tourism. The products from forest lands are of various types such as timber, fuel wood, poles, bamboo, cane, thatch leaves, fish, honey, wax, etc. Wood production from forests has declined considerably since 1972 due to over-exploitation. Over 15.4 million households in about 88,000 villages across the country possess a huge quantity of tree growth and this is the major supplier of wood for the nation. Yearly wood production from government forests is low at about 0.5-2.5 m^3/ha; whereas in homestead forests it is 7-9m^3/ha. About 70% of round wood and 80% of bamboo come from privately-owned village grooves.

8.5.1 Haor and Flash Flood Areas Agriculture

As noted in **Chapter 2**, total population of Haor and flash flood area is 15 million (10% of the national population). The primary occupation of the population is farming and fishing. As such, the population is highly vulnerable to natural hazards and climate change factors of the haor and flash flood areas. The poverty impact of this dependence to vulnerable agriculture is partly moderated by the high inflow of foreign remittances. Haor Hotspot area (1.657 mill ha) comprises a vital resource for fisheries, irrigation water, ecosystem functioning and navigation. A total of 1.31 million ha is under agricultural production, producing 4.35 million tonnes of rice per annum and an estimated 0.329 million tonne of fish from the Haor areas. In terms of national share, the Haor areas produce about 13% of the rice production and 15% of the fishing output.

Major Constraints in Haor and flash flood areas

- Degradation of natural resources and biodiversity
- Underdeveloped physical and social infrastructure
- Crop damage by flash floods
- Declining crop productivity
- Poor market linkage and value addition

The impact of flash flooding is reflected in average rice productivity by the Haor districts (**Figure 8.8**). The rice productivity is calculated as an average for two fiscal years FY10 and FY11. These years were normal years from the weather and climate change perspective. Impact of normal flash flooding is built in the yields per acre. Even within the Haor districts, the yield per acre is dramatically different by districts, ranging from a very low of 0.91 tonnes/acre for Sylhet to a high of 1.5 tonnes/acre for Kishoreganj. More generally the major brunt of the Haor flash flooding falls on the four districts of the Sylhet Division, especially Sunamganj, Habiganj and Sylhet Districts. The Sylhet district agriculture also suffers from the impacts of river erosion.

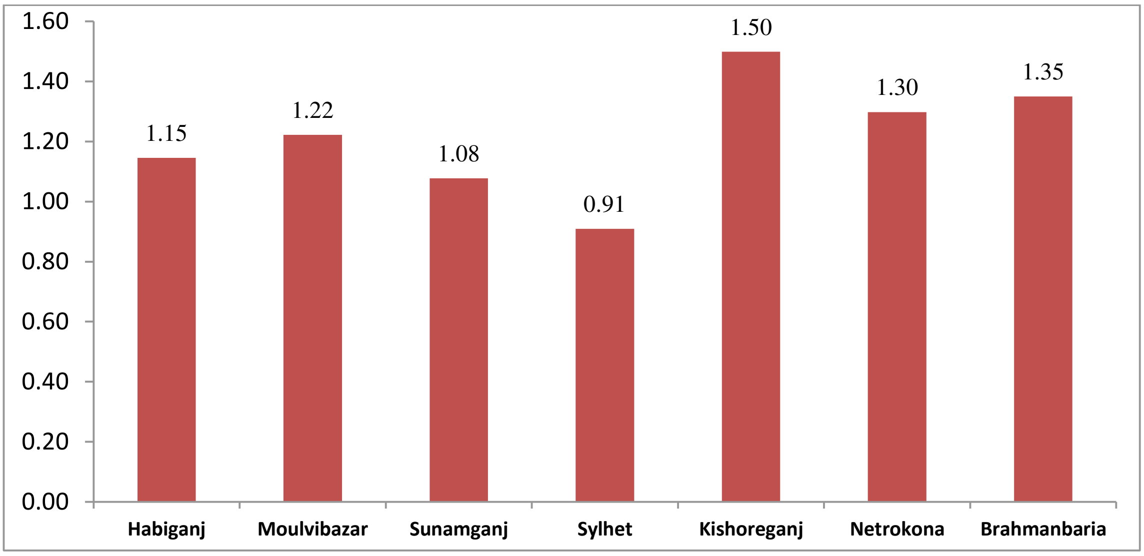


Figure 8.8: Haor Districts Average Rice Yield FY2010-FY2011 (tonnes/acre)

Source: BBS, 2011

Strategies for Development of Agriculture in the Haor and flash flood areas

The basic problem for agriculture in the Haor and flash flood areas emerges from flash flooding that must be addressed at the source to avoid the losses to crop production. The detailed strategies for addressing the water and climate related concerns in the Haor areas were discussed in **Chapter 3** (Climate Change, Envrionment and Ecology Issues) and **Chapter 4** (National and Transboundary Water Management). In terms of priority, policy attention needs to be specifically focused on agriculture issues in Sylhet, Sunamganj and Habiganj Districts. For the Haor and flash flood areas as a whole, the main strategic priorities are:

- Improved water and disaster management
- Agricultural development for food security
- Biodiversity enhancement and wetland management
- Social safety nets and improvement of living conditions
- Improved physical infrastructure, and
- Specialized enterprise and technology development for alternative sources of rural livelihood including eco-tourism based on wetland development, development of river transport, small environmental friendly manufacturing enterprises, and strengthening of forestry resources.
- Quick growing suitable varieties of vegetables, mustard, chickpea, kheshari seed to be made available before Boro rice varieties are transplanted where late Aman plantation is not feasible.
- Construction of buffer stock silos to be made in the areas encouraging private sectors.

- Mechanization for quick land preparation, planting, harvesting, seed drying and processing need to be promoted by the agricultural extension services.
- Plant breeding programme need to be encouraged crossing with the local varieties like kasalath, chengri, baorash, dumain for development of short duration quick maturing Boro rice varieties which would help cope with the flash floods.
- Strengthening of climate smart fish culture technology dissemination and social safety net programmes for the fishers in the haor areas.

8.5.2 *Coastal Zone Agriculture*

As noted earlier, the Coastal Zone has generally been identified as disadvantaged in terms of frequent extreme events; poverty, food insecurity, environmental vulnerability, and limited livelihood opportunities. This region covers nearly one third of Bangladesh land mass and is home to one-fifth of the population. Agriculture is by far the main economic activity in this region making the most significant contribution to output, employment, and income of inhabitants. Some 15% of total cultivable land is either fallow and/or not under productive use. Major physical factors responsible for land being not used intensively are soil salinity, water salinity, subsidence and water logging.

Historically, the Government has responded by providing protection against sea water encroachment through polder based embankments. The polders of the Coastal Zone are badly in need of maintenance and facing the following problems:

- ***Siltation*:** Due to empoldering, natural inundation outside the polders has been obstructed by embankments resulting in higher elevation of land outside the polder and no siltation inside.
- ***Drainage*:** Because of siltation of outfall channels, channels within polders have significantly lost drainage capability resulting in water logging. The problem has been compounded by siltation of internal drainage channels.
- ***Water logging*:** Because of land accretion, particularly in the Meghna estuary, many rivers and *canals* (drainage canals) have been silted up. Onrush of upstream flow and prolonged rainfall often cause water logging. This problem has been aggravated by empoldering.
- ***Salinity*:** Though soil salinity declines in the long run because of empoldering, problem recurs because of erosion and embankment failure (breaches or overtopping by storm surge).
- ***Land use conflict*:** Shrimp farmers bring saline water inside the polder by cutting embankments or using Low Lift Pump (LLP). This affects salinity balance inside the polder and causes damage to crops in surrounding fields. Competing land use often results in confrontation and violence and thereby affects the social fabric. Polders have not been designed for the multi-functional land use and the BWDB has no mechanism for dealing with land use conflicts.

Vulnerability of Polders

- Many polders are in dilapidated condition in terms of breach and slip in the embankment, erosion, neglect in repair works, drainage congestion because of siltation and encroachment of canals and, above all, location in the risk zone.
- Water control structures in many places are damaged or non-functional.

- BWDB has categorized that out of 139 polders 51 are “most vulnerable” and another 55 polders as “medium vulnerable”. To cope with vulnerability, it is necessary to rehabilitate damaged infrastructures of the polders

Major Constraints of Coastal Zone Agriculture

- Extreme environmental events and high vulnerability to climate change
- Low agricultural productivity, poor land use and low cropping intensity
- Low productivity of Rabi crops and little cultivation of high value crops
- Predominance of small and landless farmers
- Intrusion of saline water, water logging and occasional breaches of embankment

The impact of these risks and vulnerabilities on agricultural production is massive. Historically, the coastal belt was a major bread-basket of Bangladesh. Even as late as FY79, the coastal belt accounted for 22% of the total rice production in Bangladesh (**Figure 8.9**). The share fell to 16% in 2013-14, which is a normal year in terms of weather pattern and climate change impact. Much of the impact happens from salinity intrusion and water logging.

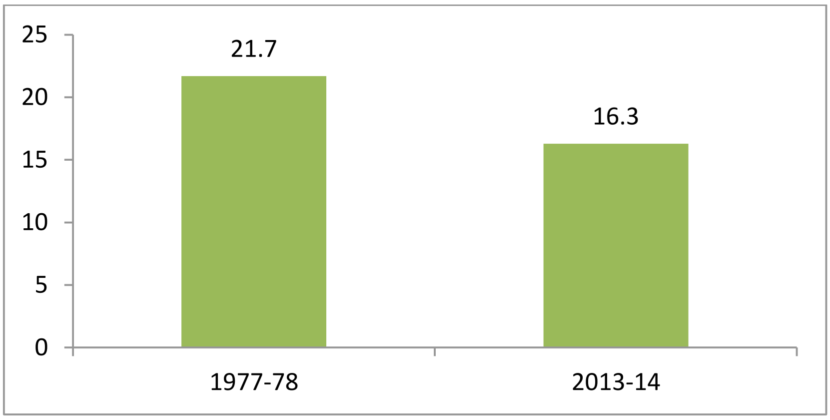


Figure 8.9: Share of Coastal Zone Hotspot Rice Production (% of National)

Source: BBS, 2015

The effects of salinity and water-logging on rice productivity in the Coastal Zone are illustrated in **Figure 8.10**. Rice productivity is measured as an average of FY10 and FY11, both normal years for rice production. With the exceptions of Cox’s Bazar, Jashore and Feni, rice productivity is lower than the national average for all other coastal districts. The lowest productivity is seen in Patuakhali at only 0.72 tonnes/acre. This is 40% lower than the national average of 1.22 tonnes/acre and a whopping 55% lower than the highest productivity observed in Naogaon (1.59 tonnes/acre). In general, agriculture of all coastal districts of the Barishal Division is very vulnerable to natural hazard risks owing to their coastal location. As such, they show very low productivity per acre of rice.

Strategies for Development of Agriculture of Coastal Zone

The protection of agriculture in the coastal belt is of highest policy priority in the field of agriculture. The water-related strategies and priorities for the Coastal Zone were discussed in detail in **Chapter 6**. The need to strengthen and modernize the polder technology and improve its maintenance needs special attention. The sound implementation of those strategies and programmes will be important to protect agriculture as well as human welfare in the coastal belt. Additionally better farm technology is needed to adapt agriculture to the peculiarities of the coastal belt, especially to adapt to the salinity problem. Diversification away from agriculture towards other more sustainable and higher value-added activities like eco-tourism, strengthening of marine fisheries, development of ports, motels and resorts and spread of manufacturing sector activities are all important elements of protecting livelihoods in the coastal belt and stemming the flow of out-migration.

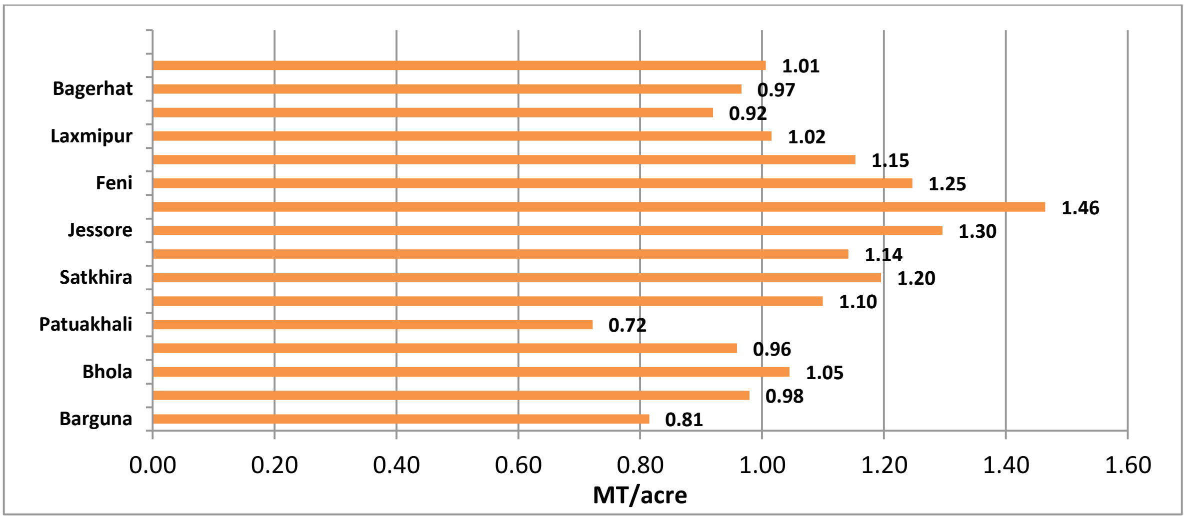


Figure 8.10: Average Rice Yield in the Coastal Zone Hotspot Districts (MT/acre)

Source: BBS, 2015

8.5.3 Chattogram Hill Tracts (CHT)

The CHT represents 9% of the landmass divided into three districts consisting of 25 Upazillas with one percent population of the country. According to the Population and Housing Census 2010, the CHT region has a total area of 13,295 km^2, 342,390 households and about 1.7 million people. Population density per km^2 is lower in the CHT (128) compared to Bangladesh (1,015). CHT is the home of a large number of small ethnic communities. The 7th FYP lists three CHT districts- Bandarban, Khagrachari and Rangamati, among the least developed districts (or most deprived districts) in Bangladesh.

Land has been a common access resource for local communities. They operate on land for agricultural purposes with customary rights obtained through an age-old traditional system. Majority of farms are of small size, less than one hectare each. Only seven percent of holdings are 'large' (being 3 ha or above). Small farms are more concentrated in Khagrachhari District, while medium and large farms are more prevalent in Bandarban and Rangamati.

The incidence of poverty is high in the CHT. About half of the population or more are poor. The income per household member in the CHT is about two thirds the income of rural Bangladesh and the percentage of main income earners that rely on manual labour, 43%, is almost twice as high as rural Bangladesh.

Land and Water: These are the two critical resources for sustaining agriculture productivity. In the CHT lands are at different elevations, Rangamati and Khagrachari are relatively low-lying. Land in Bandarban covers a wide range of elevation. Elevation is a key factor in determining crop suitability and seasonality based on agro-ecological considerations. Because of the predominance of hilly terrains with steep slopes, most of the land is not suitable for ‘plough agriculture’.

Large numbers of watersheds exist in the region. The main source of surface water is rainfall and accumulated waters in streams, *chharas*, and lakes. In total 659 watersheds have been delineated in the CHT. Khagrachhari District has been delineated into 119 watersheds. Rangamati has 273 watersheds, while Bandarban has 267 watersheds. Total length of *chharas* connected to the rivers and spreading over the CHT region is more than 7,200 km. These *chharas* are steep and so they cannot hold water for long. About 862 km of *canals* connected to *chharas* and rivers flow during the wet season.

Most of the rivers, *chharas* and *canals* dry up in the winter due to deforestation, non-scientific crop cultivation in the upland areas causing soil erosion and consequent siltation of the rivers, *chharas* and *canals*. The *Kaptai Lake* is also endangered due to siltation problem. The deforestation in all three districts is taking place at a very fast rate. Dense forest coverage has reduced by 61% in the last five years and the rate is also high for medium dense forests.

Major livelihoods practices are farming, fishing, livestock rearing and trading. Less than one-fifth of the total valley land area (270,812 ha) is currently under irrigation. Rice is the main crop grown in this Hotspot. Some HYV rice varieties are grown in the floodplains. Besides rice, maize, mustard, chili, winter vegetables and potato are also grown. Jhum is a prominent indigenous farming practice and 6.5% of the farmers depend on jhum farming system. The number of *jhum* farmers was 7,832 in 1980; it is now estimated at 22,413, although numbers have fallen recently. An average *jhum* cycle was 12-15 years to allow sufficient regeneration of natural resources during the interval. In 1961, after the construction of the *Kaptai Dam*, the *jhum* cycle was shortened to 3-5 years. At present the average is 2-3 years.

Main crops grown in the *jhum* are rice, maize, millet, sesame, cotton, cucumber, pumpkin, ash gourd, melon, chili cowpea, turmeric, flowers and medicinal herbs. Sugarcane, cotton, and tobacco are important cash crops in the CHT. Sugarcane cultivation has slowly increased because of market demand and the advent of HYV species. Tobacco cultivation is increasing and has made inroads in some of the remote areas. In some areas of CHT, tobacco is gradually being replaced by cotton. In the last five years, the area and production of cotton in the CHT region have increased.

Table 8.19: Cotton Production in CHT Areas

Year	Area (hectare)	Production (Bale)
2012-13	15,756	7,640
2013-14	16,643	8,047
2014-15	16,380	7,919
2015-16	16,810	8,068
2016-17	16,890	8,166

Source: Ministry of Agriculture (MoA), 2017

Horticulture is being popularized commercially in CHT mainly concentrated on the cultivation of banana, papaya, lemon, pineapple, mango, orange, cashew nut and jackfruit. However, a number of other fruit crops are grown in scattered areas. Farmers hardly follow recommendations on plant spacing, proper application of different fertilizers and other cultural practices. As a result, yields are relatively low and much of the potential remains unexploited.

Major Constraints of CHT

- Natural resource degradation – soil erosion and siltation of water bodies; reduced soil fertility; and biodiversity loss
- Weak provision of essential inputs and extension (seed, fertilizer, credit)
- Scarcity of adaptive research, on-farm trials and demonstrations, leading to low knowledge of CHT-specific conditions and absence of innovative practices.
- Limited access to markets, and opportunities for agro-processing
- Low productivity, and missed opportunities for diversification (and associated benefits to nutrition), due in part to poor access to improved inputs, and/or to new adapted technologies
- Poor technical capacity of stakeholders and a lack of technical coordination

Strategies for Development of Agriculture and Livelihoods of CHT

Enhancing productivity: Improved access to low lift pumps (LLP) for irrigation and the utilization of surface water should be the subject of a major investment programme, as it is in other areas of the country. A centre under the CHT Regional Council should be established for both in-situ and ex-situ conservation of genetic resources – this will require at least 100 ha of land with necessary laboratory and other physical facilities.
More sustainable adapted and improved jhum practices: Adopting such measures on a large scale will require local strategies, a major awareness raising campaign, and targeted skills development programmes such as specialist farmer field schools.

Up-scaling of technology and sustainable input supply: A programme of local adaptive research is needed, to build better bridges between research and local initiatives such as farmers field schools, supported by a network of extension staff, locally-based scientists and farmer field school facilitators. Programmes and incentives are needed to develop the agro-inputs sector.

Marketing and value chain development: HDC, LGED, DAM and AIS need to promote development of market infrastructure (market sheds, storage infrastructure, sanitary facilities, etc.) construction of link roads, improvement of transportation and market information systems. SME and household based agro-processing need to be promoted by CHTDB, HDC and BSCIC and line departments.

8.5.4 River Systems and Estuaries Hotspot

Major rivers, including the Ganges, the Brahmaputra-Jamuna, the Padma and the Meghna and their numerous tributaries and distributaries made Bangladesh a land of rivers, building the Bengal Delta, one of the largest of its kind. Though agricultural activity is mainly reliant on land resources for living and farming, it is dependent on river system for irrigation and drainage, and sweet water fisheries. A large number of rural people are dependent on rivers for their livelihood as fisherman, boatman and other business activities. Moreover, the river system also plays an important role as the source of water supply in the urban areas and the industrial sector is heavily dependent on the river for water and discharge of industrial waste. These rivers are an important means of transport and navigation facilitating intra-district movement of passengers and cargo.

The population of many of the Districts in River Systems and Estuaries Hotspot are highly vulnerable to river flooding and river erosion. Some of the poorest Districts are located in this region, including the poorest of the poor Kurigram District. Many of the poor including in Kurigram live on char land formed from river siltation. These char lands get inundated almost on a yearly basis during the monsoon season causing tremendous human sufferings. Agriculture is the main stay of the inhabitants and river flooding and erosion causes huge loss of crops, cattle, homestead and livelihood. Many of the River Systems and Estuaries Districts, especially in the northwest part, have poor infrastructure. They also have low access to international migration.

Strategies for Development of Agriculture and Livelihoods in River Systems and Estuaries

This is the Hotspot that may be described as the food basket of the country, as the region is responsible for producing nearly 8.8 million tonnes of rice (26% of total national production) and is the main source of fisheries supply of 0.738 million tonnes (34% of total national fish catch). High productivity will have to be maintained by proper water resource management, developing flood resistant and climate resilient varieties of cereals. The immediate policy challenge in this hotspot is to take safety measures against river flooding and river erosion while supporting the diversification of the economy to provide alternative employment opportunities. Improving river navigation and supporting fishing activities can provide important means of alternative livelihoods. The critical challenge for long term policy planning is to develop capacities and make adequate investment to protect and harness the riverine resources in order to augment agricultural production in a sustainable manner.

8.5.5 Barind and Drought Prone Areas

The Barind Tract of northwest Bangladesh is an area of low and erratic rainfall with limited surface water resources. Farmers in this Hotspot largely rely on rainfed cropping but face problems of late transplanting of *Aman*-season rice when the monsoon is delayed or low yields when drought sets in during the booting stage of the rice crop in October. Historically, this region has been afflicted with severe droughts in the off-monsoon period causing serious disruptions to agricultural activity and livelihoods. It has therefore been a priority to identify agricultural practices for the Barind that allow increased production in a marginal rainfall environment while at the same time improving the efficiency with which inputs, particularly labor, are used. To ensure that farmers have a productive Aman rice and Rabi system, research efforts have for some years focused on developing cost-effective ways of increasing productivity by opting for early-maturing drought-tolerant Aman rice cultivars and high-yielding disease-resistant Rabi crops such as chickpea.

The use of groundwater for irrigation of Boro rice in the Rabi season has been a major policy option contributing to a near threefold increase in rice production in Bangladesh since 1960. Since 1985, the Barind Multipurpose Development Authority (BMDA) has installed more than 5,000 deep tubewells, bringing 162,000 ha under irrigation across the entire Barind of Bangladesh. Attempts to increase the productivity of the Barind area therefore continue to focus on rainfed lands, but in recent times they have aimed to simultaneously improve the reliability and yield of Aman rice while increasing total system productivity by increasing the area planted to Rabi crops.

Part of the problem in the Barind area arises from the fact that Bangladesh is a lower riparian country of the Ganges- the Brahmaputra river systems. The presence of the Farakka Barrage and other dams or interventions upstream in India have persistently depleted water supplies during those months of the year when rainfall and flood waters are non-existent for meeting the demands of agriculture. The opposite is often the situation during the monsoons when excessive release of water flows from upstream barrages result in severe flooding in farm lands fed by the large river system and its tributaries. From all indications, climate change is expected to exacerbate problems by making the droughts and flooding more severe over time.

Agriculture of the Barind Tract and Drought Prone Areas

Historically, the variability in total rainfall, timing of onset, and cessation of the rain as well as occurrence of in-season drought periods in the Barind Tract meant that farmers must use a flexible, opportunistic approach to cropping decisions and experience considerable annual variation in production. Rice in the Aus season, either broadcast-seeded or transplanted on early pre-monsoon showers, is important for food security in September-October prior to harvest of the main aman crop. However, the Aus crop may experience drought in April to early June while in wet years seedlings can be damaged by premature flooding.

Prior to the introduction of groundwater irrigation, the major cropping pattern of the Barind Tract of northwest Bangladesh consisted of a single crop of transplanted rice. This was grown during the monsoon Aman season from June to October, when 80% of the 1,200 to 1,400 mm annual rainfall occurred. This was followed by most land lying fallow during the Aus season. Since 1985, BMDA's interventions have revolutionized rice production in the Barind and drought-prone Hotspot region. The impact of this irrigation strategy is illustrated in **Figure 8.11**. The combination of irrigation and adoption of HYV rice has also contributed to tremendous progress with rice productivity in the Barind area. The most productive rice is found in some of the dry zone Northwestern districts of Bangladesh including Naogaon, Dinajpur, Rangpur, Joypurhat, Panchagarh and Thakurgaon. Of particular mention is the productivity performance of Naogaon that averaged 1.59 tonnes/acre during FY2010-FY2011, which is the highest in the country and some 30% higher than the national average.

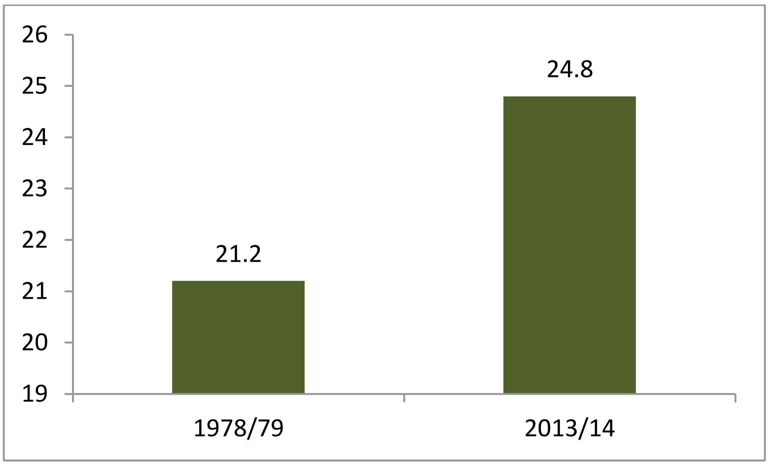


Figure 8.11: Share of Barind & Drought Prone Areas Hotspot Rice Production (% National)

Source: BBS, 2015

While there is much to celebrate the agricultural successes in the Barind and Drought Prone areas, there are important challenges. Agricultural productivity growth was made possible by the rapid adoption of groundwater mechanized tubewells under the Barind Multi-purpose Development Project. However, exploitation of groundwater has not been matched by recharge of the resource. Shortage of rainfall is a problem. Another problem in the Barind area arises from the fact that Bangladesh is a lower riparian country of the Ganges river basin.

Strategies for Sustainable Agriculture in the Barind and Drought Prone Areas

The biggest challenge is to address the winter water shortage problem by investing jointly with India on the Ganges River Basin Initiative. Other priorities are to invest in water reservoirs to enable groundwater recharge; to adopt new water-saving food crop technology and to reduce the reliance on winter Boro crop in favor of HYV Aman and fruit cultivation.

8.6 Concluding Remarks

Climate change impacts are already serious in Bangladesh and causing greater stress on vulnerable groups and lagging regions. Among main sectors, agriculture is likely to bear the main brunt of output losses. If the predictions are right, the worst is yet to come. By 2100, climate change could impose costs on the Bangladesh economy that could be significantly higher than the estimated global average loss. Bangladesh believes that combating climate change requires *global solutions* built on *principles of common but differentiated responsibility, and respective capacities*. Given high stakes for a poverty-stricken country, Bangladesh is already playing an important part in such global action.

The country has recognized climate change as a long term development challenge and has made significant efforts in adapting to climate change through its BCCSAP 2009 action plan as well as the 6th FYP and 7th FYP. However, more is needed to mainstream adaptation in development planning. While adaptation is a priority, Bangladesh should continue its efforts on mitigation by embracing practices of low carbon growth which brings considerable co-benefits. Adaptation and mitigation require a comprehensive policy framework, incentives for private sector action, elimination of market distortions, and ample financial resources which will have to be mobilized through multilateral and bilateral initiatives.

Chapter 9
Dynamizing the Inland Water Transport System of the Bangladesh Delta

Chapter 9 : Dynamizing the Inland Water Transport System of the Bangladesh Delta

9.1 Inland Water Transport Development Context

Bangladesh is crisscrossed by a network of about 24,000 km. of rivers, streams and canals, constituting 7% of the country's surface.[25] Being a land of rivers it always enjoyed the natural advantage of inland navigation. The country is characterized by low lying flat land with alluvial soil that have poor engineering characteristics resulting in very expensive costs for development and maintenance of overland transport infrastructure. On the contrary, Inland Waterway Transport (IWT) has always been a natural, environment friendly and relatively cheap mode of transport. Owing to a lack of proper planning, investment and policy attention, IWT has lost ground to land transport as it takes relatively longer time, but it is still an important means of transport for the rural population. An estimated 25% of the rural population has access to inland navigation. Inland waterways have continued to be important sometimes the only transportation mode not only for maintaining transport link between various remote parts of the country; it is a means of transporting export-import cargo as well. It provides cheaper transit of passengers and goods.

Despite being the cheapest mode of transport, the popularity of IWT as a mode of passenger and cargo transportation has been on declining. A World Bank Report[26] published in 2007 showed that the modal share of IWT registered a gradually declining trend during last few decades (**Figure 9.1**). Thus, the modal share of IWT fell from 16% passenger and 37% cargo in 1975 to 8% passenger and 16% cargo in 2005. Much of the competition came from the road transport system. This loss of ground of a low cost, environmental friendly means of transport to high-cost and environmentally taxing road transport system is unfortunate from the development and welfare point of view of Bangladesh. Road transport systems are not only environmentally unfriendly relative to IWT, the financial unit cost of service is higher. Importantly, they also add considerably to the already serious road network congestion.

Many factors have contributed to this declining role of IWT. Over a long period, many rivers of the country have been deteriorating both for natural, morphological processes and for withdrawal of water from the rivers beyond the border and within the country resulting in decreased dry season navigability. This was further aggravated by poor or no maintenance of navigability, weak regulations and safety standards, low allocation of budgetary funds and general under-investment by both public and private sectors.

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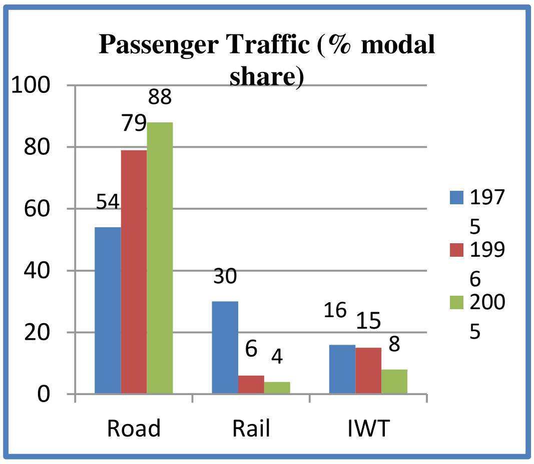
[25] Bangladesh has about 2835 kilometers of rail-way, 21,269 kilometers of paved road and roughly 6,000 kilometers of perennial and seasonal waterways (BBS 2014).

[26] *Revival of Inland Water Transport: Options and Strategies,* World Bank 2007.



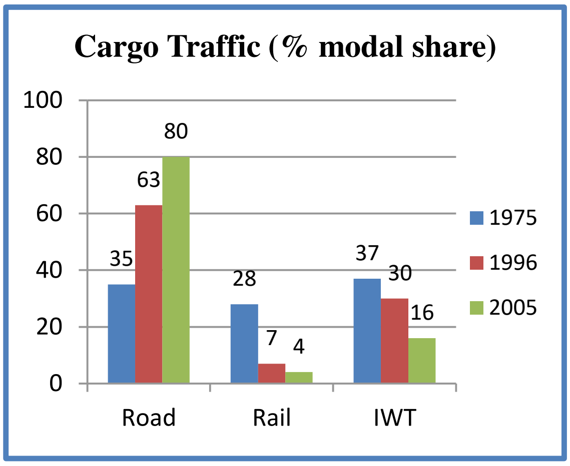


Figure 9.1: Modal Share of Passenger and Cargo Traffic

Source: World Bank, 2007

In recent years, given the rapid GDP growth and associated demand for passenger and cargo services along with constraints in developing road and railway transport (owing to land and financial scarcity), the prospects for inland waterway look brighter. There is now a growing appreciation that with proper investments, policies, regulations and institutional development the IWT can be a major low-cost transport alternative to the high-cost of land transport. The positive effects of this strategy for income, employment and poverty reduction are large.

Globally, inland waterway plays very critical role in handing large quantity of cargo and passengers. The Rhine and Danube, for instance, constitute two backbones of inland navigation in Europe. Both the networks are backed by strong institutions facilitating efficient waterway infrastructure and guided by required rules and regulation. The Mekong River is becoming an important link in international trade routes and tourism in Southeast Asia. China is a country with long water transportation tradition. The Yangtze is the first waterway in the world for the transport of goods. In the subcontinent water transport is one of the oldest means of transport in India. **Table 9.1** summarizes major inland waterway networks in Europe and Asia.

The geography of Bangladesh connects almost all 64 districts to each other by an inter-connected system of major and minor rivers. The major rivers in turn provide a convenient access to the sea. This massive network of water connectivity if properly harnessed and nurtured can provide a major development advantage for Bangladesh. With rapid economic growth, the urban and inter-city road transport bottlenecks are growing. The cost of transport for passengers and cargo are also growing. The government has responded by investing huge amount of resources in road network and bridges. The investment costs are large. Land procurement and managing the adverse environmental consequences of the large volume of road sector investment are both daunting tasks, often contributing to long delays in project completion. The focus on BDP 2100 presents a great opportunity to rethink the inter-modal transport strategy, especially when geography has presented a natural comparative advantage through the waterways. A better balancing between roads, railways and IWT can be a huge win-win for Bangladesh development.

The objective of this chapter is to contribute to this policy rethinking on inter-modal transport re-balancing and strategy. This chapter discusses and analyses a number of issues involving the country's inland water transportation system. By drawing from research on potential climate change impacts on the river system, the international evidence and best practice on managing riverine resources, it postulates strategies for dynamizing the river transport system of Bangladesh for the 21st century.

Table 9.1: Major Inland Waterway Networks in Europe and Asia

IW network and countries covered	Length, navigability and Traffic	Facts of importance	Inland navigation authority	Future focus/challenges
The Rhine - *Switzerland, Germany, France, Netherlands*	1,320 Km From Basel to Rotterdam (884km) About 330,000,000 tonnes/year	- The Rhine is used by more than two-thirds of all goods carried by inland waterway. -New markets are booming; these include the transport of containers, weight-intensive goods, chemicals and passengers.	The Central Commission for the navigation of the Rhine (CCNR) which was created in 1815 at the Congress of Vienna and has been empowered by the Mannheim Act (1868).	-Increase the focus on environmental sustainability -Increase the market share in Europe of inland navigation as transport mode -Ensure more seamless freight transport connections in Europe -Foster technology advancements
The Danube *-Germany, Austria, Hungary, Slovakia, Croatia, Serbia, Romania, Bulgaria, Moldova, Ukraine*	2,860 Km All along the Danube About 40,000,000 tonnes/year	-The Danube is the longest river in central Europe. -The Region has very wide disparities and the traffic has long been reduced owing to the cold war. The Danube River itself is a major TEN-T Corridor of the European Union and is concerned by many EU initiatives.	The Danube Commission which is an international intergovernmental organization established by the Convention regarding the regime of navigation on the Danube signed in Belgrade in 1948.	-Waste Management Issues -Underlines an integrated approach to sustainable development -Need for greater multimodality, -Better interconnection with other river basins modernizing and extending -Infrastructure in transport modes such as inland ports
The Mekong *China, Myanmar, Thailand, Lao PDR, Cambodia and Vietnam*	4,900km Seasonal variations in water (low water season sometimes 50% less traffic in upper Mekong). More than 3,000,000 tonnes/year	-The Mekong River is becoming an important link in international trade routes and tourism. -Recent efforts have been done to improve navigation 24h/year and new international navigation agreements have been settled between	-The Mekong River Commission (MRC) is an inter-governmental agency working directly with the governments of Cambodia, Lao PDR, Thailand and Vietnam on their common specific interests.	-Environmental protection measures to ensure the correct handling of dangerous goods -Resources are need for preventing and responding to oil spill pollution

IW network and countries covered	Length, navigability and Traffic	Facts of importance	Inland navigation authority	Future focus/challenges
	(containers included)	the different countries crossed.		-Maintain local ports
China Inland Waterway *China*	Navigable rivers 110,000 km (Yangtze 6,418 km with 3,000 km suitable for navigation by vessels) About 850,000,000 tonnes/year on the Yangtze 1,200,000,000,000 tonnes/year in China	The Yangtze interconnects with many lakes, railways, trunk highways and seaborne traffic. They form the largest communications and transportation network and have a very important economic position in China.	China Ministry of transport	-Continuing channel upgrades -Fleet modernization including the use of separate barges and pusher units instead of self-powered small vessels. -Further commercialization -Awareness of inland waterways for sustainable development -Operational scales in each sub-sector of IWT -Integration of IWT into intermodal transport and logistics networks
India Inland Waterways India	4,332 km have been declared as National Waterways (Ganga 2,597km) To be optimized About 70,000,000 tonnes/year	Water transport is one of the oldest means of transport in India but not very popular in the country. This is mainly due to seasonal concentration of rainfall.	The Inland Waterways Authority of India (IWAI) was set up in October 1986 with the IWAI Act of 1985. Five National Waterways are under the purview of Central Government. There are other waterways managed by the respective State Governments.	-Maintenance of the targeted LAD as a number of shoals form simultaneously during lean season. -Availability of adequate dredgers for talking the shoals. -Availability of technology for channel stabilization/ rectification -Remoteness of the area -Sufficient resources (government funding)

Source: Worldwide Inland Navigation Network, (http://www.wwinn.org/the-rhine)

9.2 The Economics of IWT in Bangladesh

9.2.1 *Unbalanced Inter-modal Transport System*

The trend in growth of value-added in transport sector and its main components is shown in **Figure 9.2**. Following a period of fast growth in the 1990s, IWT lost ground during the 1999-2005 period. There are some signs of a recovery since then, in 2006-14 period. Nevertheless, IWT value-added has been growing much slower than the transport sector in general.

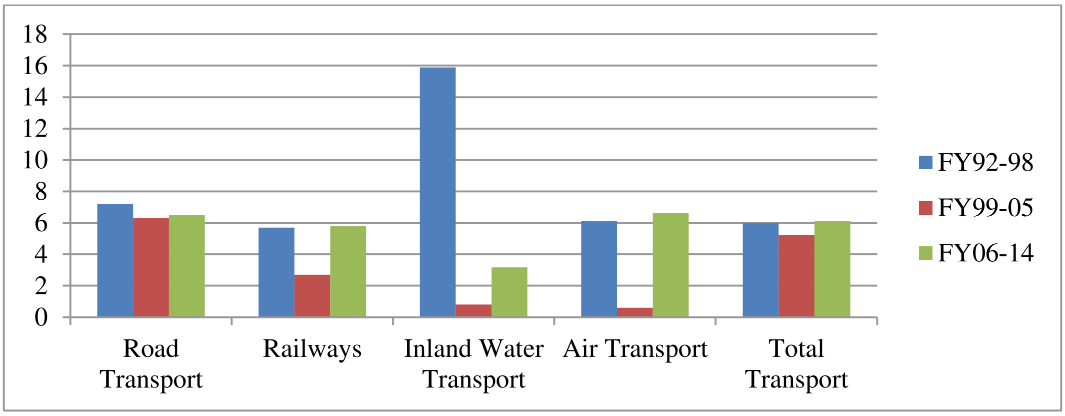


Figure 9.2: Growth Rate of Transport Sector (% per year)

Source: BBS, 2015

This slump in growth of IWT value-added has caused a sharply declining share of IWT in transport sector value-added (**Figure 9.3**). This is a combination of a lack on investment and low income activities in IWT. Yet, with proper investment and regulatory policies to ensure safety and security of IWT facilities, this activity can be a major source of economic growth in terms of facilitating low-cost transportation of goods and services as well as providing employment and income opportunities for a large number of the rural poor.

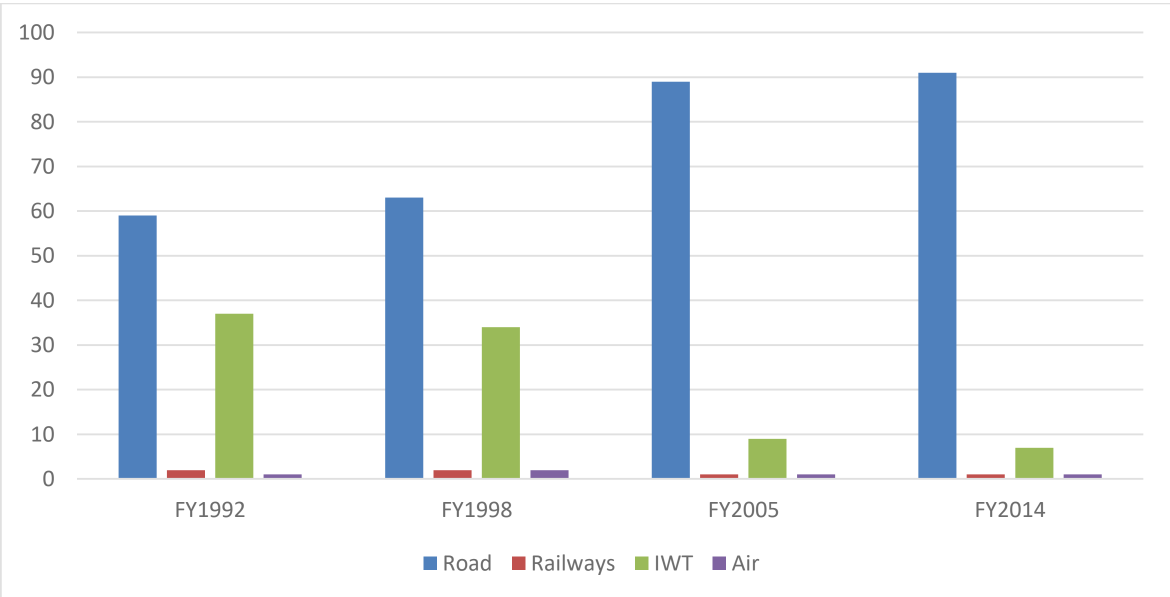


Figure 9.3: Composition of Transport in terms of Value-Added (%)

Source: BBS, 2015

Figure 9.2 and **Figure 9.3** are instructive in another way. They illustrate the poor inter-modal transport planning and strategy. Not only that the healthy balance between IWT and road transport has been destroyed over the years, the focus on road transport development has led to the stunting of growth of all other modes of transport. This unbalanced transport network is a leading factor for traffic congestion, inadequate transport options for business and individuals, high-cost transport sector and damage to environmental factors including increasing air pollution.

9.2.2 Rationale for Developing an Efficient Inland Waterway Transport System

Inland water transport provides transportation access to about 25% of rural households in Bangladesh. River transport is highly cost effective, as inland navigation is comparatively cheaper than the other available transport modes – rail and road. The unit cost of cargo transport is low and IWT is environmental friendly, requiring minimum maintenance and is by and large a safe transport option.

A number of reasons warrant the development of an efficient IWT. Modal option for development strategy of transport sector environment must be a determinant factor. IWT always remains on the top in terms of carbon saving. One liter of fuel in the river produces 100-200 tonne-km of transport output as against 25 tonne-km in road, four to eight times lower. The World Bank (2007) reports that with an estimated 1.95 billion tonne-km performed by IWT in 2005 (excluding country boats), about 58.5 million liter of fuel was saved by using IWT instead of road. Using the Integrated Pollution Prevention and Control (IPPC) conversion factors, this represents 155,000 tonnes of carbon dioxide.

Table 9.2 shows the financial cost of passenger and freight for different modes of transport. The table indicates that IWT is the second cheapest mode of transport for freight and passengers. The cost advantage for freight is especially large.

Table 9.2: Rate of Fare and Freight of Different Modes of Public Transport

Name of Transport Corporation	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014
Fare in BDT per passenger per kilometre									
Bangladesh Railway	0.38	0.38	0.38	0.38	0.38	0.39	0.39	0.58	0.75
Bangladesh Road Transport Corporation	0.78	0.87	1.05	1.05	1.13	1.48	1.48	1.48	1.48
Bangladesh Inland Water Transport Corporation	0.42	0.42	0.51	0.51	0.51	0.71	0.96	0.96	1.00
Bangladesh Biman	3.98	4.55	4.65	4.79	4.80	5.22	5.46	4.53	4.22
Freight per tonne per Kilometer in BDT									
Bangladesh Railway	1.49	1.55	1.56	1.58	1.58	1.59	1.59	2.00	5.65
Bangladesh Road Transport Corporation	2.47	2.58	3.04	3.64	3.90	4.57	4.57	4.57	6.53
Bangladesh Inland Water Transport Corporation	1.25	1.25	1.16	1.16	1.16	1.17	1.47	2.19	2.19
Bangladesh Inland Water Transport Authority								1.40 to 1.70	1.40 to 1.70
Bangladesh Biman	1.67	1.71	1.75	1.78	1.80	1.00	1.10	2.06	2.10

** For air cargo, the fare is quoted in Kg/lb. /kilometer.*

Source: BIWTA and BBS, 2015

The World Bank (2007) estimated savings at BDT 7.5 billion in transport costs of cargo from use of IWT instead of road. Cost of dredging was estimated at 0.6 billion BDT at BDT 100 per cum. In other words, benefit of BDT 7.5 billion at the cost of BDT 0.6 billion which is economically justified.[27] **Table** 9.3 illustrates the comparative per tonne-km costs of each mode.

Table 9.3: Comparison of Cargo Tariff by Modes (BDT/ tonne-km)

Mode	Dhaka-Chattogram (264 Km)	Dhaka-Sylhet (346 km)
Road	4.50	4.34
Rail	2.74	3.78
IWT	0.99	0.63

Source: World Bank, 2007

The study also indicated that in terms of productivity per kilometer of network of different modes, railway is the best followed by IWT and road is at the bottom. IWT has more than twice the productivity of road for the carriage of cargo (**Table 9.4**).

Table 9.4: Productivity of Different Modes

Comparison	Road	Rail	IWT
Network (km)	274,000	2,800	24,000
Productivity Passenger-km	359,000	1,500,000	369,000
Productivity Tonne-km	57,000	293,000	127,000

Source: The World Bank, 2007.

Moreover, from social perspectives, IWT contributes directly to social benefits nationwide by providing a relatively cheaper mode of transport and it also generates employment opportunities thereof. According to World Bank (2007), total employment in IWT sub-sector is more than 4.6 million. A substantial portion of rural population has no access to any mode of transport other than river in haor, baor and in depression areas

9.3 Present Status of Inland Water Transport (IWT)

Bangladesh Inland Water Transport Authority (BIWTA) has established 24 inland river ports and about 400 landing stations in the country. In FY2013-14, BIWTA recorded 87.40 million passengers and 35.18 million tonnes of cargo throughput of the nine major river ports. In FY2015-16, BIWTA recorded 188.10 million passengers and 15.19 million tonnes of cargo. IWT is mainly used for transport of bulk, dry bulk and liquid bulk of construction materials, food grains, fertilizers, clinker, petroleum products, etc. A large fleet of about 21,000 inland vessels are engaged in the carriage of

[27] The minimum traffic necessary to justify the cost of dredging was obtained by dividing total costs of dredging by average benefit from dredging per kilometer. The average cost of dredging per km was obtained by dividing total cost of dredging by length of navigable IWT network. The average benefit from dredging per kilometer was obtained by dividing difference between IWT and road cost by number of tonne-kilometer for IWT output. This was derived from the volume of cargo traffic transported by inland waterways by formal sector vessels only. The output of informal sector was not included as those can ply in all conditions.

goods and passengers. There are also approximately 750,000 country boats powered by the pump engines operating mainly in the rural waterways.

The two maritime ports in Bangladesh namely the Chattogram Port and the Mongla Port serve the international sea borne trade. In fiscal year 2014-15, Chattogram Port handled 54.78 million metric tonnes (MMT) of shipments (total imports and exports were 48.94 and 5.84 MMT), while Mongla Port handled about 44,000 TEU in 2012-13. A third maritime port of Payra has started operation very recently.

According to the Report of IWT Master plan prepared by DHV Consultants in 1989 BIWTA categorized the inland waterways of Bangladesh into four hierarchical classes as follows (**Table 9.5**). In terms of network length, the classified perennial routes (Class-I, II and III) amount to almost 3,600 km and seasonal routes (Class-IV) to almost 2,400 km, totaling about 6,000 km.

- *Class-I:* Comprising the perennial routes configuring the propeller–shaped spine of the system that interconnects Chattogram-Dhaka/ Narayanganj (and extending to Ashuganj/ Bhairab Bazar)-Khulna/ Mongla via Barishal (Ilsaghat/ Hizla) where the largest Least Available Depth (LAD) of 3.60-3.90 m is to be maintained all year round with a total length of about 685 km.
- *Class-II:* Routes (perennial) linking major inland ports for the northwest and northeast hinterlands i.e. Baghabari/ Nagarbari (and further north to Chilmari) and the Sylhet region to Class-I Routes where the next highest LAD of 2.10-2.40 m to be maintained all year round with a total length of 1,000 km.
- *Class-III:* Routes usually not feasible to maintain perennial Routes with a LAD exceeding 1.5-1.8 m either transit Routes such as Zakiganj-Fenchuganj-Ajmiriganj-Dilalpur (Kushiara and Kalni Rivers) or feeder Routes connected with Class-I and Class-II Routes e.g. stretches of the Kangsha, Titas, Lakhya Rivers, route around Dhaka, Karnaphuli River and tidal rivers in the southwest/central region with a total length of 1,885 km.
- *Class-IV:* Routes basically seasonal, where it is not feasible to maintain a LAD of 1.5 m in the dry season with a total length of 2,400 km.

Table 9.5: Inland Waterway Route Classification

Name of Route	Minimum Depth	Length of Route and Percentage	Minimum Vertical Clearance	Minimum Horizontal Clearance
Class- I	3.66 m	683 km (11.4%)	18.30 m	76.22 m
Class- II	2.13 m	1,027 km (17.1%)	12.20 m	76.22 m
Class- III	1.52 m	1,885 km (31.5%)	7.62 m	30.48 m
Class- IV	Less than 1.52 m	2,400 km (40.0%)	5.00 m	20.00 m
Total		***5,995 km (100%)***		

Source: BIWTA, 2015

The number of routes indicated by a first study conducted in 1960 totaled 86; 41 of them are perennial routes and 45 are seasonal routes.

Table 9.6: Classified IWT Routes (I & II)

Class		Route	Description (river/town)	Distance (km)
I	1	Dhaka-Chattogram	Buriganga, Dhaleswari, (Lower) Meghna, Shah- bazpur, Hatia Channel, Karnafuli river	306
	2	Shambhupura-Demra	Lakhya river-Narayanganj	22
	3	Shambhupura-Bhairab Bazar	Upper Meghna-Ashuganj	85
	4	Chowkighata-Maheswarpasha	Lower Meghna, Arial Khan, Kirtankhola, Gab Khan, Baleshwar, Mongla-Ghsiakhali Canal, Pussur, Khulna, Kazibacha, Bhairab	270
	Class I Total:			***683 km***
II	1	Bhairab Bazar-Chattak	Upper Meghna, Kalni, Surma river	228
	2	Mohanpur- Daikhawa	Meghna-Chandpur, Padma, Jamuna (Barhmaputra)	385
	3	Deara-Barishal Via Nandibazar	Meghna, Jayanti, Arial Khan	84
	4	Pussur-Chalna-Raimangal	Sutarkhali, Sibsa, Bajboza, Sekbaria, Arpangasi, Malanchi-Border	143
	5	Hizla-Shaistabad	Meghna-Azimpur/Dharmaganj, Arialkhan	30
	6	Sattal-Daudkandi	Meghna	24
	7	Chandpur-Ichuli	Dakatia Nullah	7
	8	Chattogram-Cox's Bazar	Karnafuli, Kutubdia & Maiskhal Channels, Bagkhali	99
	Class II Total:			***1,000 km***

Source: BDP 2100 Baseline Study Report: River Systems Management Including Morphological Dynamics of Bangladesh Delta, 2015.

Priority Routing

Maintenance of a network of 6,000 km may not be cost effective. Dredging and maintaining river navigability can be expensive and development of river navigability for transportation purposes must weigh the relative costs and benefits, including the alternative cost of land transport development. Economic justification will normally happen when transportation involves the navigability of large or medium inland vessels. The economic justification to augment the navigability in thousands of kilometer used exclusively by mechanized boats and the smallest size of inland vessels will likely be difficult. The rural waterways are being used by country boats and smaller inland vessels under existing conditions and there may be the need for simple solutions for these riverways involving community participation.

In recognition of these considerations, The IWT Master Plan Study, 2009 limited public responsibilities of maintaining navigability to the following routes, termed as core waterways network:

Table 9.7: Core Waterways Network Recommended in the Master Plan, 2009

IWT Route	Length (km)
1. Dhaka-Narayanganj-Chattogram	306
2. Dhaka-Barishal-Mongla	418
3.Chandpur-Bhairab Bazar/Ashuganj	102
4. Mohonpur-Daikhawa	385

IWT Route	Length (km)
5. Bhairab-Chatak	228
6. Jamuna/Hurasagar-Baghabari	15
7. Dilalpur-Fenchuganj	191
8. Chatak-Sylhet	53
9. Mongla-Khulna-Noapara	80
10. Dhaka-Tongi	40
11. Barishal-Patuakhali	85
12. Barishal-Barguna	97
13. Narayanganj –Narsingdi	77
14. Narayanganj –Meghnaghat	42
Total	**1,822**

Source: IWT Master Plan, Final Report, 2009

The waterways linking two maritime ports (Chattogram and Mongla) and river ports Dhaka/ Narayanganj area and routes under Bangladesh-India Protocol on IWT[28] were marked as the highest priority routes. The IWT routes between Dhaka/ Narayanganj and Chattogram maritime port is a Class-I route with adequate navigational draft for most of its length. However, during low water period, vessels plying along this route have to wait for high tide at some places in the lower Meghna and estuary areas. Another important route (Class I) is the waterway between Narayanganj and Mongla also important for the movement of vessels of goods of inter-country and transit trade under the Bangladesh India IWT Protocol. The route connects the Divisional headquarter of Barishal also. Prior to the closure of the Mongla-Ghasiakhali Canal in 2011 due to siltation, vessels used to sail through the route Sanyasi-Ghasiakhali-Mongla (length of 52 km). However, due to deteriorating condition of navigability in the canal, at present the route operates through the Sundarbans, namely Bogi-Joymoni-Mongla with a distance of 123 km, increasing its length by 71 km and thus resulting in more use of fuel which raised cost and time of transportation as well. BIWTA had to struggle to restore navigability along this important stretch and after massive dredging, the canal was declared open for traffic in 2016 but with a lower draft. This stretch is negotiable only during high tide and one-way traffic.

The route from Dhaka/Narayanganj to the northeastern part of Bangladesh, especially to Chatak and Sylhet region is classified as Class-I route up to Bhairab Bazar/Ashuganj. The depth decreases thereafter to 2.1-1.5 m and further decreases during low water period. As such, vessels are compelled to sail at half or three quarter of loading capacity, reducing the desired economic benefits from this route.

The Paturia-Baghabari route (Jamuna, Baral and Hurasagar Rivers) in the northern District of Sirajganj is of national importance on account of transportation of fuel and fertilizers to the northern part of the country. In recent years, it is also behaving erratically and unpredictably in low water periods, posing problems and sometimes even a threat to uninterrupted vessel movements.

[28] After the Independence of Bangladesh both the Governments of Bangladesh and India signed a Trade Agreement on 28 March, 1972. Under Aarticle VIII of the Trade Agreement a Protocol on Inland Water Transit and Trade (PIWTT) between Bangladesh and India was signed on 01 November, 1972.

An IUCN Report revealed that a total of 717 km of waterways that have been considered under the classification study of 1989 as perennially navigable were no more navigable during the lean period. In the same report quoting BIWTA officials and operators, IUCN concluded that presently the total length of navigable waterways during monsoon will not exceed 4,000 km and only 2,000-2,500 km are navigable during the low water period (BDP 2100 Baseline Study- Sustainable Transportation and Infrastructure, 2015)

In light of emerging needs, along with the above, the following priorities should be included:

- Raimangal-Khulna-Noapara (165 km)- route under Protocol;
- Rajshahi-Daulatdia (173 km)- this could be an important domestic route and a route for transit traffic;
- Tongi-Narayanganj (35 km), this route may contribute modal shift of passenger of greater Dhaka to remove road congestion.
- Tongi-Purbachol-Kapasia-Toke (Balu River)

9.3.1 Passenger, Freight/Cargo and Ferry Movements

Passenger Service Unit of BIWTC is mainly engaged in carrying passengers in the inland waterways, coastal areas and off-shore islands. Vessels of this unit are plying in the routes listed in **Table 9.8**.

Table 9.8: Passenger Service Routes

Inland	i. Dhaka-Barishal-Morolganj-Khulna Rocket Service
Coastal	ii. Chattogram-Barishal Steamer Service iii. Chattogram-Hatiya Steamer Service iv. Kumira-Guptachara LCT Serivce v. Hatiya-Char Bata Sea-truck Service vi. Char Changa-Char Bata Sea-truck Service vii. Manpura-Shashiganj Sea-truck Service. viii. Barishal-Mozuchowdhuryhat Service. ix. Bayarchar-Hatiya x. Alexander-Mirjakalu Sea-truck Service. xi. Teknaf-Saint Martin Tourist Sea-truck Service.

Source: Ministry of Shipping, 2015

Different categories of vessels such as Coasters, Tankers and Self-propelled Barges are used to carry cargoes. Inland and Bay crossing Barges and Tugs fall in the purview of Cargo Service Unit. The vessels of this unit carry various types of cargo in the inland and coastal water ways besides imported and exportable cargo in the two sea ports. Cargo Service Unit also engages its vessels for carrying cargo under Inter-country Trade Protocol between Kolkata in India and Bangladesh. Vessels of this unit are plying in the following routes (**Table 9.9**):

Table 9.9: Major IWT Cargo Service Routes

Sl. No.	Destination Routing
1.	Chattogram - Dhaka
2.	Chattogram - Narayanganj
3.	Chattogram - Mongla/Khulna
4.	Dhaka - Mongla
5.	Narayanganj - Mongla
6.	Narayanganj - Ashuganj
7.	Khulna - Mongla

8.	Narayanganj - Kolkata (India)
9.	Khulna - Kolkata (India)
10.	Rajshahi - Dhulian (India)

Source: Ministry of Shipping, 2015

Over the years with the growth of private sector in inland shipping, the main activities of BIWTC are concentrated in providing ferry services in major river crossings and passenger services in southern region and the coastal zone. BIWTC provides ferry services (day and night) in the following routes to connect Northern and Southern regions with the Eastern region of the country by bridging the road gaps (**Table 9.10**).

Table 9.10: Ferry Service Routes

Sl. No.	Name of Routes/Services		Distance
1	Paturia	Kazirhat	19 km
2	Paturia	Daullatdia	3 km
3	Mawa	Charjanajat	13 km
4	Mawa	Mangal Majhi	10 km
5	Chandpur	Shariatpur	10 km
6	Bhola	Laxmipur	28 km
7	Lahahat	Bhaduria	10 km

Source: Ministry of Shipping, 2015

Cost and Revenue of BIWTA and Maritime Ports

Of three major entities- BIWTA, Chattogram Port and Mongla Port, Chattogram Port Authority enjoys operating surplus. BIWTA incurs marked losses as the entity is unable to recover its cost from revenue. In 2014-15, for instance, its operating expenditure stood at Tk 3,302 million. Government grant constituted about 34% of its operating expenditure. Its non-operating expenditure was Tk 997 million during the same period. As a result, BIWTA had to incur a deficit of Tk 243 million in 2014-15. Its financial picture is not markedly different in other periods, as depicted in **Table 9.11**.

Table 9.11: Income & Expenditure of BIWTA (Figure in BDT lac)

Financial Year	Income			Operating Expenditure	Operating Surplus	Non-Operating Expenditure (Depreciation & DSL)	Net Surplus /(Deficit)
	Own Source	Govt. Grant	Total				
2009-2010	7,931.11	9,824.30	17,755.41	14,200.66	3,554.75	4,073.15	(518.40)
2010-2011	8,825.59	13,975.32	22,800.91	17,667.44	5,133.47	5,291.00	(157.53)
2011-2012	14,301.86	12,016.05	26,317.91	18,942.72	7,375.19	5,588.12	1,787.07
2012-2013	16,361.29	14,041.00	30,402.29	22,311.91	8,090.38	6,121.00	1,969.38
2013-2014	12,700.49	15,550.20	28,250.69	26,323.21	1,927.48	7,684.80	(5,757.32)
2014-2015	21,215.68	11,807.53	33,023.21	25,477.71	7,545.50	9,975.26	(2,429.76)
Total	81,336.02	7 ,214.40	8,550.42	124,923.65	3,626.77	38,733.33	(5,106.56)

Source: BIWTA Website

The Chattogram Port Authority (CPA) has been enjoying the monopoly in the trade of maritime port services with significant amount of net surplus (considering both revenue expenditure and capital expenditure) every year such as BDT 5,794 million surplus in 2014-15, according to CPA's annual report 2014-15.

The GOB has to support the Mongla Port Authority (MPA) on regular basis to meet its revenue expenditures. However, in recent years the financial picture of MPA has improved. The MPA was able to earn surplus of BDT 341.43, BDT 433.32 and BDT 480.95 million in 2011-12, 2012-13 and 2013-14 respectively.

9.3.2 Constraints, Issues and Challenges for IWT

The case for rethinking the development role of IWT and taking steps to unleash the potential dynamism of the IWT sector is substantial. In order to understand how to unleash this true potential, it is first important to understand the underlying issues, challenges and constraints in the IWT sector. A range of constraints adversely affect the supply side of IWT including those related to river morphology and climate change; river transport infrastructure; river safety; and sector financing, investment and governance. The most difficult challenge concerns the matter of maintaining the navigability of inland waterways that is expensive requiring major planning, investments and proper implementation.

9.4 River Morphology and Climate Change Issues

9.4.1 Impact of River Morphology on IWT

Dynamism and growth of river transportation depends largely on the navigability of the rivers and long term sustainability of the river system, based on the hydrological and morphological characteristics of major and minor rivers and their tributaries. Together, they constitute the navigable frontiers of the inland river transport system. Thus, they are the main drivers which influence the overall socio-economic condition of the country. Bangladesh is tectonically and seismically active and affected by different natural events and human intervention beyond the border. The huge sediment load coming from upstream is mainly carried by the major rivers of the country and thus these Rivers are morphologically very active. They are an important mode of transport and communication. They are also a significant source of water supply and irrigation. On the other hand, annually they consume several thousand hectares of floodplain land leaving thousands of people homeless and damaging or destroying infrastructure.

Navigational constraints are major problems in developing an efficient and reliable inland water transportation system in Bangladesh. There are numerous factors that affect navigability of Bangladeshi Rivers associated with hydro-morphological issues. Avulsion of the Brahmaputra and the Teesta, gradual shifting of the Ganges, tectonic subsidence and uplifting, Deltaic subsidence, and Delta progradation are the main drivers that influence the hydro-morphological development of the river systems of Bangladesh. In addition, human intervention, like- construction of dams, barrage, coastal polder, flood embankment, unplanned land use changes and groundwater abstraction, have also triggered the changing processes.

However, the active functioning of those drivers varies greatly depending on the regional physical characteristics as discussed above briefly. Moreover, seismic events, like 1950 Assam earthquake (8.5 Richter scale) have pronounced effect on the delta building process. Huge sediment generated by the earthquake has expedited the delta building process through delta pro-gradation, which is also responsible for floodplain and tidal plain development through river morphology adjustment process. An alteration of one driver causes a series of secondary alterations. In general, avulsion of the Brahmaputra River, tectonic activities, deltaic subsidence, and human intervention, along with delta pro-gradation are the main drivers which have influenced the overall river characteristics of Bangladesh in different scales. A list of drivers in different regions of Bangladesh is outlined in **Table 9.12**.

Table 9.12: Drivers in Different Regions of Bangladesh

Region	Drivers
Northwest	➢ Human intervention: Teesta Barrage in India, Teesta Barrage in Bangladesh, groundwater abstraction ➢ Teesta avulsion/shifting ➢ Brahmaputra avulsion and westward migration of the Brahmaputra
North-central	➢ Brahmaputra avulsion ➢ Changes of flow regime in distributaries ➢ Human intervention: Unplanned settlement, industrialization along the distributary rivers in this region, groundwater extraction
Northeast	➢ Tectonic subsidence ➢ Brahmaputra avulsion
Southeast	➢ Tectonic uplifting, i.e. up folding
Southwest and South-central	➢ Ganges shifting to the east ➢ Brahmaputra avulsion ➢ Human intervention: Farakka Barrage in India/ construction of series of dams, Coastal polders ➢ Deltaic subsidence ➢ Delta progradation

Source: BDP 2100 Baseline Study Report: River Systems Management, 2015

One of the main causes of declining trend of inland water transport identified is the deteriorating condition of the river system in Bangladesh caused by both morphological and natural processes, and withdrawal of water beyond the border and within the country. This has resulted in decreased dry season navigability of the rivers.

The following main causes were considered by the Daily Hourly Volume (DHV) for deterioration of waterways:

- Abstraction of water or stream flow reduction
- Reduction in cross-boundary flow
- Silting up of off takes
- Reduction in tidal volume
- On-going sedimentation

Problems in waterways of Bangladesh also prevail in inland waterways in India. From River Notices issued by BIWTA, it is evident that a vessel with 3.5 m draught may navigate between Rainmangal (entry/exit point at the border) and Narayanganj/Ashuganj loaded with 1,500 tonnes of cargo. But due to navigational problems at some spots in the Protocol route in India especially downstream of Namkhana, vessels cannot load more than 1,000 tonnes. On the other hand, vessels destined for Dhubri/ Pandu cannot load more than 500-600 tonnes due to navigational conditions in the route between Mohanpur/Ganga-Meghna confluence) and Saheberagla (entry/exit point at the border). The route between Ashuganj/Bhairab Bazar and Zakirganj (entry/exit point at border) can be used only during monsoon (July to October).

Currently, some challenges identified in the IWT sector are as follows:

- incremental dredging demand to maintain navigability;
- lack of infrastructure, non-compliance of guidelines for construction of bridge over the rivers, encroachment in the rivers;
- lack of safe vessels and skilled workforce;
- lack of policy guidelines, poor governance;
- inadequate budget allocation;
- lack of intermodal coordination;
- inadequate progress with regional cooperation.

Rivers are deteriorating and the dredging demand is increasing endlessly. Annual demand of dredging of 8.9 million cubic meter as determined by expert committee in 1990s increased to 18 million cubic meter in 2009 as recommended by the IWT Master Plan Study Report. As opposed to this, the IWT has not been able to capture the rightful place in budget allocation as it has never been a popular political choice for development in Bangladesh. Against the modal share of 8.9% and 16% respectively in passenger and freight movement, the IWT received on average less than 5% of the total ADP allocation for surface transport.

9.4.2 Impact of Climate Change on IWT

Gradually the flow of waterways has become alarmingly erratic causing huge siltation in the rivers. As a result, inland navigation is becoming hazardous and shrinking rapidly. Rivers have become so unpredictable that dredging could not yield benefit for navigation. According to the Bangladesh Climate Change Strategy and Action Plan 2009 (BCCSAP 2009) possible impacts in Bangladesh are the following:

- Increasingly frequent and severe tropical cyclones, leading to more damage in the coastal zone;
- Heavier and more erratic rainfall in the the Ganges- the Bhramaputra- the Meghna basin systems, including Bangladesh, during the monsoon resulting in higher river flows, causing over-topping and breaching of embankments and widespread flooding;
- River bank erosion resulting in loss of homes and agricultural land to the rivers;
- Increased sedimentation in riverbeds leading to drainage congestion and water-logging;
- Melting of the Himalayan glaciers, leading to higher river flows in the warmer months of the year, followed by lower river flows and increased saline intrusion after the glaciers have shrunk or disappeared;
- Lower and more erratic rainfall, resulting in increasing droughts, especially in drier northern and western regions of the country;
- Sea level rise leading to submergence of low lying coastal areas and saline water intrusion up coastal rivers.

Some impacts on inland water transport due to climate change are as follows:

- Loss of navigability due to increase in frequency and duration of dry spell may imply higher prices and losses,
- Increase in frequency in wet and stormy period may imply higher costs due to weather disturbances and safety,
- Gradual low flow conditions and resulting economic losses,
- Large variations and reduced water depth,
- Sharp increase in frequency of extreme costs,
- Damage from cyclones and storm surge to IWT infrastructure.

Despite BIWTA's aid to navigation support along the channels, change of river courses have become unpredictable resulting in grounding of vessels which often cause economic losses.

The impact of climate change is very much evident in case of 24 terminals developed by BIWTA in the early 1970s also used as cyclone shelters in the coastal zone. Not a single terminal is in use now as the rivers lost navigability or change their courses away from the terminal and some of the terminals disappeared due to river erosion. The equipment for navigation are vulnerable to cyclones and storm surges. The equipment are washed away regularly by onrush of flood water. SIDR, 2007 destroyed, damaged or washed away about 80% of such equipment installed in the Khulna and Barishal Divisions. Of the total 380 landing stations developed so far by BIWTA 43% are located in places registered under Divisions of Khulna and Barishal. About 35% of the landing stations in the above two divisions were completely damaged; pontoons were displaced, damaged or capsized during SIDR in 2007. Landing stations located in the coastal zone are exposed to saline intrusion. Floating pontoons, jetties or shore connections cannot last long due to salinity of water.

Ports and landing stations were developed by BIWTA following the benchmark of Public Works Department (PWD) calculating the high and low water variation. As climate change factors were not considered, in some places it already can be seen that facilities developed in the past are now on the shore quite a distance away from the river or in the mid-stream of the river without any shore connection. Floating pontoons are often shifted to another place due to change of course of the river or due to erosion leaving behind the piles or spuds.

Moreover, in late monsoon, due to flash floods and strong current in rivers, water increases in some stretches to such an extent that navigation becomes very dangerous. One of such examples is the confluence of the Meghna and Dakatia near Chandpur where dangerous whirlpool caused at least half a dozen marine accidents during recent years and claimed hundreds of lives.

9.5 Navigability in Waterways Management Issues

9.5.1 The Principle of Uninterrupted Navigability of Waterways

The development of an efficient IWT should be based on uninterrupted navigability of waterways. Navigability is one of the major challenges to develop a sustainable inland waterway network in Bangladesh. Navigation is complicated by the braided nature of the rivers, which are characterized by high sediment delivery and due to extremely low gradients very low sediment throughput. This makes the rivers extremely sensitive to flooding with rapid geometry (boundary and channel) changes. Further, river systems in Bangladesh exhibits high seasonality over a year i.e. abundant of water during monsoon and scarcity of water during dry season from December to May. Navigability becomes very critical during dry season in many river routes and ferry crossing.

9.5.2 *Incremental Dredging Demand for Maintenance of Navigability*

Main morphological and hydraulic problems call for a never-ending dredging requirement. The length of navigable waterways in Bangladesh determined by a comprehensive survey in 1989 was about 6,000 km in the wet season which declines to about 3,800 km during the dry period. Hydrographic Survey, the reliable means of obtaining nautical conditions of waterways for all classified routes is not sufficiently available and updated since last 27 years, rather survey works are undertaken according to route based priority.

Rivers are deteriorating and dredging demand is increasing endlessly. Very recently BIWTA prepared a long term dredging plan with 88.2 million m^3 of dredging (45.6 million cubic meter development and 42.6 million cubic meter for maintenance) annually which needs a number of additional dredgers other than contributions from BWDB and private dredgers. Moreover, the capacity of each dredger is minimal and could not be utilized due to number of factors like placement efficiency, shifts of works, maintenance and repair time, reduction in annual working days, etc. It is important to coordinate and relate the dredging activities with the BDP 2100 River Strategy and Interventions with full-fledged cooperation. All dredging must be done with prior feasibility studies to mimimize impacts on fish spawning and breeding grounds and to ensure that capital dredging does not enhance river bank erosion on any site.

9.5.3 *Weak Port and Intergrated Transport Capacities*

The main challenge of the two maritime ports is the condition of fairways between the sea and the jetty berths. The Chattogram Port installations are situated along the bank of the River Karnafuli 16 km from its outfall into the Bay of Bengal. The maximum permissible draft ranges from 8.50 to 9.20 m with length restriction of vessels being 188 m. As such vessels with more than 1,200 TEU (Twenty Feet Equivalent) cannot berth at Chattogram port, while the average capacity of the vessels calling at the South Asian ports is 3,500 TEU. The Mongla is located on the Pussur River about 130 km inland from the Bay and its permissible draft ranges from 7.00 to 8.50 m with length restriction of vessels being 225 m.

In the context of regional standard, maritime ports in Bangladesh also suffer from inefficiencies. The average handling of boxes per crane hour at the Chattogram Port is 12-15 as against 25 of South Asian standard. The Study also found that dwell time at the Chattogram Port is 6-8 days while it is 3-4 days in the South Asian ports.

Inadequate Intermodal Connectivity

Due to lack of appropriate intermodal distribution system of containers, further traffic growth is restricted. In absence of a dedicated railway line for freight and container movement between Dhaka and Chattogram, container movement by rail has to share with preferential passenger movement. The existing road does not have the bearing capacity to carry containers; presently 90% of the containers are stripped/ staffed in the ports of Chattogram and Mongla and transported as conventional general cargo. Only 10% of containers are loaded on rail and transferred to Kamlapur Inland container Depot in Dhaka, managed and operated by Chattogram port Authority.

In view of the above, a couple of studies recommended utilizing inland waterways for container traffic. In 1991, a JICA Study recommended the site of Pangaon, Dhaka on the bank of the River Buriganga to develop an Inland Container Terminal. The navigation channel is straight at this point with a width of 250m and provides a Class-I waterway that ensures LAD of 3.6 m perennially. Accordingly, an Inland container terminal had already been developed at that site and began experimental operation in 2013. The ICTL has the handing capacity of 116,000 TEUs with further scope of handling 160,000 TEUs per year. Poor or no intermodal connectivity at inland river ports and landing stations manifests the inherent inefficiency of transportation by inland waterways. A port is the interface of two or more modes of transport: this definition does not apply to river ports and landing stations in Bangladesh. At present there are about 380 landing stations developed by BIWTA in the country. Of these, two-third was developed in the rural areas with about 90% with no road link.

All 21 inland river ports (except Chandpur) do have road links. Only Narayanganj, Chandpur and Khulna do have a railway link. But landing points and stages in these river ports are established in such a way that cargo transfer between vessel and truck is not possible except one point at Dhaka, as well as at Narayanganj and Khulna. In consultation with BIWTA officials a list of 40 major landing and shipping stations of cargo was prepared according to traffic importance.

The method of transshipment is only by means of head load, which prevailed in the last centuries. This causes increase of transportation time and cost in case of inland waterways. Consequently, IWT has lost its efficiency and competitiveness compared to other modes. The consequence of the current physical appearance of inland river ports and landing stations is that transportation by inland waterways is unimodal, segmented and to some extent isolated as well. Even with the massive development of road network in Bangladesh, most of the rural people depend only on the rivers for the purpose of transport. They do not have access to actual market place due to lack of intermodal connectivity.

Road, inland waterways and rail are components of surface transport sector of Bangladesh. Coordination and connectivity among these modes could provide a multimodal transport system to establish an uninterrupted transport chain for door to door services. Development of roads and railways and the development of inland waterways had been conducted by two separate Ministries: Ministry of Communications and the Ministry of Shipping. Recently Ministry of Communications was divided into two Ministries, namely Ministry of Road Transport & Bridges and Ministry of Railways. Proposals are submitted in parallel ways by the Ministries to the Planning Commission which has to decide against available resources. As a result decisions are often taken by restoring to political considerations. Development of road network had always been a national priority in Bangladesh.

Lack of Integrated Transport Logistics

Availability of integrated logistics in the entire transport chain is the pre-condition of intermodal connectivity. Domestic traffic of cargo by waterways suffers from lack of logistics in this sub-sector. Except a few jetties developed and operated by private sector companies on a dedicated basis, the present system of loading/unloading of cargo at public jetties is mainly by means of head load, because, inland ports and landing stations are not connected with road or rail. The distance between the jetty and the place of waiting truck is such that it restricts opportunity of direct transfer of cargo required for uninterrupted transport chain.

For a head load method, the size of gang of about 100 laborers is high, but productivity is low about 7-10 days to load/unload a vessel of 500 to 800 DWT. The use of mechanized equipment could reduce this time to one to two days. Long cargo handling time increases the turnaround time of a vessel and reduces productivity. The increased turnaround time decreases the number of vessel trips which has direct impact on the cost of transportation by inland waterways. **Table 9.13** reveals comparative transport costs and revenues for two productivity scenarios concerning head load and mechanized equipment.

Table 9.13: Cargo Transport Costs and Revenue with Head load and with Equipment

Transport Feature	Manual labor	Mechanized Equipment	Variation Mechanized/Manual
Number of annual round trips	12	26	+114%
Operating costs (BDT/tonne-km)	0.90	0.67	-26%
Total annual tariff (0.92 BDT/tonne-km)	2,7000,000	5,700,000	+114%
Total annual profit in BDT	60,000	1,600,000	

Source: World Bank, 2007

With mechanization operating costs would be reduced by 26% achieved by a higher number of trips. Profits of vessel owners will increase, service will be competitive and integrated logistics costs would likely be reduced compared to present system of head load. Such mechanization of handling is only possible through establishing an uninterrupted intermodal connectivity with both growers and retailers as the beneficiaries.

Higher Turnaround Time

Table 9.14 shows the high turnaround time of a vessel operating in the main commercial routes of Bangladesh-India transboundary inland navigation.

Table 9.14: Average Turnaround Time in handing vessels

Sl	Route	Mode of trade	Time taken (Days)
1.	Narayanganj-Kolkata	Inter-country	40
2.	Kolkata-Karimganj	Transit	45
3.	Kolkata-Khulna	Inter-country	25
4.	Kolkata-Pandu	Transit	50

Source: BDP 2100 Baseline Study Report:- Sustainable Transportation and Infrastructure, 2015.

Causes for such high time for turnaround are as follows:

a) Poor navigational quality in some stretches,
b) High time for loading and unloading due to lack of appropriate handling facilities,
c) Absence of night navigation facilities,
d) Present procedures of customs and immigration,
e) Efficiency of the vessel and crew.

In course of discussion with the private operators under the Protocol revealed that from total turnaround time one-third is required for actual navigation and the remaining for loading-unloading and customs and immigration formalities.

9.5.4 River Safety and Other Key Issues

During the last decades substantial number of accidents happened in the inland waterways of Bangladesh and claimed thousands of lives. Such incidents created a public perception that waterway transport is unsafe. Despite the fact that the ratio of fatalities per billion of passenger-km is 158 for roads and 41 for IWT (World Bank, 2007). **Table 9.15** reports the number of maritime accidents and fatalities between 2000 and 2014.

Table 9.15: Waterway Accidents and Fatalities: 2000-14

Year	Number of Accidents	Number of Fatalities
2000	09	353
2001	17	33
2002	17	297
2003	31	464
2004	41	127
2005	28	248
2006	23	51
2007	11	02
2008	22	120
2009	34	260
2010	29	118
2011	22	74
2012	15	162
2013	10	22
2014	16	124
Total	325	2455

Source: Department of Shipping and BIWTA, 2015

Accident investigation reports revealed a number of causes of marine accidents. They include overloading, collision, loss of balance/groundings, absence of pilots, break down, human errors, natural calamities like cyclones, storm, tornado, etc. It was found that 56% of accidents occurred due to overloading or improper loading of passenger and cargo (**Figure 9.4**). But it was also found that the main cause was combined with other causes like quality of ship, human error and natural calamities.

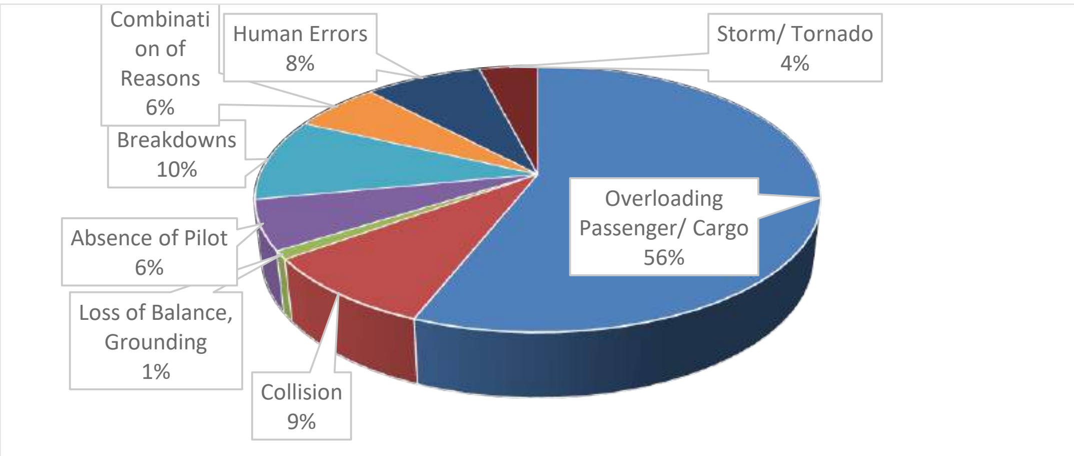


Figure 9.4: Causes of Accidents on Inland Waterways

Source: World Bank, 2007

Figure 9.5 shows the factors that causes of ferry accidents. Inclement weather, collision, overloading, among others are blamed for ferry accidents in inland waterway.

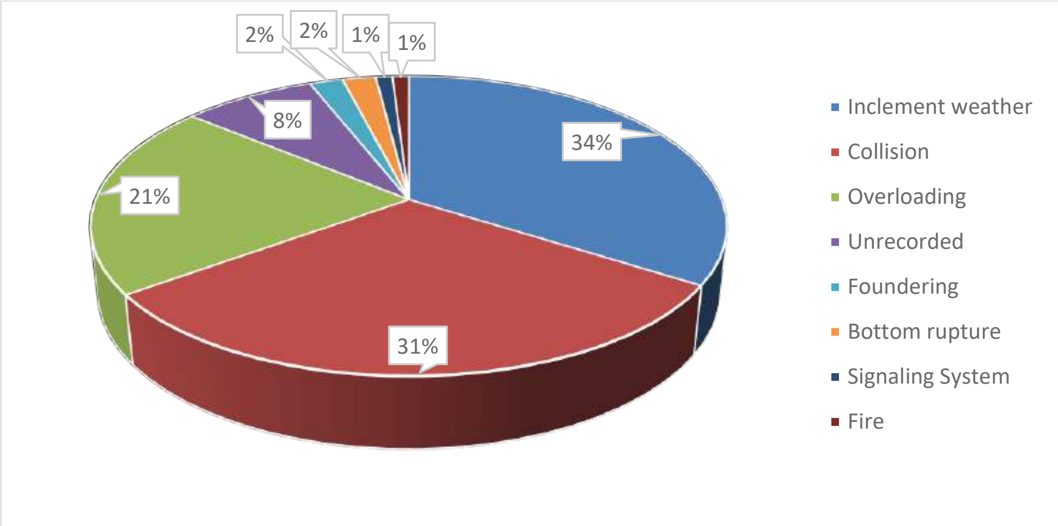


Figure 9.5: Causes of Ferry Accidents

Source: World Bank, 2007

The responsibility of BIWTA is to oversee the loading/unloading activities in the inland ports. For this purpose, every port has a certain number of Traffic Inspectors. However, very little resources are available to oversee vessels. Even in large ports only a few inspectors are present against the large number of vessels**.** The authorities have not developed the capacity of undertaking instant salvage. BIWTA have four salvage units for this purpose. But these units often fail to undertake immediate salvage operations after accidents.

9.5.5 Non-Compliance of Guidelines for Construction of Bridge/Culvert and Cables/Wires over the River

There exists a vertical and horizontal standard of every navigable stretch depending on the dimension of vessels ply in the stretch. But in many cases the standard were not followed in constructing Bridge or culvert over rivers[29]. Culverts in the rural area are so constructed restricting even the movement of a tiny boat. Road bias development plan not only restricted the navigational facilities, but also stopped the natural river flow. At some places, sluice gates constructed by the BWDB also restricted navigation of water crafts and natural water flow. Similar restrictions happen with overhead cables and high tension wires at some places.

[29] The construction of Friendship Bridge over River Buriganga can be cited an example as to how this rule was ignored. Since it is a stretch of Class-I waterway vertical clearance was set at 60 feet at the highest high water level. Ultimately the bridge was constructed with a vertical clearance of 40 feet restricted movement of larger size coastal vessel up-stream of the bridge. As a result, navigation in 110 km of waterways around Dhaka is not possible due to the existence of such low height bridges. As such waterways round Dhaka could not contribute to urban transport of heavy goods to remove road congestion.

9.5.6 *Encroachment in Rivers*

Being a land scarce country Bangladesh has a serious problem due to encroachment of rivers. Unauthorized encroachment by a section of influential people threatens not only navigation; it has emerged as a vital environmental issue. River port areas are most vulnerable places of such encroachment. Port channels have been narrowed over the years restricting safe navigation. More than 5 acres of foreshore around Dhaka have been encroached. BIWTA frequently undertake eviction programs but after some time land is again occupied with encroachment.

9.5.7 *Lack of Safe Vessels and Skilled Work Force*

There exist rules and regulations for ship design and ship construction, but these are not applied generally in case of construction. Prior to construction of a vessel, design prepared by registered naval architect must be approved by the Department of Shipping (DoS). In fact, DoS has the capacity constraints ensuring construction of vessels as per standard designs.

Another factor which threatens the safety is the skill of members of crew on board. Training facilities for crew available in Bangladesh are not sufficient to meet demand of such large fleet. Besides, private sectors owners are hardly interested to send their crew for training. Members of the crew only depend on experience not on education and knowledge obtained through training.

Investigation reports of recent passenger vessels accidents reveal that the major causes of the accidents are due to the inappropriate designs of the vessels and in many cases lack of efficiency of the masters.

9.5.8 *Institutional Constraints and Inadequate Enforcement of Regulating Agencies*

One of the main reasons of gradual declining trend of IWT is lack of good and efficient governance. Poor governance is apparent in almost all areas of regulations and management: approval of ship design, construction of inland ships, issuance of registration and survey certificates in favor of inland ships, port management, enforcing rules and regulations of navigation, issue of competency certificates to master and engine drivers, port revenue earning, etc.

Approval of ship design, supervision of construction of inland ships, issue of registration and periodical fitness survey certificates, awarding competency certificates to members of crew and enforcing rules and regulations are responsibilities of DoS. The DoS have only 4 surveyors who issue certificates to as many as 10,000 inland ships. It is understood that surveyors cannot supervise the construction of the ship nor they can physically inspect the ship prior to issue of certificates. A 62 member team of DoS is responsible for the whole sub-sector. There exist only 7 inspectors to exercise control of movement of vessels under rules and regulations.

BIWTA is responsible for providing services to users. Inland ports and landing stations are administered by BIWTA. Actual handling operations are performed by the lessees appointed by BIWTA. Term of lease arrangements is only one year. For such short term the lessee does not take any responsibility of maintenance of infrastructure or facilities available in his jurisdiction. Condition of lease arrangement is so ambiguous that before every year ending BIWTA regularly faces litigations from the lessees. In most cases the court of law issues an interim order of stay in favor of the lessee and he continues beyond his term. This has a serious impact on revenue earning of the port.

Collection of tolls directly by BIWTA employees is not transparent. Generally entry fee from passengers in the terminal of the port are collected by BIWTA. Overloading is a popular allegation against passenger vessel, while total collection of BIWTA is not more than 40% of the registered capacity of departed vessels.

9.5.9 Development and Maintenance of Waterways Navigability

Navigability is one of the major challenges to develop a vibrant and sustainable inland waterway network in Bangladesh. Regular maintenance and modernization of the river transport infrastructure is an essential prerequisite for dynamizing riverine transport within a multimodal framework. Navigation is complicated by the braided nature of the rivers, which are characterized by high sediment delivery and - due to extremely low gradients - very low sediment throughput. This makes the rivers extremely sensitive to flooding with rapid geometry (boundary and channel) changes. Further, river systems in Bangladesh exhibit high seasonality over a year i.e. abundance of water during monsoon and scarcity of water during dry season from December to May. Navigability becomes very critical during dry season in many river routes and ferry crossings.

Problems of navigation are compounded by the growth of inland water vessel size and the IWT fleet now comprises dry and liquid bulk ships of up to 3,000 deadweight tonnes, mainly trading on the Class I river routes. Moreover, the size of the IWT fleet is growing and currently there are over 22,300 registered vessels which carry over 50% of all freight traffic and one quarter of all passenger traffic. In addition, there are some 750,000 country (traditional) boats, a substantial part of which have been mechanized. This warrants maintenance and improvement of inland waterway transport infrastructure.

Consequences of non-maintenance of navigation channels are as follows:

- Transportation cost and time will be increased;
- Turnaround time of vessel will further increase to such extent that IWT will not remain cost-effective;
- Hinterland connection of maritime ports will be disrupted and will leave ports as inefficient;
- Congestions in roads and maritime ports will further increase;
- Inland container transport by rivers will not be sailed;
- Private investment in IWT sub-sector will be discouraged;
- International sea-borne trade will not be able to meet transport demand;
- Facilitation of trade and commerce will be restricted resulting unemployment; and
- Poor people will lose opportunity of cheaper transport.

The general means of maintaining the navigation routes are dredging and systematic river training works such as spurs and groins on both sides of the river. These spurs could help in developing the navigation channels away from the banks. However, these channels also require further improvement through annual dredging. These types of river training structures may be useful for smaller rivers, but for mighty braided and multi-channel rivers like the Lower Meghna where the river width varies from 5 to 12 km, the river training structures are not useful. Furthermore, river training is very expensive (about US$ 3,000 to 6,000 per running meter) and also creates lots of morphological impacts on the river regime such as erosion of river bank between two spurs. Maintenance by dredging is a preferred alternative to maintain navigability in waterways. BIWTA is the main authority to maintain navigability in inland waterways of Bangladesh.

Morphological and hydraulic problems of inland waterways demand maintenance and improvement strategies and methods. Development of shoals in navigable waterways is required to be monitored regularly using sonar techniques followed by dredging of waterways and where feasible by applying river training. For this, financial and logistics resources are required. Logistics resources include hydrographic survey equipment and apparatus and dredging apparatus. Proper maintenance and development of navigability in waterways management and functions involve the following: i) Hydrographic survey; ii) Dredging; iii) Bandalling; iv) Aids to navigation; and v) Pilotage and dissemination of navigational information.

9.5.10 Hydrographic Survey

Hydrographic survey is the reliable means of obtaining nautical conditions of waterways. The available logistics and funds is not sufficient to survey all classified routes, rather survey works are undertaken according to route based priority. If BIWTA decides to undertake dredging works based on information from the field offices and from the vessel operators regarding the navigability conditions, then the volume and shoals to be dredged are determined through hydrographic survey. The hydrographic survey carried out during 2009-2014 is shown in **Table 9.16**.

Table 9.16: Hydrographic Survey of Waterways

Year	Inland Waterways (in km)	Coastal Waterways (km^2)
FY2010	2,162	1,111
FY2011	1,208	1,190
FY2012	834	1,190
FY2013	2,052	1,200
FY2014	2,770	1,200
FY2015	1,587	1,200

Source: Hydrography Department, BIWTA, 2016

9.5.11 Dredging: Recent Trends/Volume, Demand estimation, Underutilization of Capacity

One of the major challenges in the inland water transport sector is incremental dredging demand to maintain navigability. Rivers are deteriorating and the dredging demand is increasing endlessly. BIWTA receive lists of dredging requirements from various parties. These include field offices of BIWTA, trade organizations related to IWT operations and the public sector company BIWTC.

The volume of both maintenance and development dredging is given in **Table 9.17**.

Table 9.17: Total Volume of Dredging: FY2006-FY2015

Year	Maintenance (million m^3)	Development (million m^3)	Total (million m^3)
FY2006	2.230	4.249	6.479
FY2007	2.042	1.628	3.670
FY2008	1.407	1.718	3.125
FY2009	2.335	0.911	3.246
FY2010	3.492	0.504	3.996
FY2011	4.016	2.554	6.570
FY2012	4.361	2.447	6.808
FY2013	4.465	5.603	10.068
FY2014	5.790	4.702	10.492
FY2015	5.077	12.015	17.092

Source: Dredging Department, BIWTA & BWDB, 2016

According to BIWTA, the dredging works carried out under different schemes included the dredging of the Padma, the Meghna, the Buriganga, the Sitalakhya, the Balu, the Kumar, the Upper Kumar, the Lower Kumar, the Arialkhan, the Sandha, the Shaheber Khal, and the dredging of the Madhumoti and the Goumati rivers. Furthermore, BIWTA is also involved in the dredging of ferry routes across the rivers between two road-heads. In fact, the ferry (loaded with vehicles) operation across the rivers between two road heads is the responsibility of the Roads and Highway Department. But considering the complicated navigational conditions ferry operations in the following routes have become the responsibility of the Ministry of Shipping:

(i) Paturia-Daulatdia-Kazirhat,
(ii) Mawa-Charjanajat-Kathalbari,
(iii) Harinaghat-Alubazar, and
(iv) Bhola-Laxmipur.

BIWTA is responsible for maintaining navigability of the route and for maintaining embarkation/ disembark facilities for vehicles while operation of such ferry is the responsibility of BIWTC. **Table 9.18** illustrates the dredging (maintenance) volume in priority ferry routes.

Table 9.18: Dredging Volume in the Ferry Routes

Year	Volume (million m^3)	% of total Maintenance Dredging
FY2010	24.13	60.44
FY2011	32.25	80.30
FY2012	33.28	48.88
FY2013	32.86	32.64
FY2014	35.48	33.82
FY2015	46.43	44.30

Source: Compiled from BIWTA, 2016

BIWTA has undertaken and planned three projects of navigation dredging as follows:
(i) Dredging of twelve important River Routes involving a total of 15.8 million m^3;
(ii) Capital Dredging of 53 River Routes (1st phase, 24 River Routes) involving a total of 104 million m^3 of dredging;
(iii) Capital Dredging of 53 River Routes (2nd phase, 24 River Routes) involving a total of 382 million m^3 of dredging.

Consequently, BIWTA estimated an annual dredging requirement as presented in **Table 9.19**.

Table 9.19: Estimated Dredging Requirement

Sl	Item of Dredging Works	Estimated Volume (million m^3)	No. of years Planned	Volume/year (million m^3)
1.	Capital Dredging of 53 River Routes	501.80	11	45.62
2.	Maintenance Dredging of River Routes after Capital Dredging (15% of Capital volume) 752.70 lakh m^3, taken 50% of the above Volume			37.60
3.	Maintenance of Ferry Routes and other Works			5.00
Total Dredging Requirement /year on average				**88.22**

Source: Dredging Department, BIWTA, 2015

Available Dredging Capacity

Presently BIWTA has a dredger fleet of 21 dredgers as presented in **Table 9.20**.

Table 9.20: Existing Dredger Fleet of BIWTA

Sl.	Name of the Dredger	Procurement Year	Annual Capacity (In lakh m^3)
1.	Delta-I	1972	3.00
2.	Delta-II	1972	3.00
3.	Delta-35	1975	4.00
4.	Delta-36	1975	4.00
5.	Delta-37	1975	4.00
6.	Delta-38	1975	4.00
7.	Delta-139	1975	4.00
8.	Kushiara	2011	6.00
9.	Karnafuly	2011	6.00
10.	Kopotakhsa	2011	6.00
11.	Delta-1420-1	2014	7.00
12.	Delta-1420-2	2014	7.00
13.	Delta-1418-1	2014	6.00
14.	Delta-1418-2	2014	6.00
15.	Delta-1418-3	2014	6.00
16.	Delta-1418-4	2014	6.00
17.	Delta-1418-5	2014	6.00
18.	Delta-1418-6	2014	6.00
19.	Dredger Padma	2016	6.0
20.	Dredger Meghna	2016	5.0
21.	Dredger Jamuna	2016	5.0
Total Annual Capacity			***110.00***

Source: BIWTA, 2016

With the three dredgers in pipeline of delivery total annual capacity of 21 dredgers will stand at 11.00 million m^3. The capacity of each dredger could not be fully utilized by BIWTA due to the following factors:

(i) Deployment period and placement efficiency;
(ii) Only two shift of works;
(iii) Maintenance and repair time.

DHV Consultants in its Report Bangladesh Inland Water Transport Master Plan (1989) suggested suitable options to increase the number of productive hours of dredgers through:

(i) Introducing a third (night) shift, raising productivity by about 30% and /or
(ii) Increasing the deployment time by 30% (from 27 dredger weeks to almost 35 dredgers weeks per year).

Bangladesh Water Development Board (BWDB) has a dredger fleet with 8 million m^3 annual capacity. However, almost all BWDB dredgers are engaged for own projects. The number of projects under implementation by BWDB and projects in pipeline of approval reveal that BWDB dredgers will never be utilized for navigation dredging in the years to come. So, only remaining alternative is to significantly involve and utilize private sector in navigation dredging. Very recently private sector is coming forward for investment in navigation dredging. **Table 9.21** illustrates increasing participation of private sector.

Table 9.21: Private Sector Participation in Navigation Dredging

Year	Volume of Dredging (million m^3)
FY2010	2.03
FY2011	3.86
FY2012	3.49
FY2013	6.52
FY2014	6.72
FY2015	19.79

Source: Dredging Department, BIWTA, 2016

Determinants of Dredging: Institutional and Governance Constraints

The current method of determining the Annual Dredging Program is not the result of a comprehensive hydrographic survey. In reality, knowledge gap of current conditions of navigability of Inland waterways exists, as data were not updated nor any comprehensive hydrographic survey could be conducted since 1989. So it is not possible to ascertain the accurate volume of dredging required for the maintenance of classified IWT Routes. However, different Committees indicated different volumes of dredging requirement. A Committee constituted by the Ministry of Shipping indicated a volume of 7.9 million m^3 annually. Again in 1999 a Committee constituted by MoWR indicated annual volume of 8.9 million m^3. In 2006 BIWTA estimated annual volume of 11.1 million m^3.

BIWTA undertakes efforts for monitoring of conditions of navigability of important IWT routes with a view to identification of morphological changes including shifting of sandbars. As such conservancy of navigability through dredging is an annual recurring necessity. BIWTA receives lists of dredging requirements from various parties and stake holders. These include field offices of BIWTA, trade organizations related to IWT operations and BIWTC. The accumulated demand is reviewed in a meeting involving major stakeholders. The Dredging Department of BIWTA separately estimates dredging related to development projects included in the ADP, then considering both development and maintenance dredging activities for the year vis-à-vis availability of resources. The works should be prioritized according to their relative merits.

The demand of dredging is supposed to be reviewed in a meeting chaired by the BIWTA Chairman with participation from both private and public stakeholders resulting in prioritizing of works. However, usually such meetings are presided by Chief Engineer (Dredging) of BIWTA with no participation of private stake holders.

There exists hardly any objective manner or method for preparing an Annual Dredging Program on the basis of available resources both financial and logistics. Opinions or requirements are received and listed. However, the final dredging programs are prepared not according to any prescribed method and according to need. For example, the Haor Master Plan estimated that the Haor and flash flood area shares about 37% of the total national IWT output. However, inland waterways in the Haor and flash flood area suffer most due to dry season navigability due to lack of required dredging (**Table 9.22**).

Table 9.22: Dredging Volume in the Haor and Flash Flood Area

Year	Volume (in lakh m³)	Percentage
FY2010	3.33	8.34
FY2011	Nil	-
FY2012	Nil	-
FY2013	2.13	2.12
FY2014	3.94	3.75

Source: BIWTA, 2015

Dredging of Ferry Routes

It is evident that half of the fund allocated for the maintenance dredging goes to the ferry routes, total length of which is not more than 100km, and the remaining for Class-I to III routes with length of 3,600 km. Final Report of the Inland Water Transport Master Plan study 2009 by Transport Sector Coordination wing, Planning Commission suggested that "ferry routes are in reality road links across the major rivers and relate to Roads: therefore funding should be arranged so that IWT budget meant for maintenance of waterways is not affected". Since road transport network in Bangladesh gets priority over other modes of transport, dredging in the ferry routes between road-heads gets top priority in the Annual Dredging Program and as such scarce IWT funds go to dredging in the required routes.

Dredging Priorities for the Future

Despite some progress, inadequacy of river dredging remains a major constraint on navigability of rivers and the expansion of IWT. Strong emphasis will need to be placed to this issue under the Delta Plan. In particular, the capital and maintenance dredging of the rivers Padma, Meghna, Jamuna, Brahmaputra, Dharla, Arial Khan, Kushiyara, Gorai, and Manu are of high priority for the investment programme under the Delta Plan. Regular dredging should also be considered for Ghashiakhali and other channels in the Sundarbans. Proper management of sand outputs obtained from dredging needs to be ensured. This is a valuable resource and should be managed as such. The site of 'Balu-mahal' (sand quarry) should be shifted regularly (as and when necessary) and the local administration should take necessary steps accordingly. Specific guidelines should be developed for the management of soil/sediment management resulting from dredging or Balu-mahal.

9.5.12 Other Measures to Address Navigability Problem: Aids to Navigation and Pilotage

BIWTA is responsible for installation of navigational aids indicating the channel. These are indispensable for safe negotiation of a vessel. Day to day soundings of a stretch are taken by beat pilots and marksmen using a boat and a bamboo pole or a lead line. Soundings are reported to the sectional head. The pilot inspector of the stretch can take immediate action and shift the channel mark according to the condition of channel. List of navigational aids in waterways is presented in **Table 9.23**.

Table 9.23: Equipment of Navigational Aids in Waterways

Navigation Aid Equipment	Number
Lighted Buoy	51
10m Tower Beacon	12
4.5m Tower Beacon	365
Spherical Buoy	81
P.C Pole Marks/Signs	427
Iron Marks/Signs	839

Source: Conservancy & Pilotage Department, BIWTA, 2015

An efficient inland waterways network enabling the vessel to steam round the clock is necessary to decrease transportation time and increase turnaround of the vessel. But so far BIWTA could provide night navigational facilities to one-fourth of the classified routes. Where no such facilities exist, vessels are not allowed to ply in the night and are compelled to anchor and wait for daylight. **Table 9.24** illustrates current state of night navigation.

Table 9.24: Aids to day/night Navigation

Classification of Waterways	Length (km)	Only Day (km)	Day & Night (km)
I	683	-	683
II	1,000	688	312
III	1,885	1,278	523
IV	2,400	1290	43
Total	***5,968***	***3,256***	***1,561***

Source: Conservancy & Pilotage Department, BIWTA, 2015

Other means of assistance to navigation in waterways are providing pilotage services to vessels in operation. The master of the inland ship is not knowledgeable about the unique condition of each stretch. Pilots guide the Master to keep the vessel on the right track. Pilots are engaged in 26 stations and provide services to the vessel at their respective beats (stretch). Present system of providing pilotage services increases operational time of the vessel due to (a) a vessel in operation for a long route is required to change pilots at not less than three pilot stations resulting delay in journey, (b) if any pilot is not available at a particular station, vessel will have to wait. The requirement of such services can be minimized by disseminating navigational information to the vessel in operation and intensifying aids to navigation. Total management of installation, maintenance and shifting of navigational equipment is directly performed by BIWTA. Private participation in this regard is yet to be introduced.

9.5.13 Bandalling

BIWTA undertakes Bandalling works in non-tidal river systems of the Jamuna/the Brahmaputra and Surma – Kushiara. It represents an alternative low cost indigenous method of maintenance of navigability in some specific stretches. It is applied for deepening a single channel and closure of a secondary channel.

9.6 Demand Side Development and Issues

The demand for IWT services largely emerges from domestic demand for transport services for passenger traffic and cargo. Yet, the geography of Bangladesh, whereby it sits in-between two parts of India creates an important demand from India in the form of demand for transport to facilitate transit trade between the western and eastern parts of India through Bangladesh. This demand involves all major modes of transport but demand for river transport is particularly attractive in view of its low cost. Within domestic demand this involves both domestic trade and inland container traffic linked to international trade.

9.6.1 Domestic Demand

The Bangladesh Bureau of Statistics provides data on the flow of passenger and freight traffic by IWT (**Table 9.25**). The BBS data suggest that following a period of relative stagnation between FY1996 and FY2005, there was a recovery in the activities of IWT for both passenger service and cargo during FY2006-FY2012. However, this progress was stunted in FY2012-FY2014. The slowdown in IWT service demand is symptomatic of the binding constraints emerging from the supply side including poor river navigation channels, safety standards and low quality service.

Table 9.25: Total Number of Passengers and Cargo Handled by Inland Waterways

Year	No. of passengers (in millions)				Volume of Cargo Handled (Million Tonnes)
	Motor Launch	Steamer	Ferry Service	Total	
FY1996	58.17	0.95	8.89	68.01	5.69
FY1997	67.15	0.77	11.32	79.24	5.93
FY1998	76.03	0.88	10.89	87.80	5.58
FY1999	65.72	0.97	5.39	72.08	5.87
FY2000	66.95	0.89	6.52	74.35	5.86
FY2001	86.29	0.85	8.08	95.17	5.89
FY2002	86.24	0.94	9.60	96.79	5.90
FY2003	66.56	1.18	11.40	79.14	7.93
FY2004	76.16	1.11	13.34	90.61	8.08
FY2005	49.47	1.08	13.99	64.54	11.59
FY2006	166.50	1.11	17.05	184.66	17.80
FY2007	177.62	0.94	17.84	196.40	20.50
FY2008	190.30	0.89	17.80	208.99	25.51
FY2009	199.80	0.80	17.33	217.93	26.77
FY2010	220.19	0.89	17.73	238.79	27.12
FY2011	231.52	1.00	17.90	250.52	32.60
FY2012	333.09	0.80	17.09	350.98	35.86
FY2013	232.75	0.75	16.75	250.25	18.77
FY2014	139.27	0.60	16.16	156.03	22.02

Source: BBS, 2015

Data on BIWTA earnings from major service routes is provided in **Table 9.26**. The review suggests that 4 IWT ports are particularly active and significant for both passenger and cargo: Dhaka, Narayanganj, Mawa and Aricha-Daulatdia. The Dhaka and Narayanganj are full service river routes connecting this major industrial and commercial belt with the rest of the country. On the other hand, Mawa and Aricha provide mainly ferry services for road traffic.

Table 9.26: Passenger and Cargo Throughputs of River Ports (BDT in million)

Port	FY2012		FY2013		FY2014	
	Passengers	Cargo	Passengers	Cargo	Passengers	Cargo
Dhaka	19.05	6.00	21.11	6.70	20.55	7.53
Narayanganj	23.13	10.53	22.72	12.76	24.17	13.61
Khulna	0.72	8.01	0.65	6.64	0.67	6.05
Chandpur	2.10	0.42	2.27	0.47	2.28	0.50
Barishal	5.75	0.60	5.81	0.66	6.47	0.68
Patuakhali	2.12	0.12	2.11	0.12	2.32	0.18
Mawa	13.50		14.98		16.70	
Aricha-Daulatdia	11.48	5.34	14.88	5.35	14.24	5.57
Baghabari		1.13		1.03		1.06
Total	97.85	32.15	84.53	33.73	87.40	35.18

Source: Port Department, BIWTA, 2015

A large fleet of about 10,000 inland vessels are engaged in the carriage of goods and passengers. Besides, there are approximately 750,000 country boats powered by the pump engines operating mainly in the rural waterways.

9.6.2 Container Traffic in Inland Waterways

The international sea borne traffic in maritime ports is growing faster than the GDP growth in Bangladesh, the growth of tonnage is 10% per annum while the growth of container traffic 12% per annum. The Chattogram Port has a total of 41 berths including private and public terminals and lightering operations in the outer anchorage. At the three main terminals of the port, General Cargo Berths (quay length 2,131 m), Chattogram Container Terminal (quay length 450 m) and the New Mooring Container Terminal (quay length 1,000 m), handling is being conducted by private local terminal operators. Chattogram is the gateway port, handling more than 90% of international sea borne trade cargo. At the Mongla Port, there are 5 jetties, 5 mooring buoys, 8 anchor berths and 5 private jetty berths. The length of quay wall at Mongla Port is 940 m. In FY2015, the Chattogram Port handled a total volume of 61.73 million metric tonnes of cargo (**Table 9.27**).

Table 9.27: Cargo Handled by the Chattogram Port (metric tonnes)

Financial Year	Import	Export	Inland	ICD	Total	Growth (%)
FY2011	3,99,14,145	49,80,375	47,72,786	5,32,053	5,01,99,359	24.78
FY2012	4,935	47,16,374	65,48,490	5,72,141	4,80,21,940	-4.34
FY2013	3,83,12,028	50,59,640	60,87,947	4,57,559	4,99,17,174	3.95
FY2014	4,19,60,170	53,38,377	58,33,786	4,45,218	5,35,77,551	7.33
FY2015	4,89,41,406	58,39,986	64,69,673	4,74,800	6,17,25,865	15.21

Source: Chattogram Port Authority, 2016

In FY2013, about 70% of containers handled at maritime ports are destined for or originating from Dhaka/Narayanganj area being the main consumption and distribution center.

Growth of Container Traffic

Another key factor that demands the development of IWT would be growing container traffic in inland waterways. To meet the growing demand of transporting containers between Dhaka and maritime ports, utilization of inland waterways is very crucial. Railway suffers from capacity constraint and the road does not have bearing capacity to accommodate trailers, so all the studies conducted recently recommended for inland waterways. An Inland Container Terminal has already been developed through a joint venture project of BIWTA and Chattogram Port Authority (CPA) with an annual handling capacity of 116,000 TEUs which is to be followed by another 4 inland container terminals under construction by private sector.

The Pacific International, Japan estimated container traffic volume in the ports of Bangladesh at 3.33 million TEU, 8.52 million and 19.60 million respectively in 2020, 2035 and 2055 while modal split in IWT will be 38%. The number of inland container vessels will be 55 in the short term, 152 in the mid-term and 305 in long term. Number of container terminasl will be 5 in the short term, 10 mid-term and 24 in long term. Under the Bangladesh Trade and Transport Facilitation Program, the World Bank (2014)[30] projected container traffic for the period of 2021-2030, which is shown in **Table 9.28.**

Table 9.28: Projection of IWT Container Traffic (000 TEU)

Year	Setting Sail Scenario	The World Wears Bangla Scenario
FY2021	1,299	1,588
FY2022	1,402	1,763
FY2023	1,514	1,958
FY2024	1,635	2,175
FY2025	1,766	2,415
FY2030	2,469	3,790

Source: The World Bank Study on Chattogram Port Efficiency, 2014

Setting sail assumes growth potential of inland waterway is unlocked and modal share of IWT (containers in TEU) rises from 5 to 45%[31] over the period 2014-2018 and maintains share at that level. The World Wears Bangla allows for GDP growth to accelerate over previous trends but is below the Government of Bangladesh target of 8-10%. This clearly indicates that to meet the growing container traffic there is a need for an efficient inland water transport system.

9.6.3 Demand for IWT Services for Transit and India-Bangladesh Bilateral Trade

Existing Implementation of India-Bangladesh Inland Waterway Protocol

Table 9.29 presents total tonnage of cargo transported by Bangladeshi and Indian vessels from 2001-2002 to 2013-2014 and their shares. The table shows a tremendous growth of tonnage of bilateral trade transported under the provisions of the Protocol along with the movement of vessels of both countries (India-BD IWP). From the very beginning, participation of Bangladeshi vessels was few and was zero in most of the years up to 2000. Initially, participation was limited to

[30] KCT Pre-Feasibility Study

[31] World Bank estimated this forecast in its Report "KCT Pre-Feasibility Study" under Bangladesh Trade and Transport Facilitation Program, September 2014 (Para 3.3 Page 15). The Report indicated three forecasts: Scenario A: Anchored, Scenario B: Setting Sail and Scenario C: World Wears Bangla. Scenario A did not include any container traffic in inland waterways up to 2030.

BIWTC. The private sector came forward in the carriage of goods under Protocol from 2000 and gradually Bangladesh vessels were able to outnumber the India vessels.

Table 9.29: Movements of Vessels & Cargo under Protocol on Inland Water Trade & Transit

Year	Quantity of Goods Carried (tonne)		Total (tonne)	No. of Trips by Bangladeshi Vessels	No. of Trips by Indian Vessels	Total Trips under Protocol	Ratio of Goods Carried by Bangladeshi & Indian Vessels
	Bangladeshi Vessels	Indian Vessels					
1	2	3	2+3=4	5	6	(5+6)=7	
FY2002	47,858	58,170	106,028	170	258	428	45:55
FY2003	122,335	87,100	209,435	458	390	848	58:42
FY2004	121,926	61,627	183,553	372	120	492	66:34
FY2005	376,839	36,993	413,832	1,142	90	1,232	91:09
FY2006	538,020	--	538,020	1,492	00	1,492	100:00
FY2007	881,011	--	881,011	1,540	00	1,540	100:00
FY2008	994,345	1900	996,245	1,976	02	1,978	99:01
FY2009	930,094	14,328	944,422	1,329	11	1,340	98:02
FY2010	127,7436	4,474	1,281,910	1,918	16	1,934	99:01
FY2011	142,4767	12,697	1,437,464	2,063	21	2,084	99:01
FY2012	142,9444	55,558	1,485,002	2,033	36	2,069	96:04
FY2013	1,507,357	46,661	1,554,018	1,977	32	2,009	97.03
FY2014	1,912,622	21,327	1,933,949	2,332	31	2,363	99 :01

Source: Traffic Department, BIWTA, 2015

Table 9.30 shows total tonnage of cargo of bilateral trade transported in inland waterways under provisions of PIWTT.

Table 9.30: Cargo of India-Bangladesh Bilateral Trade (in tonne)

Year	Indian Vessel	Bangladesh Vessel	Total
FY2007	-	881,011	881,011
FY2008	1,900	994,345	996,245
FY2009	-	930,094	930,094
FY2010	-	1,277,436	1,277,436
FY2011	12,697	1,424,176	1,4,36,873
FY2012	55,558	1,429,443	1,485,001
FY2013	39,256	1,507,357	1,546,613
FY2014	18,953	1,912,622	1,931,575

Source: Traffic Department, BIWTA, 2015

It is very apparent that growth of inter-country trade cargo is very attractive. Total tonnage was more than 19 lac in 2013-2014 as against about nine lac in 2006-2007.

Cargo of Transit Trade

There are five transit routes under the Protocol:

i) Kolkata- Pandu
ii) Pandu- Kolkata
iii) Kolkata- Karimganj
iv) Karimganj- Kolkata and
v) Karimganj- Pandu.

The volume of cargo of transit trade transported mainly between Kolkata and Karimganj and between Kolkata and Pandu in recent years is presented in **Table 9.31**. The discontinuous pattern of transit trade through IWT shows high fluctuations in transit trade.

Table 9.31: Volume of IWT Transit Trade

Fiscal Year	Volume (tonnes)
FY2007	12,557
FY2008	8,230
FY2009	14,628
FY2010	4,474
FY2011	590
FY2012	2,695
FY2013	18,685
FY2014	2,373

Source: Traffic Department, BIWTA, 2015

9.6.4 Issues and Challenges

India-Bangladesh Cooperation: Protocol on Inland Water Transit and Trade (PIWTT)

One of the examples that already established cooperation between India and Bangladesh is the cooperation on inland waterway transportation. IWT through Bangladesh is an important and efficient way for India to link the millions of people of the seven northeastern states with the rest of the country. Due to geographical conditions, India's eastern states are only connected by a small land corridor with the rest of India. However, the northeast of India is also connected via the Brahmaputra and Barak rivers with the Bay of Bengal and consequently with the rest of India. To avoid cumbersome transport routes, India is interested in access to Bangladesh's inland river network.

After the independence of Bangladesh, the Governments of Bangladesh and India signed a Trade Agreement on 28 March, 1972. A Protocol on Inland Water Transit and Trade (PIWTT) between Bangladesh and India was signed on 01 November, 1972 and came into force from the date of the signature. The two governments have agreed to extend the protocol in 2015 for successive five year with the provision of its automatic renewal. Article VIII of the trade Agreement between Bangladesh & India and the features of the successor PIWTT are as follows:

- Carriage of cargo of bilateral trade and transit trade.
- Each country shall ensure smooth navigation in the route within respective jurisdiction and will extend necessary facilities required for navigation. Night navigation is allowed where such facilities exist.
- A total of eight routes are nominated in the Protocol. Main corridors are Kolkata-Narayanganj (cross-border trade); Kolkata-Karimganj (transit trade), Kolkata-Pandu (transit trade) and Karimganj-Pandu (transit trade).
- A total of 10 Ports of Call, five on each side; are agreed to load- unload the cargo of bilateral trade. These are on the Indian side (Kolkata, Haldia, Pandu, Silghat and Karimganj and on the Bangladesh side: Narayanganj, Mongla, Khulna, Sirajganj and Ashuganj).
- The routes between Sirajganj and Daikhawa (upstream of Chilmari near Bangladesh-India border) in the Northern delta section of the River Jamuna-Brahamputra and the routes

between Sherpur and Zakiganj in the North Eastern delta section of the Kushiara river are recognized by both sides as route being maintained primarily for the use of Indian transit traffic. The Government of India shall pay an agreed amount (now 10 crore BDT annually) of money towards cost of maintenance.

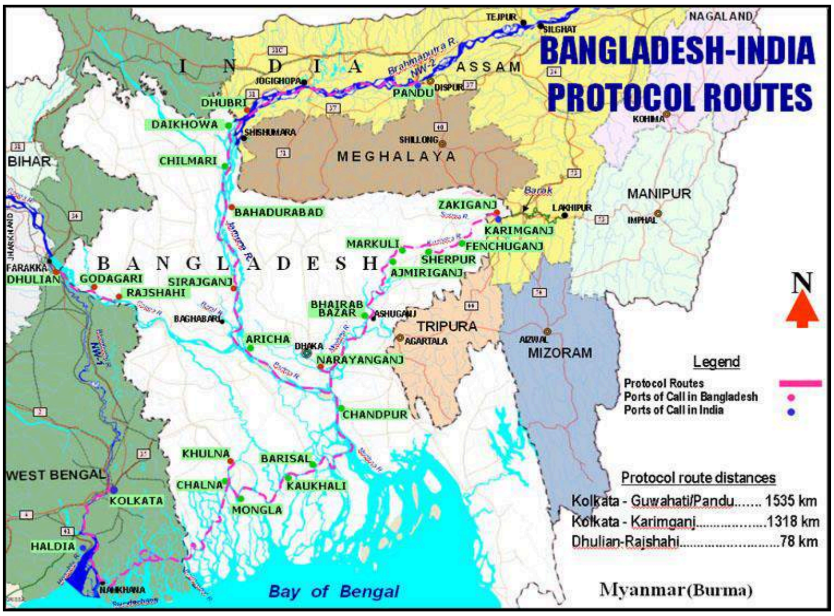
- Transshipment between vessel and truck is allowed at Sherpur and Ashuganj.
- There is one standing committee involving the representatives from Ministry of Shipping of Bangladesh and Department of Shipping, Ministry of Shipping, Road Transport and Highways of India, the Ministry of Finance of Bangladesh and India, BIWTA and BIWTC of Bangladesh and IWAI and CIWTC of India and the concerned customs officials of both countries to review the operation of the Protocol and to recommend for the development and will meet at least once in each six month.

The routes under the Protocol are reported in **Table 9.32** and **Map 9.1**.

Table 9.32: Key Routes of India-Bangladesh Inland Water Transit and Trade

1	Kolkata- Haldi - Raimongal- Chalna- Khulna- Mongla- Kawkhali- Barishal- Hizla- Chandpur- Narayanganj- Aricha- Siraganj- Bahadurabad- Chilmari- Shubri- Pandu- Shilghat
2	Shilghat- Pandu- Dhubri- Chimari- Bahadurabad- Sirajganj- Aricha- Narayanganj- Chandpur- Hizla- Barishal- Kawkhali- Mongla- Khulna- Chalna- Raimongol- Haldia- Kolkata
3	Kolkata- Haldi - Raimongal- Mongla- Kawkhali- Barishal- Hizla- Chandpur- Narayanganj- Bhairab Bazar- Ashuganj- Ajmiriganj- Markuli- Sherpur- Fenchuganj- Zakiganj- Karimganj
4	Karimganj- Zakiganj- Fenchuganj- Sherpur- Markuli- Ajmiriganj- Ashuganj- Bhariab Bazr- Narayanganj- Chandpur- Hizla- Barishal- Kawkhali- Mongla- Raimongal- Haldia- Kolkata
5	Rajshahi- Godagari- Dhulian
6	Dhulian- Godagari- Rajshahi
7	Karimganj- Zakiganj- Fenchuganj- Sherpur- Markuli- Ajmiriganj- Ashuganj- Bhariab Bazr- Narayanganj- Chandpur- Aricha- Sirajganj- Bahadurabad- Chilmari- Dhubri- Pandu- Shilghat
8	Shilghat- Pandu- Dhubri- Chimari- Bahadurabad- Sirajganj- Aricha- Chandpur- Narayanganj- Bhairab Bazar- Ashuganj- Ajmiriganj- Markuli- Sherpur- Fenchuganj- Zakiganj- Karimganj

Source: BIWTA, 2015



Map 9.1: India-Bangladesh Protocol Map

Source: BIWTA, 2015

9.6.5 *Current Routes and Shipments*

According to the (PIWTT, there are eight agreed routes on which both countries can make cross border goods transport as well as India can use several of them as transit routes. Recent BIWTA data suggests that since January 2015, a total of 2,599 shipments have been made, of them 21 shipments have used Bangladesh waterways as transit from Pandu to Kolkata. These routes are mainly used for importing fly ash (inputs for cement manufacturing) from India, about 99% of the above mentioned shipments have imported fly ash. Few have shipped stones, iron/steels and consumer goods. As of now, these routes have not been used for exporting to India. The major reason behind this is the lack of proper port facility and road transport to the river ports. Again, custom procedure is another reason for fly ash being the only imported item. As the cement manufacturing units are basically located by the rivers, it is very convenient for them to import fly ash through rivers. Threads/yarns/cotton can also be imported through these routes, but importers have to arrange necessary transport from the river ports to their factories. Custom procedures for imported products can only be administered at Khulna, Narayanganj and Ashuganj. According to the BIWTA authorities, there are some difficulties during the dry season along some of these routes.

9.6.6 *The Challenge of Setting Proper Transit Fees*

A panel of experts group set up by the Ministry of Commerce in 2011 advocated the proper transit fee based on cost of providing necessary infrastructure and other related services. This amounted to Tk 580/tonne. Subsequently, the Government of Bangladesh proposed to have a minimum rate of Tk 282/tonne. Finally, both the government agreed to set the fee at Tk 192/tonne.

Inland Waterway Protocol with Myanmar (Potential)

Bangladesh is planning to sign an Inland Water Transport Protocol (IWTP) agreement with Myanmar to increase connectivity aimed at boosting trade between the two neighbors. As per the protocol 25 non-conventional Bangladeshi ships would be able to transport goods through the rivers of Mayanmar while the same number of Myanmar ships would be plying the rivers of Bangladesh.

9.6.7 *Agreement on Coastal Shipping*

Rapid growth in bilateral trade between India and Bangladesh has led to congestion on the road at Indo-Bangladesh border and at the Land Custom Stations/integrated Check Posts. The traffic congestion at "Petrapole" and "Benapole" on the Bangladesh side has emerged as one of the biggest impediments to the movement of export-import (EXIM) cargo. Due to such congestion, the exporters/importers on both sides have been facing undue increase in the transportation cost. The present connectivity through sea route with Bangladesh is through ports of Colombo and Singapore. The long sea route adds significantly to the transportation costs of EXIM trade. Several Joint Technical Committee (JTC) meetings have led to an Agreement on Coastal Shipping between Bangladesh and India signed on 6th June, 2015. The cooperation in coastal shipping between the two countries would be based on the principles of national sovereignty, mutual benefits as per national laws and international conventions.

Advantages of the Agreement:

1) The opening of coastal shipping between India and Bangladesh would enable the movement of cargo to the North East through coastal shipping upto Chattogram and thereafter by road/inland waterways.
2) The deep draft ports on the eastern coast of India can be 'hub ports' for the onward transportation of cargo to Bangladesh via the coastal mode through River Sea Vessel (RSV) category of vessels.
3) The Indian ports will attract enhanced cargo and also the overall transportation cost to Bangladesh will get reduced.
4) The Indian ports serving as trans-shipment ports for Bangladesh cargo will derive benefits by way of enhanced throughput as a result of Indo-Bangladesh coastal trade.

Development of coastal shipping lines involving India and Bangladesh could further heighten the importance of inland waterway between the two countries.

9.7 Governance and Institutional Structure of IWT

9.7.1 Institutional Structure of Inland Waterway Transport

The institutional arrangements for development, maintenance, management and operation of inland navigation and inland and maritime ports in Bangladesh are shown in **Figure 9.6**.

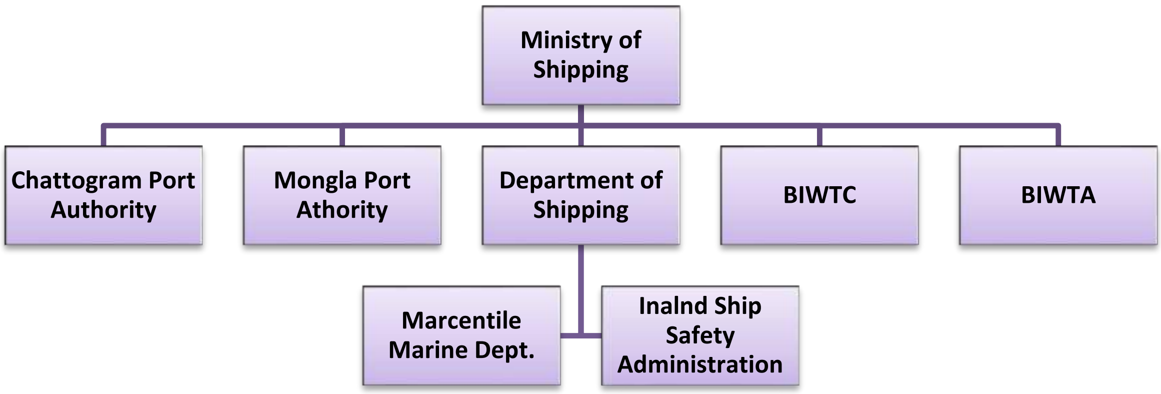


Figure 9.6: Organizational Structure

Source: Ministry of Shipping, 2015

Under the Ministry of Shipping, the Department of Shipping is a Government Department, while the others are semi Government autonomous organizations and were set up according to respective laws.

I) *Department of Shipping*: This department (DOS) was set up under the Merchant Shipping Ordinance, 1983. But under the Inland Shipping Ordinance, 1976 the Government delegated the powers and functions of inland ship safety, ship registration and survey to the DOS. Inland Ship Safety Administration (ISSA) under DOS is responsible for enforcement of ship safety and registration and survey of inland ships.

II) *Bangladesh Inland Water Transport Authority*: BIWTA is responsible for development, maintenance and control of inland water transport and navigable waterways. Main functions of BIWTA include:

(a) development and maintenance of navigability by dredging and river training,
(b) hydrographic survey,
(c) provision for aids to navigation and pilotage,
(d) development, maintenance and operation of inland ports and landing stations,
(e) approval of time tables and fare chart for passenger launches,
(f) operation of the IWT Protocol between Bangladesh and India, and
(g) research and training.

III) *Bangladesh Inland Water Transport Corporation*: BIWTC is a state owned corporation providing passenger and freight shipping services. Over the years with the growth of private sector in inland shipping main activities of BIWTC are concentrated in providing ferry services in major river crossings and passenger services in southern region and the coastal zone.

IV) *Chattogram Port Authority*: the CPA is responsible for improvement, management and operation of the main maritime port of Bangladesh: Chattogram Port.

V) *Mongla Port Authority*: the MPA is responsible for development, management and operation of the second maritime port: Mongla Port.

VI) *Payra Port Authority*: Payra Port will be the third maritime port located at Ramnabad channel in the southern Patuakhali District as decided by the Government. The PPA was set up by the end of 2013. A detailed feasibility study is now underway for development of port infrastructure.

Besides public institutions the following trade bodies in private sector are also involved in IWT sub-sector:

- Bangladesh Inland Water Passenger Carriers' Association (BIWPCA)
- Bangladesh Launch Owners' Association (BLOA)
- Bangladesh Cargo Vessels Owners' Association (BCVOA)
- Bangladesh Coastal Ship Owners' Association
- Bangladesh Oil Tankers Owners' Association
- Bangladesh Bulk-Head and Engine Boat Owners' Association
- Dredger Owners' Association of Bangladesh

9.7.2 *Management of IWT Sub-Sector*

DOS is responsible for ship safety, ship registration and survey while BIWTA exercise control of movement of inland ships in waterways and also of loading-unloading of passengers and goods at inland ports and landing stations. DOS employees have the legal power to take action against vessels committing offence against the law. A total of 62 DOS persons are engaged in inland shipping, as such they could hardly be seen in the port. On the other hand, BIWTA personnel remain present at ports and landing stations but they do not have the judiciary power to take actions against vessels violating laws and orders.

DOS has got only four surveyors to exercise control of ship construction and periodical survey of inland vessels. BIWTA undertake training programs for crew but certificate of competency to crew is awarded by DOS.

The Overlap of Responsibilities between BIWTA and DOS

BIWTA defines construction design, DOS certifies the same vessel after construction; crew members are trained by BIWTA but licensed by DOS. BIWTA issues some classification rules for ship operations with DOS monitoring these rules. All of these functions could be better executed by one of these two organizations. An adequate level of resources is required to ensure good sector management. Priority should be given to making enough human resources available to enforce safety regulation (controlling the technical quality of vessels design and construction, controlling overloading). An equivalent priority would be to provide the human and financial resources to monitor sector performance. Particularly important is monitoring of the waterways network as the last comprehensive hydrographic survey was carried out in 1989. Since then only surveys limited to the most important inland and coastal waterways have been carried out, and the present condition of the network of navigable waterways is unknown. As a result, planning is based on ad-hoc decisions without real sector perspective, objective information and technical and economic justification, making it difficult to resist political pressure. Improved monitoring would include environment for which equipment has been purchased during the past decade but has remained unused because of lack of human and financial resources.

9.7.3 Disparity in Budget Allocation and Utilization

The IWT had not been able to capture adequate budget allocation as it has not been a priority for development in Bangladesh. Against the modal share of 8.9% and 16% respectively in passenger and freight movement, the IWT received on average less than 5% of the total ADP allocation for surface transport (**Table 9.33**). This seriously affects its capacity to undertake dredging and other infrastructure maintenance activities inland waterways.

Table 9.33: ADP Allocation in the Surface Transport in Percentage

Year	Road	Rail	IWT
FY2010	76.20	20.57	3.33
FY2011	74.60	20.71	4.69
FY2012	64.55	31.03	4.42
FY2013	57.89	37.98	4.13
FY2014	71.42	25.47	3.11

Source: BIWTA Planning Department, 2015

On average IWT received 3.9% of total ADP allocation of surface transport. It should be mentioned that this is the best scenario in favor of IWT. Earlier IWT received on average only 1% of ADP allocation.

Similarly disparity prevails in BIWTA's expenditures. Most of BIWTA's expenditures are allocated for the central region, next to river crossing ferry points. Haor area in the northeastern region contributes 37% of national IWT output according to Haor Master Plan. But expenditures for maintenance of waterways and landing stations in the Haor area are the lowest in BIWTA'S budget.

BIWTA cannot always recover its cost from revenue. For example, in the FY 2013-14, the total revenue expenditure of BIWTA was BDT 3,164.06 million as against revenue earning of BDT 3,041.05 million, incurring a deficit of BDT 123.01 million. Of the total revenue earned by BIWTA, 55% on average comes from GoB grants and contributions.

The Government has prioritized the improved development and maintenance of the Class I routes and linked Class II and III routes along the Dhaka-Chattogram IWT corridor. It also has plans for a US$ 100 billion investment program, Capital Dredging Project in all major rivers for sustainable river management through extensive dredging programs to control river bed siltation and aggradations, reclaim land, and improve inland navigation.

Financial Management Issues

Financial management of BIWTA needs to improve for more efficient and transparent use of resources allocated to the sector. There is uncertainty on the actual cost of dredging executed by BIWTA. BIWTA estimates this cost at Tk 98 per m^3, which is in the range of unit costs in or outside Bangladesh. In view of the quantity of dredging performed by BIWTA (3.48 million m^3), BIWTA would have spent TK 341 million for dredging in FY2005, which is very low compared to BIWTA's total expenditures of Tk 1,115 million that year as dredging is supposed to be the main and most costly activity of BIWTA. The question would be then to justify the significant amount of resources that are spent on other activities than dredging, in particular administrative purposes. Revision of the sector's financing structure would also contribute to the more transparent and efficient use of sector resources. Presently, the Government finances maintenance of ferry channels without a clear view of performance and costs. On the other side, BIWTC operates ferry services with profits that are used to subsidize loss making coastal passenger services. It is proposed that coastal passenger services be subsidized only after the level and quantity of services as well as the level of subsidy have been defined, and incentives have been introduced to improve efficiency and control costs. Dredging of ferry channels executed by private contractors through contracts and financed by a fee paid by ferry users would also give a much clearer view of the costs, revenues and expenditures. Involvement of IWT users in management of resources for maintenance of navigable waterways would improve transparency in the decision-making process to allocate resources, and ensure adequacy of resources allocated to maintenance.

An IWT Maintenance Fund is envisaged in the draft Integrated Multi-modal Transport Policy has been discussed for some time in Bangladesh. While arrangements for the management and operation of the Fund will be confirmed by the Government, using the Road Maintenance Fund as a model, IWT users would be represented in the Board of Directors of the Fund and user fees paid by IWT users would be transferred directly to the Fund.

9.7.4 Management of the Country Boat Sector

Management of the country boat sector should be increasingly decentralized similarly to rural roads. Involvement of country boats owners in the decision-making process at the local level will improve the consistency between the sector investments and the needs. This has often been an issue in the past when infrastructure was not built in consultation with the users. Registration of country boats at the local level will also generate revenues, which can be used then for the benefits of the local population.

9.7.5 Improved Sector Governance

Analysis of the IWT sector has identified several sources of governance concerns that should be addressed. To improve the governance, there is a need to better control dredging expenditures (fuel consumption and overtime) as well as revenues collected from the passenger terminal fees and cargo fees. In addition, the Government needs to put in place the regulatory and control mechanisms to prevent misuse of Government funds that may occur as a result of increased private sector participation in port operations or dredging.

9.8 Developing a Dynamic Inland Water Transport System

In preceding sections a host of issues involving Bangladesh's river transport system was discussed. The analysis on economics of IWT suggests that river transport system of Bangladesh is an under-explored and under-invested area. As a result, the economy has not been able to exploit its full potential. More importantly, compared to other two modes of surface transport, road and railway, the share of IWT is on the decline, both in terms of passengers and cargo handling. The economics of IWT sector also provides rationale for development of an efficient IWT. IWT always remain on the top in terms of carbon saving. Moreover, from social perspectives, it contributes directly to social benefits nationwide by providing a relatively cheaper mode of transport and it also generates employment opportunities. Another key factor that demands the development of IWT would be growing container traffic in inland waterways in line with steady economic growth. To meet the growing demand of transporting containers between Dhaka and maritime ports, utilization of inland waterways is very crucial. Then there are new opportunities emerging from regional initiatives, primarily through the protocol on inland waterway between India and Bangladesh. More regional initiatives could emerge involving other countries in the near future depending on the progress of India and Bangladesh on the protocol on inland waterway.

However, development of a dynamic river transport system has been constrained by a number of issues, affecting navigability of waterways adversely. Some challenges are incremental dredging demand to maintain navigability, lack of infrastructure, non-compliance of guidelines for construction of bridge over the rivers, encroachment in the rivers, lack of safe vessels and skilled workforce, lack of policy guidelines, poor governance, inadequate budget allocation, lack of intermodal coordination, poor level of regional cooperation. Finally, navigability challenges further constrained by climate change which could exert even more pressure to maintain navigability in decades, if not years, to come.

Thus, any development plan of IWT should be based on increasing, if not uninterrupted, navigability of waterways. There are at least four sets of issues that policymakers should consider in developing an efficient IWT:

First, addressing river morphological and climate change issues. In this regard, policymakers need to address twin challenges emanating from both domestic as well as from cross border water management issues;

Second sets of issues relate to river transport infrastructure development. In this regard, the policy should be prioritising routing based on economic viability and those priority routes should be modernised and integral part of multimodal connectivity, among others.

Third sets of issues involve governance and investment issues, the former is critical to governing the sector for better functioning of the IWT system and the latter is critical to maintain navigability and develop modern facilities and human resources. Final sets of issues should focus on economics and governance of cross-border rivers, aimed at making the river transport viable. In this regard, the corresponding parties should have a clear roadmap on user fees, tariff rates, and joint efforts to develop infrastructure, among others.

9.8.1 Addressing River Morphological Issues

As it was discussed, the major rivers of Bangladesh influence the hydrological and morphological characteristics of other rivers significantly. Strategies to address the aforesaid problems should take region specific problems into account. In the Northwest region of the country, for instance, there should be plans to limit the impacts of human intervention such as the Teesta Barrage in India and Bangladesh, and groundwater abstraction, among others. In the North-central zone, policies have to address human-induced problems, particularly unplanned settlement, industrialization along the distributary rivers in this region and groundwater extraction. Similar problems exist in the Southwest and South-central regions owing to Farakka Barrage in India, construction of series of dams and coastal polders.

The holistic management of water resources involves several interlinking aspects: Regional Cooperation, Agriculture and Food Security, Fisheries, Ecological Settings and Biodiversity, Environmental Pollution, Land Resource and Population Management, Climate Change, Disaster Management, Coastal Development, Socio-economic implications of water resource management. All these aspects are intricately related with the River System Management issues. The existing knowledge gaps in developing long term plans for river management issues appear enormous. Training of the large rivers to ensure optimum utilization of river resources, river responses to climate change impacts, driving a balance between economic development and sustainability of the delta with onset of climate change, lack of information and uncertainty regarding upstream intervention and lack of sediment data, to name only a few, together constitute a substantial agenda for knowledge development in the river management sector.

9.8.2 Climate Change Adaptation

As discussed, climate change increases the cost of the maintenance of vessels and of infrastructure and allied services. The navigators of Bangladesh have adopted through experience to navigate in the deteriorating conditions of the river. Due to increased cost for maintenance of the vessels, owners have decreased the cost for safety. As a result, accidents have become regular incidents in inland navigation. To adapt with the growing threats of climate change the following are suggested:

- Dredging technique and dredging method should be determined in a manner that can adapt to the erratic conditions of the rivers due to climate change. Through morphological and social studies dredge spoil may be discharged to raise the river banks.
- For sustainable navigability river training works should also be carried out. Through practical experience it was evident that bandalling in some stretches of rivers may develop navigability to some extent. As such bandalling programs should be carried out where feasible.
- Facilities in the river ports and landing station should be made flexible in a way to adjust the changing conditions of the rivers due to climate change.
- Due to climate change rivers will be more meandering and river bed will be raised to such extent that will restrict smooth navigation. For adapting the changing condition of the river, design and dimension of vessels must be changed. The breadth of a vessel may remain unchanged but the draft and the Length Overall (LOA) must be changed. Deeper draft long vessels must be replaced by flat bottom with shorter LOA vessels.

9.8.3 River Transport: Priority Routing and Infrastructure Development

The river transport system of Bangladesh lacks modern infrastructure. Apart from inadequate facilities there is shortage of skilled manpower. However, given the resource constraints it is not advisable to modernize the entire IWT infrastructure, particularly the routes that are subject to seasonal volatility in terms of navigability and does not generate much revenue from passengers and cargo. Economic justification is there where large or medium inland vessels navigate. No rationale exists to augment the navigability in thousands of kilometers used exclusively by mechanized boats and the small size of inland vessels.

River corridors between Dhaka and Chattogram and between Dhaka and Ashuganj (with extensions to Narayanganj and Barishal) are identified as high priority routes for domestic trade and bilateral trade with India. About 80% of country's IWT transport is routed through these corridors and daily about 200,000 passengers use these routes. Inland river terminals at Dhaka, Narayanganj, Chandpur and Barishal along these routes play very important roles in transporting and handling passenger and cargo.

The cargo terminal at Ashuganj is a key terminal for Bangladesh – India trade and it is connected by road to the northeastern states of India. Cargo transport is heavily orientated towards imports and in volume terms, most is trafficked on the Class 1 river routes, primarily between Chattogram, Narayanganj and Dhaka. Given the importance of the route the MoS through the BIWTA is preparing the Project to improve the IWT sector along with related infrastructure. BIWTA has approached the World Bank for financing the project. The important works that are proposed, among others, under the Project are as follows:

- Dredging/river maintenance and provision of visual aids between Dhaka and Chattogram Corridor, including branches to Ashuganj, Narayanganj and Barishal;
- Maintenance dredging of the main river ferry crossing routes (Chandpur and Shariatpur; Lakshmipor and Bhola; and Beduria and Laharhat).
- Development of facilities and skills.

9.8.4 Integration of IWT with Multimodal Transport System

Development of a standalone waterway system is not enough. IWT has to be integrated with other transport modes. Due to lack of appropriate intermodal distribution system of containers, further traffic growth is restricted. Road, inland waterways and rail are components of surface transport sector of Bangladesh. Coordination and connectivity among these modes could provide a multimodal transport system to establish an uninterrupted transport chain for door to door services.

Development of roads and railways and the development of inland waterways had been conducted by three separate Ministries: Ministry of Roads and Bridges, Ministry of Railways and the Ministry of Shipping. Policies within the National Integrated Multimodal Transport Policy (NIMTP) to improve safety in Inland waterway sector are:

- Set up Deck Engine Personnel Training Center (DEPTC) for training of engine and deck hands;
- Ensure that water vessels are designed and built following correct design through modernization of design checking and involvement of naval architects;
- Reform and improvement of vessel registration system;

- Improve regulations and enforcement to prevent overloading of vessels;
- Ensure that vessels are provided with sufficient life saving devices;
- Ensure adequate vertical clearance in inland waterways for safe passage of vessels and providing Low Tension Lines and High Tension Lines to safe heights;
- Ensure addition of necessary equipment including Differential Global Positioning System to use electronic hydrographic chart;
- Ensure use of Digital Mobile Radio and wireless technology to ensure uninterrupted communication from bank to bank, vessel to bank and vessel to vessel; and
- Strengthen marine guards/marine police and establishing police station for waterways to ensure security of passengers and freight.

9.8.5 Integrated Transport Logistics

Availability of integrated logistics in the entire transport chain is the pre-condition of intermodal connectivity. Domestic traffic of cargo by waterways suffers from lack of logistics in this sub-sector. Except a few jetties developed and operated by private sector companies on a dedicated basis, the present system of loading/unloading of cargo at public jetties is mainly by means of head load, because, inland ports and landing stations are not connected with road or rail. The distance between the jetty and the place of waiting truck is such that it restricts opportunity of direct transfer of cargo required for uninterrupted transport chain. To address these drawbacks an integrated transport logistics has to be developed.

9.8.6 Increasing Investment in IWT

Budgetary constraints

The IWT has been least priority area in budget allocation compared to roads and railway. It does not receive adequate budgetary allocation in line with its modal share of passenger and freight movement vis-a-vis the road and railway sector. This financial constraint seriously affects its capacity to undertake dredging and other infrastructure maintenance activities inland waterways. Thus, budgetary allocation for IWT has to be increased to financing dredging, infrastructure and skill development.

Determining dredging needs based on river morphological and economic, not political, priorities

The current method of determining the Annual Dredging Program is not the result of a comprehensive hydrographic survey. In reality knowledge gap of current conditions of navigability of inland waterways exists as data were not updated nor any comprehensive hydrographic survey conducted since 1989. Therefore, it is not possible to ascertain the accurate volume of dredging required for the maintenance of classified IWT Routes unless a fresh hydrographic survey is conducted.

There exists hardly any objective manner or method for preparing an Annual Dredging Program on the basis of available resources both financial and logistics. Opinions or requirements are received and listed. However, the final dredging programs are prepared not according to any prescribed method. It is apparent that political choice prevails while finalizing the program ignoring the needs of important inland waterway routes. Thus, it is imperative that given the budgetary and other financial constraints, dredging needs should be met based on morphological needs and economic merits. Moreover, it is evident that half of the fund allocated for the maintenance dredging goes to the ferry routers total length of which not more than 100km, the remaining for Class-I to III Routes with the length of 3,600 km. Thus, the budget for dredging of ferry routes should come from the Roads and Highway Department budgets.

9.8.7 River System management and Making Cross-boundary IWT Viable

Sustainability of IWT is highly dependent on the availability of adequate water in concerned rivers, particularly during dry seasons. As Bangladesh is located in the low-lying delta of the Ganges- the Brahmaputra- the Meghna basins, water resources management is complex and very much dependent on upstream developments. As discussed, upstream infrastructural developments and water diversion projects are expected to have a notable impact on the dry season flow. All these plans, if implemented, will impact the water availability in Bangladesh as well as the ecological condition of the rivers. Thus, the ongoing or forthcoming projects in various parts of the Ganges- the Brahmaputra- the Meghna basins, particularly in upstream regions, coupled with climate induced vulnerability imply that Bangladesh has to cooperate with India and other upper riparian countries to ensure water flows during dry seasons to facilitate irrigation and navigability, among others.

Nevertheless, as mentioned, India's growing interest in connecting its Northeastern parts with its mainland through inland waterway flowing between the country and Bangladesh opens new opportunity to devise more predictable cross-border river management mechanisms.

However, there remains knowledge gaps related to water resources and international developments. To adequately assess the potential impacts of transboundary development on water resources, the following knowledge gaps with relation to transboundary rivers have to be studied further.

A documented understanding of the impacts of various infrastructure scenarios of the Inter River Linking Project on:

- Low and high flows in the Ganges, Brahmaputra, Teesta (and other minor) rivers
- Sediment availability and river morphology
- Groundwater recharge from cross-border aquifers and transboundary river systems
- Climate variability and climate change in the whole the Ganges- the Brahmaputra- the Meghna basin, affecting e.g. rainfall-runoff patterns
- Socio-economic developments, reflected in changing water requirements, upstream storage and consumption;
- Quantification of the demand: to determine the impact of periods of water scarcity (low discharge and rainfall) on different sectors, requirements at national level have been assessed (e.g. CSIRO 2015). Given the variation between the hydrological regions and expected impact of external drives, the demand needs to be quantified in detail at the level of each region for each of the key sectors.

What has become clear is that climate change, through increased sea level rise, increased flooding and increased sediment deposition, will change the paths of water ways in Bangladesh. Exactly what will happen is still unknown. It is essential more research is done to ascertain likely scenarios. To ensure adaptation to reduce the vulnerability to climate change on inland navigation and shipping, it is critical to bridge the knowledge gaps by conducting a study to ascertain the impact of climate change on inland water transport (navigability, port, landing stations) and to draw up an action plan for adapting to climate change and taking mitigation options.

9.9 IWT Strategy Aligned with BDP 2100 Goals

The BDP 2100 Vision and Goals indicate that a comprehensive strategy on the river transport system and navigation are required. It is clear that IWT already contributes significantly to the BDP 2100 Vision specifically on economic growth and to social demands regarding water transport. In **Chapter 6**, detailed strategies for the River Systems and Estuaries were provided. Strategy RE5 (Allow reliable and safe waterway transport) includes two relevant sub-strategies for the IWT sector: RE 5.1 Improve navigability of the river system and RE 5.2 Improve marine infrastructure facilities. There is also a strategy for sedimentation management. These strategies follow the Adaptive Delta Management approach and take into account several scenarios of climate change as well as socio-economic development of the country.

Strategies for inland waterway sector mainly include:

- *Develop reliable water system conditions for long term sustainable IWT through the capital and maintenance dredging of the rivers Padma, Meghna, Jamuna, Brahmaputra, Dharla, Arial khan, Kushiyara, Gorai, and Manu.*
- *Regular dredging should also be considered for Ghashiakhali and other channels in the Sundarbans.*
- *Ensure efficient and equitable use of sand through the regular shifting of the 'Balu-mahal' (sand quarry). The local administration should take necessary steps accordingly. Specific guidelines should be developed for the management of soil/sediment resultant from dredging.*
- *BIWTA to cooperate and coordinate with BWDB to provide optimal levels of surface water for navigation*
- *Develop the navigation network according to the societal and economic demands*
- *Develop, maintain & operate inland river ports, landing ferry ghats and terminal facilities in ports or ghats*
- *Contribute to dealing with trans-boundary water aspects by developing mutual understanding and cooperation*
- *Development of riverine and maritime ports*
- *Initiatives for activating transboundary waterways*

Specific sectoral strategies to achieve better utilization of the potentialities of the IWT network and services need to incorporate the following:

1. Strategy for improvement and development of the physical system
   a. Address deteriorating conditions of rivers and natural morphological processes
   b. Increase productivity by innovation next to manual labor based operations
   c. Increase intermodal capacity, connectivity and coordination; develop road network in coherence with and support of IWT
   d. Improve IWT in coherence with water management at national and regional levels
   e. Construction of bridges and culverts in compliance with navigation standards and requirements
   f. Replacement of riverside consolidation centres of cargo by Growth Center Markets developed by LGED
   g. Physical measures to reduce marine accidents
2. Strategy on IWT related institutional strengthening
   a. Increase investment by Government in IWT sector

b. Improve management capacity of IWT related organizations
c. Provide effective governance mechanism to increase efficiency and decrease corruption
d. Increase mutual trust and respect for public-private-partnership
e. Stimulate private sector participation in strategic and maintenance dredging
f. Stimulate and develop container traffic between maritime ports
g. Recognize importance of country boats and improve provisions for their effective use
h. Take measures to prevent from overloading of vessels due to unhealthy competition and regulated pricing policy
i. Increase participation of development partners in investments in IWT
j. Measures to reduce number of marine accidents
k. Measures to reduce pollution by ships, landing places and ports

3. Strategy on Knowledge Management and Research
   a. Knowledge gaps regarding modernization of IWT e.g. research on future transport demands
   b. New classification of waterways
   c. IWT services with respect to new land reclamation and economic zones

9.10 Goalwise Elaboration of IWT Strategies, Sub-strategies and Projects

Dynamizing IWT and port development can be achieved in relation with BDP 2100 Goals as outlined below.

Goal 1: Ensure Safety From Floods and Climate Change related Disasters

This goal focuses on managing the risks of floods and other climate change related disasters in the Delta at a well-defined and acceptable level. This level is set relation to IWT strategies and measures:

Strategy 1.1: Develop reliable water system conditions for long term sustainable IWT and economic development

Short term measures: Provide a flood and climate change resilient operational environment for shipping, ports and related facilities;

Medium term measures: Ensure the performance of key societal and economic functions of IWT.

Goal 2: Enhance Water Security and Efficiency of Water Usages

Maintaining a balance between economic development, an expanding population and the need to secure water for multifaceted uses is the core of this goal. The goal aims to ensure reliable and available water to support equitable and sustainable economic development including waterway transportation, environmental sustainability and livelihood security. This includes with respect to river transport system and navigation:

Strategy 2.1: Cooperate and coordinate with BWDB to provide optimal levels of surface water for navigation

Short term measures:

- Coordination on water levels and necessary measures to be taken

Medium term measures:

- Renew river classification and standards
- Coordinating maintenance of water levels.

Long term measures:

- Ongoing maintenance dredging.

Strategy 2.2: Increase water use efficiency across whole IWT sector and ensure sustainable water use

Short term measures:

- Promote recycling and safe reuse of water with latest technology
- Small-scale water harvesting techniques at large ports including recycling / safe reuse of water

Medium term measures:

- Full coverage small-scale water harvesting in all ports and landing places

Long term measures:

- Advanced water supply and sanitation system and wastewater treatment in all ports and ships

Strategy 2.3: Control pollution, ensuring water quality and provide sustainable and safe water supply and sanitation systems

Short term measures:

- Improve water quality by reducing pollution
- Installation of appropriate water supply mechanism in ports to ensure safe drinking water (including gravity flow systems, water harvesting and tubewells where applicable)
- Application of sustainable water supply for boats
- Motivational work for proper sanitation practices on boats

Medium term measures:

- Water supply and sanitation, including solid waste management in ports, landing places and ships
- Improve water quality by reducing pollution

Long term measures:

- Advanced water supply and sanitation system and wastewater treatment in all ports and ships

Goal 3: Ensure Sustainable and Integrated River Systems and Estuaries Management

This goal considers sustainable integrated management of river systems and estuaries, considered as one of the cornerstones of the Bangladesh Delta. The river systems of the country offer key development ingredients for the economy, society and the environment. With respect to IWT, sustainable rivers and estuaries management as a whole should contribute to: 1. Short, medium and long term solutions for navigation, 2. Land reclamation in support of economic growth, taking into account importance of navigation routes and port development, 3. Inter-connected major and minor river systems and navigation routes for social and economic development.

Strategy 3.1: Develop the navigation network according to the societal and economic demands

Short term measures:

- Conduct traffic surveys to establish passenger and cargo requirements on the main rivers, feeders and creek routes
- Reclassify the inland waterways network according to sustainable navigability and traffic importance.
- The core waterways should include fairways between maritime ports and central regions, economic zones and intra-regional routes
- Dredging Master Plan with prioritization and phasing to be prepared
- Implementation should be done in short and medium term. The maintenance dredging is also needed during and after the dredging period. Class I and part of Class II and Class IV (especially for retention) will be completed in the short term
- Increasing the implementation capacities of BIWTA and BWDB play an important role here also in relation to PPP-opportunities.
- Carry out river conservancy works including river training works for navigational purposes and for provision of aids to navigation including marks, buoys, lights and semaphore signals.

Medium term measures:

- Conduct traffic surveys to establish passenger and cargo requirements on the main rivers, feeders and creek routes
- Reclassify the inland waterways network according to sustainable navigability and traffic importance. Classify network into two categories: National and Rural. Rural waterways should include local and rural routes
- The core waterways should include fairways between maritime ports and central regions, economic zones and intra-regional routes
- Implementation of remaining Class II together with Class III and IV routes will be completed in the medium term
- Carry out river conservancy works including river training works for navigational purposes and for provision of aids to navigation including marks, buoys, lights and semaphore signals

Strategy 3.2: Contribute to integrated management of rivers

Short term measures:

- Draw up programs of dredging requirements and priorities for efficient maintenance of existing navigable waterways and for revitalization of dead or dying rivers, channels, or canals, including development of new channels and canals for navigation
- Prepare a dredging strategy for the short term to accommodate and stimulate economic growth, to support implementation of the BDP 2100 targets of the river strategy and to justify investments (e.g. also purchasing and operation of dredgers), considering:
    1. Evaluate the impact of dredging works in terms of maintenance required after the works are executed to ensure that the depth will be maintained; and

2. As component in an integrated River Systems and Estuaries Strategy, the main issues of IWT supporting economic development and social functions should be safeguarded balancing with other aspects of river management. The need for river engineering and capital dredging for navigation (e.g. channelization) may in certain instances conflict with activities of river control works.

- River and khal restoration
- Integrated sediment and erosion management; local erosion control by using hard materials
- Reduce silt; silt traps, remove debris
- Carry out river conservancy works by river training works for navigational purposes and providing aids to navigation: install marks, buoys, lights and semaphore signals

Medium term measures:

- Prepare a dredging strategy and dredging program for the medium term to accommodate and stimulate economic growth, to support implementation of the BDP 2100 targets.
- Management sediment supply to the rivers
- Manage river beds to levels required for navigation
- River erosion control by creating green belt along banks

Strategy 3.3: Develop, maintain and operate inland river ports, landing / ferry ghats and terminal facilities in ports or ghats

Short term measures:

- Carry out removal of wrecks and obstruction in inland navigable waterways
- Coordinate and integrate programs of BIWTA with BWDB and LGED in relation to navigability, dredging and port development
- Provide and further improve pilotage and hydrographical survey services

Goal 4: Conserve and Preserve Wetlands and Ecosystems and Promote their Wise Use

Strategy 4.1: Safeguard and maintain the wetlands including its ecosystems and also to ensure quality of water in relation to pollution by water crafts and ports.

Some of the components to be safeguarded under the goal are mangrove forests, water and riverine ecosystems, coastal greenbelt, seasonal and perennial wetlands, tidal freshwater frontier, etc.

Goal 5: Develop Effective Institutions and Equitable Governance for In-Country and TransBoundary Water Resources Management

The goal aims to improve the existing governance in relation to navigation. Key strategic elements include:

Strategy 5.1: Mainstream IWT

Short term measures:

- Ensure adequate financing for investment, operation and maintenance by adequate short, medium and long term strategy sectoral development and sound project preparation in relation to economic and societal transport demands
- The IWTA Ordinance provides for an Advisory Committee on matters relating to the development, maintenance and operation of IWT and inland waterways in Bangladesh. Since this Advisory Committee has never been formally created after 2000, the advisory, coordinating and mainstreaming function should be taken up.
- Minimizing the gaps between planning and implementation
- Support integrated water resource management at regional and local levels, taking into account the interests of all prominent water users
- Disseminate navigational and meteorological information including publication of river charts. Exercise knowledge development for integrated decision-making through modeling, data and information sharing and management
- Conduct traffic surveys to establish passenger and cargo requirements on the main rivers, feeders and creek routes

Strategy 5.2: Prepare and implement capacity building and institutional strengthening to professionalize IWT-performance and sector in relation to stakeholders

Short term measures:

- Develop need based Capacity Building and Strengthening Program at National level, including possible proposals for reforms and restructuring
- Strengthen local and regional institutions for navigation and port management
- Involve stakeholders in participation at all relevant levels:
- Involve sector stakeholders in the preparation of the three-year ADP, especially for the identification of development priorities
- BIWTA and BWDB should work closely together when drawing up programs for effective coordination
- Coordinate, set and enforce standards for bridges: increase coordination of different public authorities to ensure sufficient clearance under bridges
- Stimulate participation of owners of country boats in design of sluice gates and navigation locks
- Encourage local authorities to develop facilities through self-financing by user charges

Strategy 5.3: Enhance private sector participation in the IWT sector

This strategy includes port O&M, development of IWT infrastructure, dredging and maintenance of waterways, mechanization of cargo handling, development of inland container terminals and container traffic in the waterways.

Short term measures:

- The existing lease arrangement should be replaced by a mid term and long term concession arrangement to private stevedores and terminal operators to encourage investment for better services to users and maintenance of facilities. BIWTA should not involve itself in toll or revenue collection, rather will monitor performance of private operators. Infrastructure at commercially attractive places should be developed and operated by private sector or on a PPP basis. BIWTA should continue to develop landing stations in rural areas and in coastal areas;

- BIWTA should concentrate more in preparing dredging strategies and programs on the basis of comparative traffic importance against available resources. Actual dredging could also be performed by the private sector. BIWTA should restrict itself in procurement of dredgers, it should rather lease out the existing fleet to private sector;
- Installation of aids to navigation and maintenance in core waterways could be awarded to private sector. Pilotage service should also be awarded to private sector;
- Appropriate support should be given to private sector for construction of inland container terminals and for development of container traffic. Determining tariffs at such terminals should be deregulated and operators must have independence to fix an attractive and competitive tariff. Operation of Pangaon Container Terminal should be leased out to private terminal operator.

Strategy 5.4: Streamline the existing regulatory mechanism of inland ship safety and ship construction.

Short term measures:

- Ship design, supervision of ship construction, awarding survey certificates, determining workforce required for each ship should be licensed to qualified private firms.
- The Department of Shipping should concentrate more on monitoring performances of such private firms appointed for the purpose. Competency certificates to different categories of crew should be awarded by training institutes after successful completion of service and training modules for each category.

Strategy 5.5: Contribute to dealing with transboundary water aspects by developing mutual understanding and cooperation to attract more regional and intra-regional traffic in the waterways of Bangladesh.

Short term measures:

- Under the existing Protocol on Inland Water Transit and Trade between Bangladesh and India, the following joint initiatives and assurances should be committed by both Governments:
    a. Improve navigability of existing routes and identify new routes. Upstream cooperation and commitment to maintain navigability in the downstream routes.
    b. Identify most economic and efficient transport chain and establish connectivity with other modes.
    c. Identify the benefits of this regional IWT cooperation on socio-economic and environmental aspects.
    d. Find out the appropriate technology to improve efficiency of inland navigation.
    e. Identify the requirements for amendment, simplification, waiver of existing procedures.

Strategy 5.6: Early warning, storm surge and flood risk preparedness

Short term measures:

- Revision of cyclone / storm-surge warning systems
- Harmonize flood patrolling / fighting procedures
- Development of community based early warning and forecasting systems
- Flood hazard zoning and building conditions (incl. flood proofing): mapping and enforcement
- Plans for shelter and evacuation optimization, establish disaster management social groups

Goal 6: Achieve Optimal and Integrated Use of Land and Water Resources

The primary aim of the goal is to ensure efficient integration and proper interaction between land and water use aspects. The goal would mainstream the inter-connected resource functions including navigation. The key topics covered by the goal are land use, water use, multi-modal transportation infrastructures, navigation network, port connectivity and utilities, etc. Establishment of connectivity of water courses, and inducing integration between different modes of resources interactions are highly encouraged under this goal.

Strategy 6.1: Prepare and implement a sustainable IWT-vision and strategy

Short term measures:

- Prepare a short term, up to 2030 vision and strategy based on sustainable navigability and traffic importance to ensure sustainable development of IWT in line with the Integrated Multimodal Transport Policy
- Develop rural water transport by stimulating modernizing and mechanizing of country crafts
- Improve Transboundary IWT
- Ensure co-ordination of Inland Water Transport with other forms of transport, with major sea ports, and with trade and agricultural interests for the optimum utilization of the available transport capacity;

Medium term measures:

- Renew IWT-vision and strategy based on economic, social and environmental advantages

Strategy 6.2: Promote renewal and innovation of IWT sector and fleet

Short term measures:

- Maintain liaison with the shipyard and ship repair industry to meet the requirements of the Inland Water Transport fleet repairs and new constructions over time, incorporating new technologies, larger dimensions, etc.;

Strategy 6.2: Promote development of maritime ports

Short term measures:

- Analyze the economic and financial return of port investments
- Development of a deep sea port is indispensable to keep the growth moving in Bangladesh
- Efficient transport links to central region are required for development of traffic through Chattogram and Mongla ports

- More private sector involvement should be ensured through experience worldwide that demonstrates that Bangladesh maritime ports should apply a landlord model under which public port authorities should withdraw themselves from day to day operations and focus on regulation, planning, investing and market promotion
- At all container terminals International Terminal Operators (ITO) should be engaged who will be responsible for all categories of container handling equipment
- Private sector involvement initiative
- Empowering port authorities
- Substantial reduction in import related processing time
- Increase container storage charges
- Private ICDs used for import
- Introducing automated system for customs data

Addressing the River transit fees: GATT rules and best practices

The growing importance of cross-boundary river transit suggests the need to develop a proper policy for river transit fees based on international good practice.

Article V of the GATT 1994 lays down the following agreed principles governing transit trade:

1) "There shall be freedom of transit through the territory of each contracting party via the routes most convenient for international transit, for traffic in transit to or from the territory of other contracting parties. No distinction shall be made which is based on the flag of vessels, the place of origin, departure, entry, exit or destination, or any circumstances relating to the ownership of goods, of vessels or any other means of transport"

2) "Any contracting party may require that traffic in transit through its territory be entered at the proper custom house, but, except in cases of failure to comply with applicable customs laws and regulations, such traffic coming from or going to the territory of other contracting parties shall not be subject to any unnecessary delays or restrictions and shall be exempt from customs duties and from all transit duties or other charges imposed in respect of transit, except charges for transportation or those commensurate with administrative expenses entailed by transit or with the cost of services rendered."

3) "All charges and regulations imposed by contracting parties on traffic in transit to or from the territories of other contracting parties shall be reasonable having regard to the conditions of traffic."

4) "With respect to all charges, regulations and formalities in connection with transit, each contracting party shall accord to traffic in transit to or from the territory of any other contracting party treatment no less favorable than the treatment accorded to traffic in transit to or from any third country."

However, Article V rightly recognizes that there may be genuine costs of providing transit access by the host country that must be recognized and compensated by the guest country. These costs are identified in Article V to include: (a) transportation services (if used); (b) administrative expenses (e.g. costs of inspections etc); and (c) charges for use of services. Of these three categories, the third is most significant for determining transit fees. Even if guest countries use their own transport facility (ships, trucks or trains), transit may involve the use of port services, road services, or rail network services from host countries. These are economic services the provision of which requires real resources in terms of investment in fixed assets as well as financing of operation and maintenance. Accordingly, guest countries are obliged to pay user fees for these services in the transit process.

Best Practices

There are several best practices in some countries and region for suitable transit fees but mostly based on road transits.

The Royal Government of Cambodia and the Government of the Socialist Republic of Vietnam signed Waterway Transportation Agreement 2010 on December 19, 2009[32]. According to the agreement, following rules and regulations mandated on transit and other facility fees -

1. No dues of any kind may be levied anywhere on the regulated waterways and in ports and terminals, other than proportional dues in the nature of payment for specific services effectively rendered to vessels. These dues shall be as low as possible.

2. Without prejudice to paragraph (1), vessels engaged in transit transportation shall pay a formality fee, a channel fee and, in case pilotage services are used, a pilotage fee.

3. Without prejudice to paragraph (1), vessels engaged in cross-border transportation shall pay a formality fee, a channel fee, a tonnage fee, and, in case pilotage services are used, a pilotage fee.

4. Vessels using the regulated waterways shall not be liable to pay any other due, tax or fee of any kind other than those specified under paragraphs (2) and (3).

5. The tariffs of fees referred to under paragraphs (2) and (3) shall be adopted by the Competent Authorities of the Contracting Parties in conformity with the laws and regulations of the respective Contracting Parties.

The agreement also mandates to form a The Mekong Navigation Facilitation Committee that will review the tariff/dues according to following decree –

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[32] For details see, The Agreement between the Government of the Socialist Republic of Vietnam and the Royal Government of Cambodia on Waterway Transportation. Available at: http://www.mrcmekong.org/assets/Publications/policies/agreement-waterway-trans-btw-Cam-n-VN-Eng.pdf

Cross border rules and regulation. Ministry of Public Works and Transport, Cambodia. Available at: http://www.ciwn.mpwt.gov.kh/index.php?option=com_content&view=category&id=28&layout=blog&Itemid=40&lang=en

a. Regularly and at least annually review the tariffs and make proposals for harmonisation to the Contracting Parties, whereby the tariffs in force upon entry into force of the present Agreement shall serve as a basis for the first revision;

b. Elaborate proposals for the introduction of more advantageous rates for regular users, such as reductions or fixed periodical rates.

Institutions to strengthen cross-border IWT

There has been a tremendous growth of tonnage of bilateral trade transported under the provisions of the Protocol along with the movement of vessels of both countries. As India and Bangladesh further strengthen their trade relations and pledged to increase connectivity, the importance of IWT is likely to grow in years to come. However, to support bilateral and transit trade as well as transhipment, more needs to be done in terms of institutional development to govern the two-way waterborne trade and passenger movements. Experience from Europe suggests that with a comprehensive dedicated regulatory framework, active involvement of a wide range of stakeholders and adaptation of new technology, sustainable navigation is possible and can be the basis for the economic development in a river basin.

The Protocol on Inland Water Transit and Trade that guide India-Bangladesh waterway trade and transit has identified eight routes and 10 Ports of Call. Moreover, transshipment between vessel and truck is allowed at Sherpur and Ashuganj under the protocol. Moreover, India is paying Bangladesh to dredge its water ways. While these are some significant achievements, there is a need for a joint institution to sustain the process as India-Bangladesh relations often affected by political changes in these countries. Moreover, given the lack of coherent policies of the centre and state in India, Dhaka often finds difficulties to deal with multiple actors as far as its Indian counterparts are concerned. An institution akin to the Central Commission for Navigation of the Rhine (CCNR) that regulates navigation on the Rhine could overcome the problems that India and Bangladesh face with regard to cross-border waterway connectivity. CCNR, for instance, regulates navigation on the Rhine, maintains good conditions for navigation, promotes ecological inland navigation and develops laws involving inland navigation. In doing so, it has developed navigation police rules / traffic rules, formulated criteria for the vessels sailing on the Rhine, provided guidelines and rules for crews and personnel.

Similarly, the Protocol can also learn from the legal framework for cross-border navigation between Vietnam and Cambodia in the Mekong Delta. The Treaty signed between the two countries in 2009 legally binds Cambodia and Vietnam to reducing the official restrictions that have existed for cross-border navigation. The agreement will also put in place a range of measures for ensuring river traffic safety and regulating the transportation of dangerous goods by river. By standardizing rules and regulations, the MRC claims that there will be a considerable improvement to the safety of the shipping of oil and hazardous liquid cargoes, port services and safe navigation. Both countries have agreed to grant to each other's vessels “most favoured-nation treatment”.

9.11 Concluding Remarks

The preceding analysis has highlighted the critical importance of inland water navigation system as an integral part of Bangladesh’s future development agenda. The growing domestic demand for inland water transport services which could be further accentuated by rapid growth of container traffic and greater prospects of cross-border trade and transit clearly indicates that the development of IWT is an economically viable option. IWT is also environmentally friendly and consumption of fossil fuel is four to eight times lower than that of roads. Strategic shifts towards cost-effective IWT could be a win-win proposition for sustainable development, a commitment that Bangladesh has made to the UN SDG of 2030. Clearly, IWT is in a position to contribute significantly to the Government effort for sustainable growth and reduction of poverty given the rural people's heavy reliance on this mode of transport. However, the analysis in the present study has also revealed that inland navigation is becoming hazardous and waterways are shrinking rapidly as the flow of waterways has become alarmingly erratic due to significant siltation in the rivers. This calls for addressing a host of issues discussed in this study at length, in particular navigational challenges including climate induced vulnerability and unpredictability in cross-boundary water flow. Other supply side challenges namely inadequate investment, lack of multimodal transport system with modern logistics facilities, skill shortage and regulatory issues, among others, also need to be addressed to modernise the country's IWT system.

Budgetary resources allocated to IWT have hitherto fallen short relative to the importance of this sector in the nation's economic activities. The current road-focused transport development strategy, which is reflected in the government's budgetary allocation, needs to be rebalanced making the country's transport sector de facto multi-modal. Investment in dredging and other critical infrastructure requires sound strategies based on economic merits. The transport development strategy should take into account the rise of capacity and number of sea ports in the country which should be linked with rail and road infrastructure.

Managing cross-boundary river systems for transport and trade adds complexity to the issue of riverine transport but also opens enormous opportunities through the development of cross-boundary institutions and regulatory framework. This Plan has therefore highlighted the lessons to be drawn from two promising institutional frameworks, namely, Europe's Central Commission for Navigation of the Rhine, and The Mekong River Commission in Southeast Asia. In light of the rapidly growing between Bangladesh and here neighbours and the concomitant issue of river transit facilities, the development of cross-boundary inland waterways along with effective managing institutions and proper legal framework has gained significant importance going forward.

To conclude, dynamizing Bangladesh's river transport system for the 21st century will require the confluence of four critical strategies: (a) managing the nation's hydrological resources and the river system, (b) adapting to climate change impacts on river morphology and channel configurations, (c) developing institutions and establishing legal framework for cross-boundary navigation for seamless movement of goods and people, and d) adopting sound investment and financial management policies.

Chapter 10

Urban Water Management

Chapter 10: Urban Water Management

10.1 Urban Water Management Challenge

Bangladesh has been experiencing rapid urbanization during the last few decades. This has been accompanied by continuous increase in demand for water in cities and towns of the country. As Bangladesh becomes more industrialized and urbanized, the demand for fresh water has grown. Bangladesh has also been quite successful in meeting this demand to a large extent by the concerted efforts of the government, non-governmental organizations, development partners and the general public (consumers). There are, however, a number of major challenges that must be addressed if the urban water supply systems are to be sustainable.

Around 30% of the urban population get piped water supply while the rest have to depend on household-managed hand pumped tube-wells (BBS, 2012). The primary source of piped water is also groundwater that is extracted using deep tube-wells. This over-dependence on groundwater is making tube-wells vulnerable to falling water tables. Treatment of surface water has also become difficult due to industrial and other pollution sources. Financial viability of existing water supply systems is also threatened by low tariff rates and huge losses of water due to leakage illegal connections, etc. The issue of water quality is challenging for both urban and rural water supply. Along with water supply, the issues of urban waste management, sanitation and drainage will increasingly become chronic. Progress in these areas has been more limited. Financial and institutional arrangements for handling these challenges are weak. Growing urbanization pressure will further stress these institutions.

Overcoming these challenges would require integrated water management strategies. It will require strong resource mobilization effort and appropriate institutional arrangements to tackle the expanding demand for basic urban services in a rapidly changing urban environment of the Bangladesh Delta. This Chapter focuses on issues of water supply, sanitation, waste management and drainage issues of the urban hotspots of the Bangladesh Delta.

10.2 Urban Water Management and Sustainable Development Goals (SDGs)

SDG 6 calls for ensuring the availability and sustainable management of water and sanitation for all. The targets for achieving this goal include the following:

- By 2030, achieve universal and equitable access to safe and affordable drinking water for all.
- By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.
- By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.
- By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.
- By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.

- By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.
- By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.
- Support and strengthen the participation of local communities in improving water and sanitation management.

As one of the 193 member states involved in adopting the UN Resolution No. A/RES/70/1 through a deliberative process, Bangladesh is committed to work hard for reaching the SDGs to "end poverty, protect the planet, and ensure prosperity for all". In particular, SDG 6 provides an opportunity for policy makers to mobilize collective efforts to improve water management for the benefit of people and protection of environment. Reaching the water-related targets for implementation of SDG 6 would require undertaking of concrete actions on a number of water topics: access to safe drinking water and sanitation, wastewater and solid waste management as well as management of storm water. However, to achieve the targets one needs to analyse the current situation, identify the issues and challenges, formulate strategies and translate the strategies into concrete actions.

10.3 Urban Water Supply

10.3.1 Source of Water Supply

Bangladesh has made significant progress in the supply of improved water in both urban and rural areas. According to the Joint Monitoring Programme (JMP) Report 2014 of WHO/UNICEF for Water Supply and Sanitation, the improved water supply coverage in urban areas as percentage of total population has increased from 81% in 1990 to 86% in 2012. The details of the water supply coverage as per the report is presented in **Table 10.1**.

Table 10.1: Water Supply Coverage

Year	Total Improved (%)	Piped onto Premises (%)	Other Improved (%)	Other Unimproved (%)	Surface Water (%)
1990	81	23	58	17	2
1995	82	25	57	16	2
2000	83	27	56	16	1
2005	84	29	55	15	1
2010	85	31	54	15	0
2012	86	32	54	14	0

Source: JMP Report, 2014.

The Multiple Indicator Cluster Survey (MICS) report 2012-2013, however shows same difference in the improved water supply coverage as shown in **Table 10.2**. In urban areas about 99% of the household are covered by improved water source. Coverage of households by piped water is a little bit lower compared to JMP report. This difference may be due to the difference in the methodology adopted for estimation of the coverage. It may be noted that the coverage of population by improved water source is reasonably high.

Table 10.2: Water Supply Coverage in Urban Areas, MICS Report, 2012-13

Location		Improved water source (%)		Unimproved water source (%)
		Piped water	Other improved source	
Division	Barishal	0.7	94.6	4.7
	Chattogram	3.6	93.4	3.0
	Dhaka	16.5	83.4	0.1
	Khulna	2.3	92.1	5.6
	Rajshahi	4.2	95.1	0.7
	Rangpur	0.7	99.2	0.1
	Sylhet	3.5	90.3	6.2
Area	Urban	28.7	70.4	0.9
	Rural	1.3	96.3	2.4
Total		***7.0***	***90.9***	***2.1***

Source: Compiled by BDP 2100 Technical Team, GED, 2015

Coverage does not necessarily indicate the quality of service to the people. There are significant variations across urban centers in term of piped water supply. In Dhaka, for example direct connection coverage is 87% whereas in Sherpur, a small town, it is only 22% (WHO/UNICEF, 2014). There are also quite significant variations across cities of different sizes in terms of water production and consumption. In Dhaka, production of water per capita per day (lpcd) is about 180 litres while in Sherpur this amount is only 85 litres. Per capita consumption of water is however, less than production due to losses. In Dhaka per capita consumption per day is 127 litres while in Sherpur this amount is 68 litres indicating that unaccounted for water is about 30% in Dhaka and 20% in Sherpur. Existence of many illegal settlements and illegal connection in low-income communities are largely responsible for higher proportion of unaccounted for water in Dhaka. **Table 10.3** presents data on coverage of population by piped water supply, production, consumption and loss of water in 7 city corporations and 31 paurashavas grouped according to population sizes. It may be noted that the coverage of population by piped water is lower in smaller urban local bodies (ULBs) and higher in larger ULBs. In Paurashavas with population less than 100 thousand, only 37% of the population is covered by piped water supply while in city corporations with more than one million people (Dhaka and Chattogram) 64% of the population get piped water supply on an average.

Table 10.3: Piped Water Supply -Coverage, Production, Consumption and Loss of Water

Population Size (in thousands)	Type of Urban Local Government	Number	Average Coverage (% of population)	Average Production (liter/capita/day)	Average Consumption (liter/capita/day)	Loss of Water (Unaccounted forWater (%)
Less than 100	Municipality	21	37	101	78	22
100 to 299	Municipality	10	51	88	71	21
300 to 999	City Corporation	05	40	97	69	27
1000 and more	City Corporation	02	64	152	113	25
	Total	***38***	***42***	***100***	***77***	***23***

Source: World Bank (WSP), 2014

10.3.2 Adequacy of Water Supply

Adequacy of water depends on the norms of water in terms of litres of water per person per day (lpcd). In Bangladesh, there is no specific norm or standard to judge the adequacy of water. Accessibility of population to an improved water source is considered as an indicator to evaluate the performance of water supply system. In India, the Central Public Health and Environmental Engineering Organization (CPHEEO) suggested norms for water supply are to be followed by Indian cities and towns while designing water supply schemes. These are as follows:

Table 10.4: Water Supply Norms for Indian Cities

Classification of Towns/ Cities	Recommended maximum water supply levels (lpcd)
1. Towns provided with piped water supply but without sewerage system	70
2. Cities provided with piped water supply where sewerage system is existing or contemplated	135
3. Metropolitan and Megacities provided with piped water supply where sewerage system is existing/contemplated	150
4. Towns with spot-sources/ stand posts	40

Source: CPHEEO, 2012

Above figures exclude unaccounted for water (UFW) which should be limited to 15%. Comparing these figures with production and consumption of water (lpcd), an assessment can be made of the adequacy of water in different cities and towns. The World Bank study (World Bank, 2014) found that nearly 45% of the cities and towns without sewerage system have supply levels lower than the recommended level. This observation, however, is valid only for population covered by piped water supply. As shown in **Table 10.5**, some 42% of the population of 31 (21+10) municipalities and 7 (5+2) city corporations are covered by piped water. Moreover, nearly 66% of these ULGBs supply piped water to less than 50% of their populations while the rest 34% cover more than 50% of their population. In municipal areas about 45% of the people get water supply from household managed hand pumped tubewells.

Table 10.5: Distribution of Urban Local Government Bodies (ULGBs) by Water Consumption

Population Size (in thousands)	Type of ULGBs	Number	Distribution of ULGBs by Water Consumption		
			Less than 70 lpcd	More than 70 lpcd	Total
Less than 100	Municipality	21	8 (38.1%)	13 (61.9%)	21 (100%)
100 to 299	Municipality	10	6 (60%)	4 (40%)	10 (100%)
300 to 999	City Corporation	05	3 (60%)	2 (40%)	05 (100%)
1000 and more	City Corporation	02	0 (0.0%)	2 (100%)	02 (100%)
Total		***38***	***17 (44.7%)***	***21 (55.3%)***	***38 (100%)***

lpcd = litres per capita per day

Source: World Bank (WSP), 2014

10.3.3 Sources of Water Supply

In Bangladesh, groundwater accounts for over 90% of the drinking water supply sources. Groundwater in most cases does not need treatment while surface water cannot be used for drinking purposes without treatment because of pollution from agricultural, industrial, domestic and municipal sources. At present, groundwater accounts for about 78% of total water supply in Dhaka. At present, the groundwater is extracted by using a total of 644 deep tubewells. Surface water, which accounts for about 22% of total water supply in Dhaka, is supplied by treating water of the river Sitalakha and Buriganga through four water treatment plants (**Table 10.6**)

Table 10.6: Water Supply Status in Dhaka City

Source of Supply	2010 – 2011	2011 – 2012	2012 – 2013
Deep Tubewells (No)	585	615	644
Water Treatment Plant	4	4	4
Water Production/Day	2150 MLD	2180 MLD	2420 MLD
Water Line	2800 km	3040 km	3040 km
Water Connection (No)	3,02,132	3,10,314	3,25,317
Hydrant (Active)	38	38	38
Roadside Taps (No)	1643	1643	1643

MLD - Million Litres per Day; km. = kilometers.

Source: Dhaka WASA

However, Dhaka WASA's strategic plan is to reduce dependence on ground water through the implementation of some ongoing projects by providing surface water treatment plants (SWTP). By the year of 2021, Dhaka WASA wants to use 70% of water from surface water source and 30% of water from ground water extraction. Following the Water supply master plan, Saidabad Phase-III will be implemented by 2020 and it's water treatment capacity will be 450 MLD. SWTP in Gandharbapur will be established in three phases with total capacity of 1500MLD. Among them, phase-I will be operational during 2020 and phase II and phase III will be implemented by 2030 and 2035, respectively. Padma (Jashaladia) SWTP phase I and phase II will be operational by 2020 and 2030, respectively with a total capacity of 900MLD.

The status of water supply of other five city corporations is given in **Table 10.7**. Out of these five city corporations, three city corporations (Chattogram, Rajshahi and Sylhet) have treatment plants to supply a small proportion of total water demand from surface water sources.

Table 10.7: Water Supply Status in Other Cities under WASAs

WASAs	Estimated Population in 2010 (million)	Daily Water Production (m^3)	GW Source (No. of PW)	SW Source (No. of TP)	Pipe line (km)	House Connection (Number)	Supply Hours	Improved Coverage by Piped Water Supply (%)	Basic Coverage by Piped Water Supply and Water Points (%)
Chattogram	3.31	200,000	73	1	556	46,299	12	41	46
Khulna	1.26	35,000	56	-	227	15,300	12	45	85
Rajshahi	0.61	75,190	49	1	512	26,000	12	73	84
Sylhet	0.42	16,890	18	1	145	9,892	12	40	69
Barishal	0.30	10,721	18	-	165	9,852	12	40	45

GW- groundwater; PW- production well; TP- treatment plant;

Source: Water and Sewerage Authority (WASA), June 2009: Status Report

The status of water supply in municipalities is given in **Table 10.8**. Piped water supply covers only 40% of the population while the rest 60% get water using 152,077 hand pumped tubewells in 102 paurashavas.

Table 10.8: Piped Water Supply Status in Paurashavas, 2009

Items	Amounts
Number of Paurashavas having Piped Water Supply	102
Total Population in the 102 Paurashavas in 2009	7.93 million
Total Water Production	238,542 m^3/day
Total Number of Hand pump Tubewells	152,077
Total Number of House Connections	175,532
Number of Street Hydrants	3,355
Supply Hours	2-12 hours
Population served by Piped Water Supply	40%
Population covered by Piped Water Supply and Hand pump Tubewells	85%

Source: DPHE, 2010

10.3.4 Water Tariff and Cost Recovery

Tariff for water supply varies considerably between cities. Although tariff for water should ideally cover operation and maintenance cost of the system as well as capital costs, in many cities and towns the operation and maintenance cost is not recovered. Water is provided in many urban areas at very low rates and in most cases the rates are not revised regularly to reflect the prevailing cost. **Table 10.9** presents average revenue, average cost and average cost recovery (revenue-cost ratio) by municipalities and city corporations of different population sizes. Average revenue for 38 urban local bodies is Tk. 8.12 per cubic meter of water while average operating cost is Tk. 5.48. As the amount of revenue is larger than cost, average cost recovery is greater than 1, that is, 1.48. This, however, does not mean that all the urban local bodies get enough revenue to cover cost.

Table 10.9: Cost of and Revenue from Water Supply

Population Size (in thousands)	Type of ULGBs	Nos.	Average Revenue (Tk. per cubic metre)	Average Cost (Tk. per cubic metre)	Average Cost Recovery (Revenue/Cost)
Less than 100	Municipality	21	06.38	5.66	1.13
100 to 299	Municipality	10	07.15	5.03	1.42
300 to 999	City Corporation	05	16.60	4.43	3.75
1000 and more	City Corporation	02	13.70	8.51	1.60
Total		38	08.12	05.48	1.48

Source: World Bank (WSP), 2014

Table 10.10 presents the distribution of 38 ULGBs by cost recovery. Some 11 ULGBs have revenue cost ratio less than 1.00 which indicates that nearly 30% of the ULGBs do not generate enough revenue to cover operating costs. Cost recovery rate for 4 city corporations and 4 paurashavas exceed 1.50 or more than 150% of the cost required for supplying water. This constitutes about 21% of the sampled ULGBs.

Table 10.10: Distribution of ULGBs by Cost Recovery

Population Size (thousand)	Type of ULGB	Nos.	Cost Recovery (Revenue/Cost)		
			Less than 1.00	1.00 to 1.50	More than 1.50
Less than 100	Municipality	21	06 (28.6%)	12 (57.1%)	03 (14.3%)
100 to 299	Municipality	10	03 (30.0%)	06 (60.0%)	01 (10.0%)
300 to 999	City Corporation/ WASA	05	02 (40.0%)	01 (20.0%)	02 (40.0%)
1000 and more	City Corporation/ WASA	02	00 (0.0%)	00 (0.0%)	02 (100%)
Total		***38***	***11 (28.9%)***	***19 (50.0%)***	***8 (21.1%)***

Source: World Bank (WSP), 2014

10.3.5 Capital Investment Requirements

According to the United Nations Development Report of 2006, every US dollar invested in water and sanitation provides an economic return of eight US dollar on average. WHO estimated that the return on US$ 1 invested in water intervention to achieve the MDGs would be US$ 3.5 while the return on investment to achieve universal coverage would be US$ 3.70. The Urban Water Sector Development Plan (2011) prepared by LGD of the Government of Bangladesh determines investment requirements of urban water supply for short (FY2011-2015), medium (FY 2016-2020) and long (FY 2021-2025) term targets. For calculating costs, three scenarios were developed (**Table 10.11**) which are as follows:

Table 10.11: Service Level and Operating Efficiency Indicators for Urban Water Supply

Scenario	Service Level Indicators					Operating Efficiency Indicators		
	Coverage by Piped Water Supply (% of Population)	Supply (hours per day)	Per Capita Consumption (l/day)	Water Quality in Terms of Arsenic (mg As/l)	Water Quality in Terms of Bacteria (Bacteria /100 ml)	UfW (%)	Staffing (Staff / 1000 Connection)	Collection Efficiency (%)
Scenario 1 (Base Case)	45-95	<6	<70	Up to 0.05	>10	>35	>13	<75
Scenario 2 (Moderate)	60-100	12-24	70-100	0.05-0.01	>0-10	20-35	10-13	75-95
Scenario 3 (High)	75-100	24	>100	<0.01	0	<20	<10	>95

Source: Local Government Division, 2011

Scenario-1 represents the current sector condition characterized by low service level and low operating efficiency. *Scenario2* shows moderate service level and moderate operating efficiency. *Scenario-3* is characterized by high service level and high operating efficiency. If the socio-economic and institutional conditions are taken into account, then scenario-2 appears to be a more realistic and achievable option during the plan period (2011-2025). Total investment costs of urban water supply for this scenario were estimated at Tk. 714,945 million, out of which Tk. 165,220 million would be required for short term (2011-2015), Tk. 280,467 million for mid-term (2016-2020) and Tk. 269,257 million for the long term (2021-2025).

10.3.6 Institutional Arrangements for Urban Water Supply

In Bangladesh, the constitutional responsibility of the Water Supply and Sanitation (WSS) lies mainly in government's hand. Predominantly, this responsibility is bestowed with the MoLGRD&C. It remains accountable for a large portion of the main implementation and supervision responsibilities regarding public sector WSS in the country, mainly through its subordinate departments. But the tasks of policy making, decision assembling, sectoral allocation and funding, as well as project appraisals, approval, evaluation and monitoring are shared with the Ministry of Planning and the Ministry of Finance.

For major infrastructure development and operations, the functional responsibility is assigned to DPHE in all urban and rural areas, except Dhaka, Chattogram, Khulna and Rajshahi. In these large cities, separate Water Supply and Sewerage Authorities (WASAs) are accountable for the connection and conservation of services facilities. The Dhaka WASA also provides services to the city of Narayanganj. All WSS outside WASA areas are covered by the DPHE. It constructs water supply facilities for the municipalities and transfers ownership of infrastructure to the concerned municipality after three years of joint operation without any charge for the capital cost recovery. Non-recovery of capital cost leads to low tariff charge by the municipalities for the service. DPHE also provides low cost sanitary materials to poor households for the construction of sanitary latrines with the vision of ensuring 100% sanitation coverage in the country. Provision of technical assistance to the local bodies like Pourashavas and City Corporations (except WASA areas) is also considered to be its foremost concern.

Relevant WASAs are responsible to undertake necessary water supply and sanitation programs in Dhaka, Chattogram, Narayanganj, Khulna and Rajshahi city areas. Any type of program like infrastructure development, installation and maintenance of water and sanitation management system in the respective areas becomes their primary vision. The activities of the Pourashavas Water Supply Sections (PWSS) are mostly confined to the operation of pumps and reactive maintenance of the existing systems. These agencies only remain project and hardware-based lacking orientation in process-based approaches.

The City Corporations in Dhaka, Chattogram, Khulna, Sylhet and Rajshahi as well as municipalities in other urban centers have responsibilities also in the management, operation and treatment of wastewater and maintaining a sanitary environment within their boundary.

LGED shares its responsibilities in some urban centers with DPHE for water supply and sanitation services. To be specific, foreign aided projects where overall infrastructure package is explicitly required, LGED plays a significant role in collaboration with DPHE. In such externally supported integrated project-based cases, LGED provides vivacious assistance to the concerned municipalities in their execution activities and provides required technical assistance.

There are many NGOs who are working as active stakeholders in water and sanitation programs. They finance and implement a variety of water and sanitation programs in both urban and rural areas. They provide hardware support, advocacy, networking, institution building, training, information, research, evaluation and monitoring services. Private sector response in WSS service provisions is very promising since private hand pumps comprise almost 88% of total urban hand pumps. NGOs and private sector investment is mostly concentrated in the manufacturing, sale and distribution of different types of WSS components. They also contribute to the installation of piped water supply system, wherever feasible. DPHE, NGOs, private sectors and CBOs frequently collaborate with one another for the provision of better services in the WSS sector.

Most often, urban water supply and sanitation programs are comprehensively reinforced by the external support agencies like UNICEF, UNDP, World Bank, ADB and so on. In 2000s, some new stakeholders have arrived in the scene, notably the Bangladesh Municipal Development Fund (BMDF) and the Hygiene, Sanitation and Water Services (HYSAWA) Fund. These funds are registered as government-owned companies but so far have received financing and funding only from international agencies.

10.3.7 Existing National Policies and Plans for Urban Water Supply

National Policy for Safe WSS initiated in 1998 mainly focuses upon water supply procedures in urban and rural area. It states that in order to make the water supply system sustainable, water would be supplied at cost instead of being free and water tariff should be determined according to the cost of water production, operation and maintenance, administration and depreciation. Although it states that WASAs and Pourashavas shall be mainly responsible for operational and financial management, it promotes the role of the private sector and NGOs in urban water management. This policy also specified that WASAs and relevant agencies shall support the collective initiative of slums or squatters in accessing water supply services on payment. Finally, it articulates that efforts shall be made to upgrade the capacity of the Pourashavas and WASAs for planning, designing, implementation, management and human resource development and the DPHE shall have appropriate institutional linkage for this purpose.

National Policy for Arsenic Mitigation established in 2004 provides a guideline for the mitigation of the effects of arsenic on people and environment in a sustainable and all-inclusive way. It ensures the access to safe water for drinking and cooking through implementation of alternative water supply options in all arsenic affected areas. It accentuates that all arsenic-prone areas shall be analyzed, brought under an effective management system and impact of arsenic on agricultural environment shall be assessed thoroughly.

The WASA Act of 1996 defines the nature of WASAs as public corporations and their responsibility to deliver water supply, sewerage, and storm-water drainage services. It provides for autonomous corporate management structures of WASAs which are accountable to their Board of Directors representing a range of stakeholders. This act safeguards financial control over the authority by the Government of Bangladesh and allows WASAs to increase tariffs to a maximum of 5% every year which is subjected to the approval of the Government.

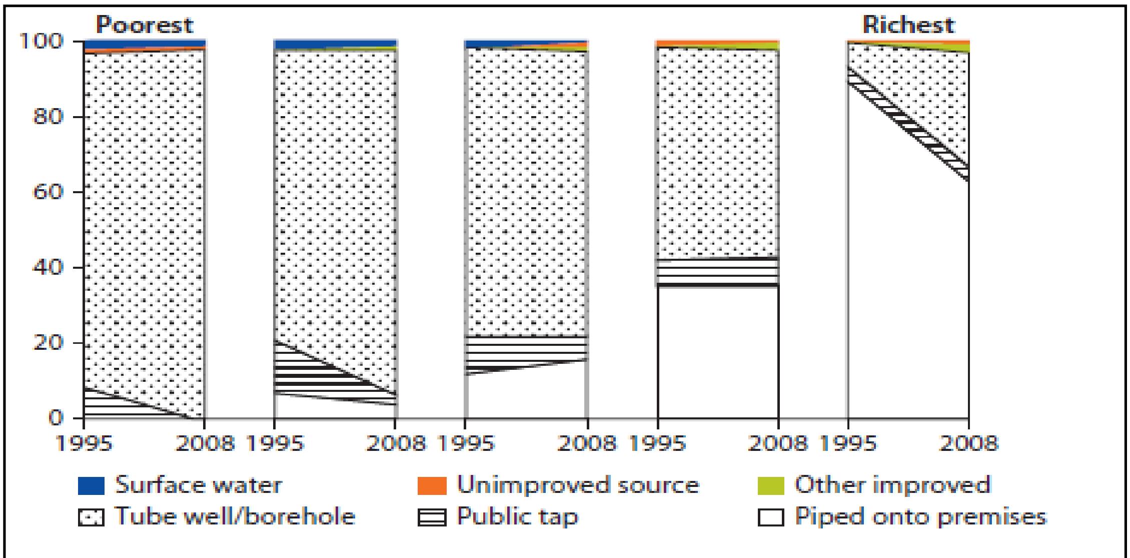
The Water Sector Development Plan (2011-25) of Bangladesh is considered as the strategic and planning document for the sector to achieve their national goals and targets (LGD, 2011). In this revised WSDP, a broader consensus has been built through a series of stakeholder consultations on a set of principles related to cost recovery, which include: a) operation and maintenance of the water supply and sanitation systems, b) adoption of cost recovery measures for WSS services in the shortest possible time, c) ensuring fairness and social justice among the customers and service providers, d) providing safety net for the poor and address the needs of women, children and people with disabilities.

10.3.8 *Issues and challenges*

Rapid Urbanization and Urban Poverty

Rapid growth of urban population poses a serious challenge for the urban institutions responsible for the supply of water. Piped water supply is available only in urban areas but the coverage reaches only about 40% of the urban population. As a consequence, people have to depend on shallow hand pumps connected to each household for drinking water. In most of the City Corporations and Paurashavas a significant proportion of households who are connected to piped water also rely on hand pumps for drinking water as the supply of piped water is intermittent and unreliable. The poor people especially the slum dwellers are the worst sufferers.

As **Figure 10.1** shows, people with lowest income (bottom quintile) depend entirely on tube-wells for drinking water. The situation is precarious in slums and squatter settlements. Slum dwellers in Dhaka reported paying per bucket of water (20 litres) several times the price paid by those who had the legal piped connection. In addition, the quantity of water the poor get is also insufficient. A study conducted by Human Development Research Centre (HDRC, 2009) as part of the urban component of the GOB-UNICEF Water and Sanitation Project revealed that in smaller cities and towns, most people (79%) use shallow tube-wells and 41% are not tested for arsenic. Only 10% of the households have access to municipal piped water. Households have to carry water for household consumption and different other purposes from an average distance of 156 feet. Only 40% of the households individually or jointly own the water source.



Source: JMP 2013.

Figure 10.1: Access to Urban Water in Bangladesh by Income Quintile, 1995 and 2008 (%)

Hard to Reach Areas (HRA)

According to the National Strategy for Water and Sanitation in HRA of Bangladesh (2011) about 21% of the total unions in the country have been identified as HRAs. These unions again have been categorized as extremely (582 unions), very (532 unions) and moderately (30 unions) HRAs. These are mainly hilly regions, islands (chars), coastal areas, beels and haors, tea gardens and water scarce areas.

Problems of water supply vary across various types of HRAs. In coastal zone, salinity of water and damage of water infrastructures due to cyclone, tidal surge and inundation of low lands are major problems. In char areas and wetlands people face natural disasters like monsoon floods, flash floods and river erosion on a regular basis washing away or damaging and polluting water infrastructures. Arsenic contamination of groundwater is also widespread. Barind areas are drought prone and face severe water scarcity during 4-5 months a year. Surface water sources (ponds, canals etc) in many cases dry up and groundwater levels decline during dry season. In hilly areas extraction of groundwater becomes difficult due to varying altitude and rocky formation. Water levels also fluctuate seasonally. In HRAs a large part of the population is poor and hardcore poor and therefore cannot afford to have expensive options. Inaccessibility to services is further compounded by the absence of adequate road communication network.

Climate Change Impact

People in Bangladesh are already experiencing climate-related shocks and stresses. Climate change is raising average temperatures and is likely to exacerbate extremes as well as causing new hazards such as sea-level rise. Poor people in particular are vulnerable to floods and cyclones to drought conditions and water scarcity. **Table 10.12** below summarizes the different climate change hazards and the impact on the water supply infrastructures in different ecological/ hydrological zones.

Gradual change phenomena such as temperature rise and erratic behavior of rainfall will cause major changes in the water cycle. Water sector in Bangladesh is already experiencing significant stresses of the natural hazards. Climate change related extreme events such as cyclones will damage water supply infrastructure while sea level rise and salinity intrusion will deteriorate water quality in the coastal regions (WSDP working document number 17, LGD, 2011).

Table 10.12: Main Climate Change Hazards and Impacts on Water Supply Installation in Different Zones

Ecological / Hydro-geological Zones	Main Climate Change Hazard	Impact on Water Supply Installations
Flood plain	-Water logging -Inundation	-Contamination of water sources -Damage to infrastructure
Low water table area	-Further decline of groundwater -More droughts	-Depleted water resources -Increase in repair and maintenance cost of water installations
Coastal Zone	-Saline intrusion -Tidal/storm surge -Inundation	-Damage to water installations -Increased salinity of groundwater abstracted by hand pumps or other means -Drainage congestion
Haor Basin/ Low lying area	-Water logging -Inundation	-Damage to infrastructure -Contamination of water sources
Chattogram Hill Tracts/ Hilly regions	-Drought -Excessive lowering of groundwater level -Increased rainfall -Land slide	-Depleted water resources -Damage due to land slides
Urban Areas	-Extreme heat stress -Urban flooding	-Damage to infrastructure -Demand peaking during hot summers -Contaminaiton of water sources

Source: Based on WSDP Working Document No. 17, LGD, 2011

The impacts of climate change should also be viewed in relation to other factors that will affect water demand and quality. Urbanization will place greater stress in water resources. When this will be combined with increase in summer temperature, water demand in urban areas for drinking and bathing as well as demand for water from industry, power, recreation and the environment will put tremendous stress on urban water supply systems. Economic growth will also increase water demand for all uses and far higher levels of services through piped water. Climate change will interact with these factors and in many cases magnify their impacts.

Groundwater Issues

It has already been indicated that groundwater is the main source of water supply accounting for about 90% of the total supply of drinking water in the country. Most sources of water supply are tube wells with hand pumps and motorized pumps sunk by households, water utilities and local governments. Over abstraction of groundwater is making tube wells vulnerable to falling water tables. The water levels of deep aquifers are dropping in many towns, especially in larger industrial areas in and around Dhaka. In Dhaka, groundwater level is declining by 2-3 metres per year due to continuous abstraction of water (WSDP 2011). As a consequence, Dhaka WASA has now started collecting water from the deep aquifer having depth equal to or greater than 1000 feet. The quality of the water is also an issue; many of the wells are contaminated with arsenic and bacteria. A study by International Training Network (ITN) of BUET and DFID found that 29% of shallow tube wells and 9% of deep tube wells are contaminated with bacteria (WSDP 2011). Poor maintenance of tube-wells and their surroundings and poor hygiene practice were found to be the main reasons for such a situation.

Management of Water Supply System Issues

Poor management of water utilities (WASAS and ULBs) as reflected in high water losses is also an important issue. Unaccounted for water averages 25% for Dhaka and Chattogram City Corporations and this proportion is even higher for other city corporations. The benchmarking study of Water and Sanitation Program (WSP) of the World Bank (2014) showed that out of 37 Urban Local Government Bodies (ULBs) only 10 had metered connections. Discontinuity of service is also a major problem of the water utilities. Service varies between 1.50 hours to 22.5 hours. About 24% of the ULBs supply water for upto 5 hours while about 54% of the ULBs supply water between 5 to10 hours. Collection of revenue is also a major problem for many of the ULBs. About 19% of the ULBs can collect upto 60% of the revenue while about 40% of the ULBs can collect between 61% and 80%. Collection rate for upper 40% of ULBs is between 81% and 98%. Periodic maintenance of the systems in most ULBs is also poor. As a consequence, leakages in pipelines are frequent and the conditions of pipes, wells and machineries deteriorate quite quickly. The problem is compounded by inability of ULBs to fix water rates commensurate with cost.

10.3.9 Water Supply Management Strategy

An integrated approach to water supply management is a better alternative to conventional water supply management. In the integrated approach, the gap between supply and demand is addressed through demand management, use of alternative water sources and use of soft measures to improve treatment while in the conventional approach the main emphasis is on increasing supply and treatment capacities. An integrated approach also takes into account the linkages between water supply and other urban management sectors such as health, energy, waste management, transport, parks and recreation, etc. Thus, the shift in approach from conventional to integrated water supply management can open up plenty of opportunities for a city to start developing a more sustainable water supply system. Some of the important Integrated Water Supply Management (IWSM) strategies include the followings:

Strategy WSS 1: Ensure Improved Governance and Increased Financial Sustainability in Water Supply Sector.

Successful operations in the water supply sector require: effective governance, operations, public service and revenues. Investment programmes must be paired or even preceded by some institutional restructuring and improved financial performance.

Sub-Strategy WSS 1.1: Provide effective water services

While the public need of suitable water supply service may impose public 'ownership' and authority (as is, for instance, the stipulation by law in The Netherlands), the service providers need to function effectively and efficiently. It is important that water operators have sufficient and predicable revenues to bear their expenses. In this regard it will be important that water supply revenue serves the purpose of water supply operations and capital investments, and is segregated from parallel municipal expenditure (roads, drainage, solid waste, etc.).

While GoB policy to introduce a regulatory authority for independent tariff setting could well be paired to corporatization, the sector needs would benefit from increased progress in its formalization and implementation.

Sub-Strategy WSS 1.2: Achieve Sustainable Water Supply

At present the water supply sector is not self-sustainable. In (almost) all cases revenue is insufficient to bear the full cost of both Operations and Maintenance and capital expenditure. In many cases revenue is insufficient to even allow for satisfactory Operations and Maintenance performance (paying for energy/chemicals for 24/7 service, allowing for budgets for leak repairs and meter replacements, etc.). It is required that the revenue position of water operators improves to enable them to offer a satisfactory service. It is necessary to have a spiral up effect (consumers are willing to pay (more) for good service), rather than going down further (consumers are unwilling to pay, and policy-makers are not keen to increase tariffs, while service is poor).

Sub-Strategy WSS 1.3: Include incentives for sustainable performance on sectoral funding

BDP 2100 recommends that sector funding includes incentives for sustainable performance. GoB and International Financial Institutions (IFI) funding to water supply projects could be made conditional to sustainable operations: water operators applying for funds should prove effective Operations and Maintenance performance, or provide evidence of confirmed tariff adjustments to ensure financial sustainability.

Sub-Strategy WSS 1.4: Adopt safety net tariff policy with suitable focus

Social concern (basic human needs) has prevented financial sustainability. To mitigate this restriction, block tariff systems with subsidized initial (low) consumption have been proposed. This is a sensible compromise to improve financial sustainability while 'protecting' low income user groups. The system must be focused however; specifically in serving low consumption categories.

Strategy WSS 2: Maximize Sustainable Exploitation of Groundwater for Domestic Water Supply

Groundwater will continue to be the preferred and obvious choice for water supply systems. Bangladesh will need to proceed on its policies to maximize its sustainable exploitation, and to ensure prioritized allocation to drinking water needs.

Sub-Strategy WSS 2.1: Develop Hydrogeological knowledge base

Good understanding of the country's groundwater resources is required. Presence, quality, flow patterns, recharge quantification, and hydro-geo-chemistry mechanisms need to be better understood and mapped. If funds for development and maintenance of this knowledge base cannot be released from central budget, financial arrangements need to be ensured in water resources exploitation to accommodate for this expense.

A particular field of further study is the hydro-geological behaviour of Arsenic. Current policy is to shift to alternative, low arsenic aquifers (deeper). Better understanding of the mechanisms of arsenic migration is required, as well as possibilities of its (en route) immobilization. These insights will substantially improve predictable safe yield applications.

Sub-Strategy WSS 2.2: Ensure sustainable allocation of groundwater amongst sectors

Initiatives must be taken to apply rightful share policy in water resources allocation, and to enforce its practice by levies, monitoring and sanctions among sectors.

Sub-Strategy WSS 2.3: Develop technology to remove Arsenic contamination

Arsenic is and will be part of Bangladesh' groundwater reality. Bangladesh will need to continue its participation in arsenic removal technology for both on site and centralized systems. In view of mid-term to long term development towards increased service levels (increased coverage by piped systems), ongoing trends towards centralized systems will accelerate in the years to come. In most cases, Iron Removal Plants (IRPs) will effectively remove arsenic content to acceptably low levels. An area that needs further improvement which is effective and safe (environmental) for handling and disposal of arsenic sludge. It is important that both the sector, as well as the general public, is aware that arsenic removal is a manageable technology.

Strategy WSS 3: Shifting towards alternative Water Sources

Groundwater resources are limited in some parts of the country, which will require a partial shift to alternative sources. For Bangladesh the obvious alternative in most instances will be surface water. Even apart from pollution/contamination, surface water poses a more complex technical challenge for safe drinking water production. Moreover, infrastructure layout will result in larger, centralized systems as compared to small/medium scale groundwater systems. Effective and successful sector shift towards surface water (or even other sources like seawater and wastewater re-use) will only be feasible with improved professional capabilities, and effective governance within the sector. The higher cost level of surface water systems will underline the need for increased financial sustainability.

Sub-Strategy WSS 3.1: Develop surface water based supply systems for major cities

Starting with Dhaka and Chattogram, Bangladesh will proceed on its (partial) shift towards surface water systems. This is inevitable, and desirable to cater for increasing municipal demand, while avoiding over exploitation of limited groundwater resources. The shift towards surface water systems needs to be supported by adequate technical, institutional and financial competence within the sector and its stakeholders.

Sub-Strategy WSS 3.2: Promote desalination and wastewater re-use

In the water supply sector, current revenue position is insufficient compared to unit costs required for advanced technology applications. However, specific regions (coast/salinity, Barind/scarcity) are recognized to pose resource challenges where advanced applications are required. Already small scale desalination is applied in Coastal Zone at effective unit prices that very much exceed common benchmarks in urban Bangladesh. Municipal need for (drinking) water will show the willingness to pay for reliable and safe water supply service.

While wastewater re-use may find some scope of application in Bangladesh, it is likely (as elsewhere in the world) that its application will be towards non-potable use purpose (industry, agriculture, non-potable municipal uses).

Strategy WSS 4: Stepping up the Service Ladder

Over 95% of Bangladesh population is reported to be served by improved water supply (although major improvement is still required with regard to arsenic exposure and faecal pollution). However, in achieving SDG ambitions, and in line with economic development (towards middle income status), GoB aims at further service development. In water supply, this may typically be constituted by a shift towards piped systems: the comfort of showers, flushed toilets, washing machines and other modern life amenities involves household water consumption levels that are neither easily nor economically provided from on-site systems. Gradually coverage by piped water supply systems will increase (cities → towns → villages → rural areas).

Sub-Strategy WSS 4.1: Expand piped system coverage

Piped system coverage needs to expand gradually in coming years from cities to towns, towns to rural areas. This requires competent, mandated service providers of suitable size and scale. The strategy to establish WASAs for major cities fits very well with this development. For towns (Pourashava's) similar arrangements need to be accelerated. For smaller villages, and rural areas, a regional service provider, possibly by extension from Pourashava providers, needs to be established.

Sub-Strategy WSS 4.2: Accelerate application of meter system in water supply

Low revenue collection, poor water quality and lack of regular O&M have restrained metering campaigns in Bangladesh. In BDP 2100, strategies to increase metering system need to be amongst the high priorities to improve the status and sustainability of the sector.

Sub-Strategy WSS 4.3: Reduction of Non-revenue Water

Reduce non-revenue water portion to less than 10% by 2050 by adopting full metering system, technological improvements, and building institutional capacity.

Strategy WSS 5: Strengthening of Institutional Capacity for Sustainable Water Supply

Institutional responsibilities in the sanitation sector need to become more firm. The mandate, the institutional responsibilities, the O&M roles and capabilities, and the cycle of costs, and revenues, have not yet sufficiently materialized in major cities, in towns and in villages and rural areas. The implementation of infrastructure needs to be combined with interventions to enable and develop executive institutions and a legislative framework.

Sub-Strategy WSS 5.1: Ensure planned maintenance and proper management of assets

In order to keep the system functioning at optimum efficiency, it is necessary to develop a time bound plan for retrofitting and replacement of existing infrastructure. However, sustainability of water supply system requires that the existing infrastructure needs to be replaced or rehabilitated in a phased manner. It is also necessary to realize the significance of planned maintenance. The water agencies should have a system of regular monitoring and planned maintenance with adequate resources allocated to the activity.

Sub-Strategy WSS 5.2: Build awareness through education

People tend to think that water is a public good with unlimited supply. This often leads to wastage of water. Education and publicity campaigns can go a long way to convince people that clean and safe water is a scarce resource which is costly to produce and therefore needs to be paid for accordingly.

Sub-Strategy WSS 5.3: Involvement of Stakeholders

Sustainability of water supply management largely depends on the involvement of stakeholders in decision-making and implementation processes. Planners, developers, consultants, businesses, utilities and most importantly, users are among the stakeholders that have large influence in the success or failure of interventions designed to develop integrated water supply management system.

10.4 Urban Sanitation and Wastewater Management

Bangladesh has made significant progress in sanitation in terms of population coverage. The progress in sanitation started mainly in 1990's. The government conducted a baseline survey in 2003 which revealed that one-third of the population (33%) was using hygienic latrines while about one-fourth of the population (25%) was using unhygienic hanging latrines. The remaining 42% resorted to open defecation, as they did not have access to any kind of latrine facility. This led the government to launch the national level sanitation campaign. The government also set a national sanitation goal of "100% sanitation by 2010". Realizing the practical difficulties, this goal was revised in 2009 and the government set 2013 as the year for achieving "100% sanitation". According to MICS (2014), there is still 5% of the rural population that still resort to open defecation.

10.4.1 *Types of Sanitation Facilities*

JMP categorized sanitation facilities into improved, unimproved and shared. JMP definitions of these facilities are given below:

Improved Sanitation Facilities

Sanitation facility that hygienically separates human excreta from human contact through the use of:

- Flush toilet
- Piped sewer system
- Septic tank

- Ventilated improved pit latrine
- Pit latrine with slab
- Composting toilet

Unimproved Sanitation Facilities

Unimproved sanitation facilities include the following:

- Flush or pour flush to elsewhere (excreta are flushed to open sewer, a ditch, a drainage way or other location)
- Pit latrine without slab or open pit
- Bucket
- Hanging latrine

Shared Sanitation Facilities

Shared sanitation facilities refer to all public toilet facilities and sanitation facilities (although of an unimproved kind), which are shared between two or more households. Types of sanitation facilities in Bangladesh can also be summarized in the form of a ladder as shown in **Figure 10.2**.

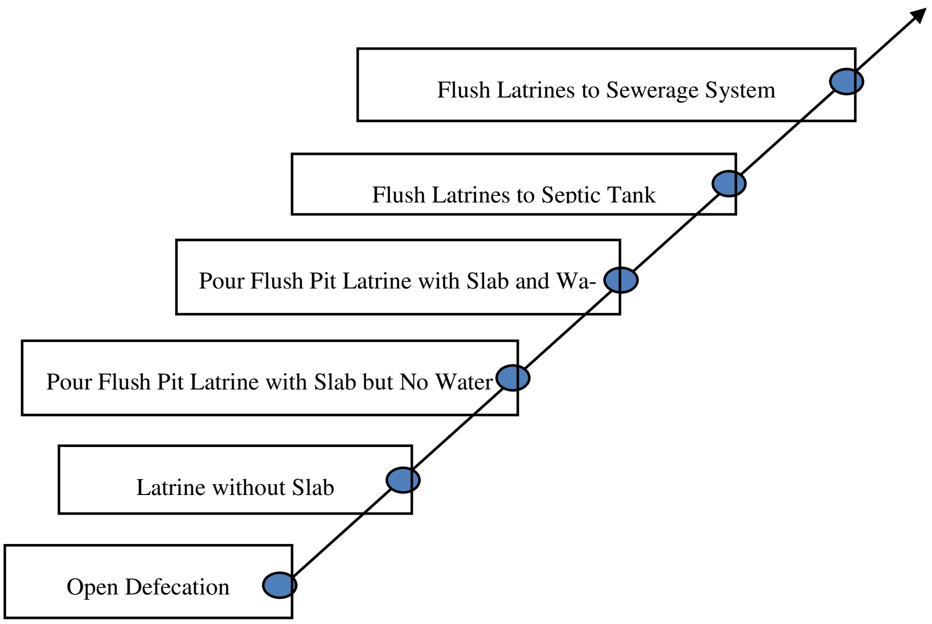


Figure 10.2: Sanitation Ladder in Bangladesh

Source: SDP for water Supply and sanitation 2011-25 Analysis, LGD, 2011

Open defecation is on the bottom ring of the ladder while flush latrines to sewerage system is on the top. Quality of sanitation facility improves as one moves up the ladder. In Bangladesh, sewerage system is available in only Dhaka City and that serves only 20% of the city's households, mostly high income groups. The rest of the households use different kinds of onsite systems from basic pit latrines to septic tanks. While good progress has been achieved in sanitation coverage, quality of sanitation still remains a problem. Providing better quality sanitation service would depend on how fast the country can climb up the sanitation ladder.

10.4.2 *The State of Sanitation Coverage in Bangladesh*

Since independence, Bangladesh has seen significant economic growth. In the last five years the GDP growth rate had been steady above 6%. It is envisaged that the trend will continue. The 7th FYP (FY2015/16 – FY2019/20) predicts a GDP growth of above 7%. The per capita income has increased from US$ 619 in 2008 to US$ 1,314 in 2015 and is likely to be around US$ 1,450 in FY2016/17. Standard of living of the populace is also increasing due to growth in income and manageable inflation rate, which is around 6.2% in 2015/16.

Population growth and its distribution are also taking an interesting shape. According to the census of 2011 the population of the country was around 152 million. Of this, 24% people were living in the urban areas and the rest in rural areas. Recent studies predict that the population of the country will be 215 million in 2050. Around 56% people will live in urban areas and the rest in rural areas. This means that the share of population between urban and rural areas is reversing. By around 2040 equal number of people will be living in urban and rural areas. This trend is also pointing to a demand for better standard of living.

Major Cities

Of the seven major cities, Dhaka, Chattogram, Sylhet, Khulna, Barishal, Rajshahi and Rangpur, only Dhaka has a limited separate sewerage system and a conventional Sewage Treatment Plant (STP) of capacity 120,000 m^3/d. This STP can serve 20% of the Dhaka population. However, dysfunctional collection system in many parts due to sedimentation or damage to sewer lines only allows about 10% of generated load to reach the Pagla STP. The sewage which cannot reach the STP is spilled and accumulates in various city areas causing major concern to public health. Around 33% of households in Dhaka city dispose their sewage/wastewater by connecting to storm water drainage network and water bodies. This untreated sewage/wastewater flows directly to the surrounding river system causing major deterioration of water quality. These rivers are presently the main sources of surface water treatment plants in Dhaka and Narayanganj. Therefore, this cannot be considered as an improved sanitation system because of its potential threat to public health. Improved on-site sanitation system (flush or pour-flush toilets to septic tanks or pit latrines) is utilized by 25% of the population. Faecal Sludge Management (FSM) is practically absent in these areas. It is estimated that 22% of the population are still using unhygienic on-site sanitation means.

According to Sewerage master Plan of Dhaka city (March, 2013) the current design capacity of Pagla Sewage Treatment Plant is 96MLD (average flow rate) and 120MLD (peak flowrate) while the current sewage generated within the catchment served by the centralized sewerage system is approximately 250-300MLD, and is expected to exceed 500MLD at the Master Plan design horizon. Due to damage of the trunk mains and sewerage system, the actual flow rate entering the Pagla STP is approximately 30-40MLD.

There is absolutely no formal sewage collection system in other major cities. Inhabitants of the cities discharge sewage directly into inadequate surface drains while retaining (often partially) faecal sludge in septic tanks. Systematic faecal sludge management is practically absent. Occasionally some of the septic tanks are cleaned and sludge is disposed into drains which ultimately discharge into water bodies, khals and rivers. According to MICS (2014) 28% of the population use shared, 12% unimproved sanitation and 1.4% open defeacation.

Therefore, it is evident that the major cities of Bangladesh lack proper sanitation facilities for metropolitan areas. Also the current sanitation practice totally ignores the environmental consequences which are already demonstrated by significant pollution of the surface water bodies and rivers. The problem with inadequate sanitation and sewerage in the major cities will increase with the growth of the city areas and its population. Predictions from various studies shows that the population in the major cities will increase from 30 million in 2011 to 42 million in 2030 and 57 million in 2050. With demand for better living conditions the demand for improved sewerage system and sanitation will increase. This will be major challenge which needs to be tackled head-on.

Pourashavas/Municipalities/Towns

Apart from the major cities other urban areas includes 359 pourashavas/municipalities/towns in Bangladesh. With economic development in the country which is associated with industrialisation and growth of service sector significant migration from the rural to the urban centres are very evident. Recent projection shows that population in these towns will increase from 18 million in 2011 to around 30 million in 2030 and 64 million in 2050. As the present pourashavas/municipalities are taking shape of more formalised modern urban centres, demand for improved sewerage and sanitation facilities are becoming a general requirement. According to MICS (2014), around 56% of the population are under improved sanitation coverage. The rest are either using shared or unimproved sanitation facilities. As is the case for major cities, improved sanitation here means on-site flush or pour-flush toilet to septic tanks, pits or unknown places, pit latrines with slab or ventilated improved pit latrines. Faecal sludge management is a major problem in all the urban centres. Disposal of sludge remains an issue much neglected which is causing significant health, economic and environmental damages. In the long run the situation seems unsustainable.

Rural Areas

Rural areas may be divided into areas which have piped water supply and those which are using point sources for water supply. In recent times, DPHE is implementing rural piped water supply schemes in 37 rural areas where population density is sufficient for such schemes. DPHE has carried out pre-feasibility studies of 200 of such schemes and feasibility study of 150 schemes. It is envisaged that 9,500 such rural piped water supply schemes will be implemented by 2050 covering around 50% of the rural population. Piped water supply schemes will allow flush toilets to sewers or septic tanks. In areas which are having point water sources, it is likely that the inhabitants would go for pour flush toilets to septic tanks or pits. According to MICS (2014) 55% of the rural population use improved sanitation means and 40% use shared or unimproved sanitation. Around 5% are still opting for open defecation. The challenge is big, although it is understood that rural areas will have limited piped sewerage facilities and will mainly depend on flush or pour-flush toilets to septic tanks on pits.

Hard to Reach (HtR)Areas

The National Strategy for WSS in Hard to Reach Areas of Bangladesh (2012) defined hard-to-reach (HtR) areas as “areas having poor water and sanitation coverage due to adverse hydro-geological condition, having poor and inadequate communication network, and frequent occurrence of natural calamities which in turn results in higher rate of child mortality and accelerates the vicious circle of poverty”. The HtR areas are usually geographically remote and the people living there are least likely to have access to benefits from mainstream development activities. The Strategy divided HtR areas into six different geographical categories. They are: (1) Barind, (2) Beel, (3) Char, (4) Coast, offshore Islands and Saline areas, (5) Haor and (6) Hilly areas. The National Strategy for WSS (2014) identified 1,144 unions as hard-to-reach unions for water supply & sanitation in 257 Upazillas of 50 districts. About 21% of the total geographical areas of Bangladesh are found to be hard-to-reach with about 28.62 million people living in these areas. The strategy provided directions for separate development projects or separate components within development projects specifically for the hard-to-reach areas and for the vulnerable people and to adopt different approaches considering the local infrastructure, cultural values and socio-economic status. It emphasised on addressing area specific needs when considering and developing technologies, such as sanitation technology requiring less flushing water and light weight construction materials for hilly areas.

Urban Slums and Squatter Settlements

As migration from rural to urban centres are increasing at a rapid pace due to economic reasons, so do the urban slums and squatter settlements grow to accommodate the large influx of marginalised poor and vulnerable people from disaster prone areas. Most of the latrines in slum areas are unhygienic, families use mainly shared latrines, which are unhygienic; also many practice open defecation. In many slums open defecation is practiced by as much as 20% of slum population (OXFAM and ITN-BUET 2014). Appropriate sanitation in urban areas, especially in the low income communities, is a burning issue, yet to be resolved. Main problems of facilitating improved sanitation in urban slums are (1) most of the slums are on private lands in mainly low lands or wetlands without proper running water or good drainage facilities; (2) authorities are oblivious of the needs for better living conditions of the slum dwellers on the plea of illegal construction/occupation; (3) lack of understanding and knowledge about the ill effects of unsafe water and unhygienic sanitation. The National Strategy for WSS in HtR Areas (2012) focussed on formulation and implementation of appropriate policy and strategies for water supply and sanitation improvement. It emphasised that basic services including water and sanitation must be made accessible to slum dwellers irrespective of legal status of lands. It stressed on community water points and community sanitation blocks to be managed by Community Based Organizations (CBO).

10.4.3 Wastewater Management

Wastewater disposal is a major problem in most cities in Bangladesh. Only Dhaka city has a sewerage system but the coverage is partial. In view of heavy capital requirement and funding needs for regular maintenance, providing sewerage system to all urban centers is currently not feasible. Poor state of municipal finances and shortage of water (in dry season) also make it difficult to choose this option. Therefore, the urban centers that do not have sewerage systems and cannot provide one, usually opt for low cost solutions. Septic tanks and low cost sanitations are the solutions for providing safe sanitation facilities for most of the urban centers including those that have partial coverage by sewerage system.

10.4.4 Wastewater Management Systems

There are two basic wastewater management systems: on-site (or non-sewered) and off-site (generally sewered with centralised treatment). In sewered systems the removal/transport part of the service chain is performed by the sewer; water washes the waste through a pipe system. This may require the use of pumping stations to ensure that the waste reaches the treatment or disposal point. In on-site systems, waste accumulates on-site in a pit or septic tank, which requires periodic emptying or re-siting; in the case of emptying, waste is taken by road for treatment and/or disposal. Dumping of untreated septic tank/pit contents into rivers, lakes and the sea is, in many low- and middle-in- come countries, a regular practice.

Broadly speaking there are two types of 'conventional' sewerage networks that have been developed and introduced over time; the 'combined' system and the 'separate' system. In the combined system both surface run-off (storm water) and foul sewage are conveyed in the same pipe, while in the separate system different pipes are used to transport the sewage and the surface run-off. When properly installed, operated and controlled the separate system is most effective, as it reduces the amount of sewage to be treated, avoids the problems of discharges from combined sewer overflows and deals more effectively with periodic and potentially large volumes of urban runoff which occur under storm conditions.

Effective collection systems are a key for good waste-water management where off-site centralised treatment is chosen; they are also the most expensive element of total capital cost of good operational management. However, in Bangladesh only Dhaka has a collection (sewer) system while in other cities and towns the sanitation/wastewater management system is on-site (non-sewered). **Figure 10.3** below shows the distribution of sanitation systems in Dhaka city.

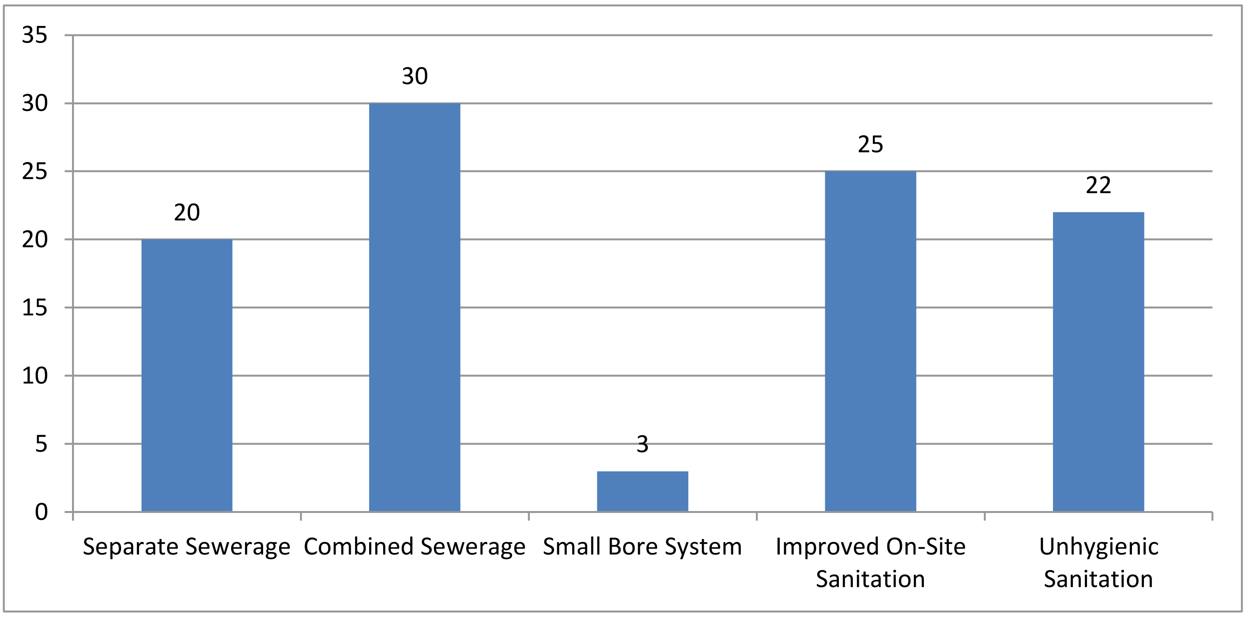


Figure 10.3: Wastewater Management in Dhaka (% of people covered)

Source: BDP 2100 Technical Team Analysis, GED, 2015

10.4.5 Wastewater Generation

The quantity of wastewater generated depends largely on the quantity of water supplied. In urban centres where the formal supply does not cover the entire population, informal sources of water supply would also contribute to wastewater generation. **Table 10.13** presents the volumes of wastewater generated by households in three cities. In Dhaka 20% of the wastewater generated in the city is covered by a sewerage network and a treatment plant, while 70% pits/septic tanks in the areas that are not under sewerage coverage is connected to storm drainage system or other types of drains or water bodies. In Khulna and Faridpur 98.23%, and 98.50% of the on-site sanitation facilities respectively need emptying, safe transportation and treatment.

Table 10.13: Estimated Volume of Wastewater in Dhaka, Khulna and Faridpur

Description	Unit	Dhaka	Khulna	Faridpur
Total population (in 2011)	Number	15,018,594	1,728,760	146,667
Total Household (in 2011)	Number	3,337,470	384,169	24,840
Total production of wastewater (Faecal Sludge & Grey Water)	m^3	2,740,893	315,499	26,767
Coverage under sewerage system	%	20.00	0.00	0.00
Coverage under drainage	%	69.23	0.00	0.00
Open defecation, hanging, etc.	%	0.77	0.77	1.50
Coverage under OSS	%	10.00	98.23	98.50
Coverage under OSS	m^3	541,585	815,276	25,434

**0.5 ltr per person per day including grey water*

Source: Opel, Bashar and Ahmed, 2012

Table 10.14 presents the volume of industrial wastewater from industrial clusters in Dhaka. Highest volume of industrial wastewater is produced by textile industries followed by leather and chemical. Leather industries are concentrated in Hazaribagh and produce about 16 thousand cubic metres of wastewater per day, which is the highest in terms of production of wastewater by area. Textile industries are dispersed throughout the city and the volumes of wastewater produced by these industries vary by location.

Table 10.14: Volume of Industrial Wastewater in Dhaka

Cluster Name	Type of Industries	Number of Industries	Total Wastewater Discharge (m^3/d)	Discharge Point
Hazaribagh	Leather	136	15,800	Turag river
Tongi BSCIC	Textiles	13	4,300	Tongi khal
Fatulla	Textiles	6	3,400	Buriganga river
Tejgaon	Textiles Chemical	16 27	3,350 535	Begunbari khal
Kachpur	Textiles	9	4,300	Lakhya river
Tarabo	Textiles	14	1,150	Lakhya river

Source: BDP 2100 Technical Team Analysis, GED, 2015

10.4.6 *Wastewater Discharge*

In Bangladesh, the dominant sanitation technology currently used by urban households is the on-site system that consists of a toilet and a storage infrastructure such as lined or unlined pit or septic tank. Although majority of the urban households have improved toilet facilities within premises, collected sewerage are discharged directly into open drains, water-bodies (canals, lakes, rivers etc.) or undesignated places that result in pollution and health hazards for the public. **Table 10.15** shows the destination of extracted sludge in three cities, Dhaka, Khulna and Faridpur. It is a great environmental concern that in most cases collected sludge is not managed in an environmentally safe way. Sludge is released randomly ('here and there') or dumped into open drains or water-bodies which contaminate surface water. In 18.2% of the cases in Faridpur, 30.6% in Dhaka and 24.5% in Khulna, collected sludge is dumped in a designated sites. (Opel, Bashar and Ahmed, 2012).

Table 10.15: Destination of Extracted Sludge

Dumping Locations	Dhaka (% of sludge)	Faridpur (% of sludge)	Khulna (% of sludge)
Dumped here and there	2.3	0.3	2.4
Dumped into open drain	43.5	4.2	30.0
Dumped in a designated place	30.6	18.2	24.5
Put into a mud-hole and covered with mud	8.3	75.2	39.7
Open Water Body	15.3	2.1	3.4
Total	***100.0***	***100.0***	***100.0***

Source: Opel, Bashar and Ahmed, 2012

Figure 10.4 presents the fecal waste flow matrix in Dhaka. The width of the arrows and the percentages shown represent the proportion of the population whose fecal waste takes each route. Although nearly all waste is effectively contained at the household level, unsafe management of on-site facilities combined with highly inadequate sewerage and wastewater treatment mean that fecal waste is distributed throughout the urban environment. Although 20% of the population of the city is connected to the sewerage system, only 2% of the sewage reaches the treatment plant and is effectively treated while the rest 18% ends up in drains and water bodies.

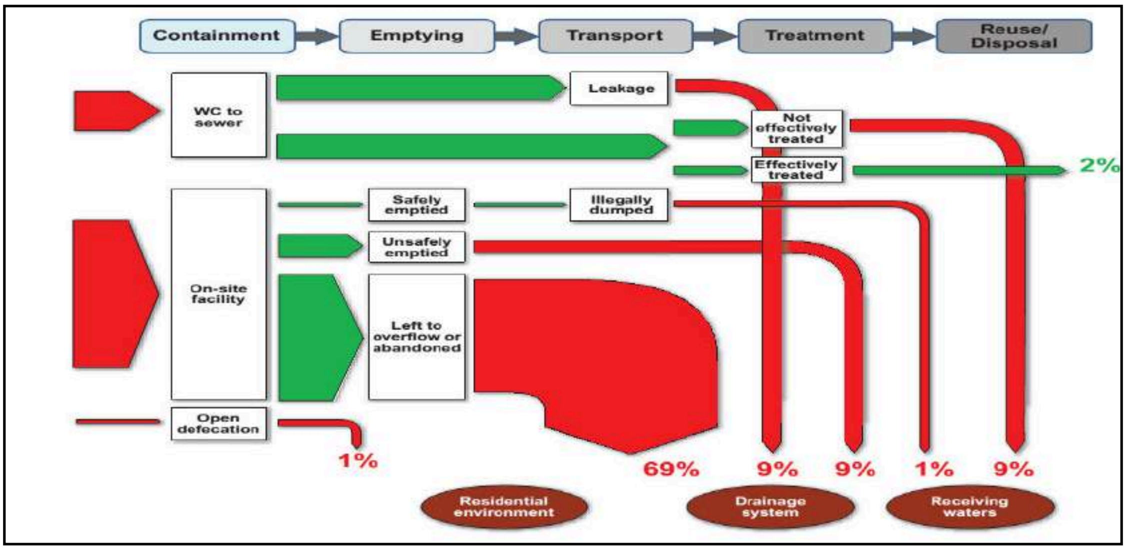


Figure 10.4: Fecal Waste Flow Matrix in Dhaka
Source: BDP 2100 Technicla Team Analysis, GED, 2015

10.4.7 *Faecal Sludge Management (FSM)*

Sanitation in Bangladesh is on-site based (latrines and septic tanks). Even when sewerage may gain momentum in the coming years, the on-site sanitation will be part of the sanitation sector for the next 30 years or more. FSM facilities are urgently required, and will be needed for the foreseeable future. Internationally, many FSM concepts have been, and are being, developed. In Bangladesh several FSM options are presently explored and implemented by both NGO's and public authorities. The major issues for faecal sludge management are:

- Lack of coordination
- Absence of financial stability
- Absence of environmental legislation and enforcement.

10.4.8 *Wastewater Re-use*

Technically drinking water quality (or better) can be produced from any feed water. In areas of water scarcity, wastewater re-use is being implemented. Singapore (lack of own water resources) and Australia (arid areas) are typical examples. In view of public opinion wastewater re-use is not preferably targeted for drinking water, but rather may be more acceptable as 'process water' for industries or agriculture.

Wherever, alternative freshwater resources are available, wastewater reuse is not likely to be economic. Some notions on perspectives on future wastewater re-use in Bangladesh include:

- In the Coastal Zone, freshwater resources are scarce. In this context wastewater re-use may be applicable;
- As in most places, re-use for drinking water application will not be preferable (Public Health risks, lack of social acceptance);
- In surface water "Re-use" is indirectly practiced in upstream wastewater treatment, and downstream intake/abstraction. With conventional WWTP effluent (perhaps after further polishing or disinfection) re-use in aquaculture or other agricultural application can be considered;
- Industries can be encouraged to apply internal recirculation (re-use) of water. By increasing cost for both supply (private abstraction) and wastewater discharge, an incentive can be created for water recycling.

10.4.9 *Industrial Water Supply and Wastewater Treatment Perspectives*

While domestic wastewater can be typically characterized by its BOD/COD content and nutrient loading, industrial wastewater will vary in chemical composition according to the type of industry, and may contain serious environmental threats. Similar to domestic and municipal water supply and sanitation, industrial water supply and wastewater treatment can also be both centralized and decentralized. Centralized industrial water supply and wastewater treatment follow the same process as centralized domestic and municipal water supply and wastewater treatment and is, as a matter of principle, integrated in the previous chapters. Decentralized water supply and wastewater treatment is common for industries in Bangladesh. These are individual, private (or clustered) water supply and water treatment systems with both regulated and illegal practices.

The challenges for industrial wastewater include:

- Ensuring effective zoning of industrial activities;

- Preparing inventory of current practices in industrial wastewater usage, treatment and disposal;
- Categorizing principal fields of industry in occurrence, and wastewater characterization, including inventory of suitable treatment technology; and
- Inventory of governance principles to improve industrial compliance to environmentally sustainable practice.

Industrial water demand is rather extensive (especially for textile manufacturing processing and dying industries). The private water abstraction (both by industries, communities and households) represents a substantial percentage of the total groundwater abstraction, putting pressure on domestic consumptions and stress upon groundwater resources. In addition, industries are considered to be the biggest polluters of surface water bodies. There are cases where effluents, heavy on hazardous chemicals and biological agents are uncontrollably discharged untreated into surrounding rivers or water bodies which further create pressure on SWTPs.

While industries are expected to operate their own 'Effluent Treatment Plants' (ETPs), it is widely recognized that both the installation and operation of ETPs is often inadequate or non-existent. Compliance on industries and expertise in industrial wastewater treatment are inadequate.

10.4.10 Investment Requirements

The economic benefits from safe water supply and sanitation are substantial. The return from investment in these sectors is quite high, ranging from about US$ 5 to US$ 35 for every US$ 1 investment. The return on US$ 1 invested in water and sanitation interventions in Bangladesh was estimated to be US$ 5.4 (LGD 2011). For sanitation, this ratio is even higher and stands at US$ 6.4.

The Sector Investment Plan (SIP) of Sector Development Plan (SDP, 2011) determined investment requirement for short (FY 2011-15), medium (FY 2016-20) and long (FY 2021-25) term targets. For calculating costs, three scenarios were developed (**Table 10.16**).

Table 10.16: Service Level and Operating Efficiency Indicators for Urban Sanitation

Scenario	Service Level Indicators			Operating Efficiency Indicators	
	Coverage by Technologies (% of Urban Population)	Technology / Options Used	O&M Status of Toilet Facilities	Sludge from Onsite Sanitation Safely Managed	O&M Cost Recovery
Scenario 1 (Base Case)	50-80	Conventional and small bore sewer with treatment and septic tank with safe desludging and disposal up to Paurashavas levels	Poorly maintained	Low	Low
Scenario 2 (Moderate)	35-95	Conventional and small bore sewer with treatment and septic tank with safe desludging and disposal up to Paurashavas levels	Moderately maintained	Medium	Medium

Scenario	Service Level Indicators			Operating Efficiency Indicators	
	Coverage by Technologies (% of Urban Population)	Technology / Options Used	O&M Status of Toilet Facilities	Sludge from Onsite Sanitation Safely Managed	O&M Cost Recovery
Scenario 3 (High)	20-100	Conventional and small bore sewer with treatment and septic tank with safe desludging and disposal up to Paurashavas levels	Well maintained	High	High

Source: WSS Sector Development Plan, 2011

Scenario 1 represents the current sector condition characterized by low service level and low operating efficiency, while scenario 2 shows moderate service level and moderate operating efficiency. Scenario 3 is characterized by high service level and high operating efficiency. If socio-economic and institutional conditions are taken into account, then scenario 2 appears to be a more realistic at the stage of economic development and achievable option during the plan period (2011-2025). Total investment costs of urban sanitation for scenario 2 were estimated at Tk. 335,891 million out of which Tk. 93, 513 would be required for short term (2010-2015), Tk. 107, 555 million for medium term (2016-2020) and Tk. 134,823 million for the long term (2021-25).

10.4.11 Existing National Policies and Strategies for Sanitation

National Policy for Safe Water Supply and Sanitation initiated in 1998 explicitly emphasizes upon the self-sufficiency and self- sustainability of urban sanitation systems. It also called for the promotion of sanitary latrines in every household and along with individual sanitation, public and community latrines were to be set-up by City Corporation or Pourashavas. According to the Policy, the City Corporations and Pourashavas are empowered to set tariffs, by-laws, appoint staffs, etc. according to their needs and in accordance with the guidelines laid down by the government. It highly encourages the participation of private sector and NGO in sanitation and states that behavioral development and changes in users shall be brought about through social mobilization and hygiene education in alliance with the Ministries of Health, Education, Social Welfare, Information, Women & Children Affairs, DPHE, NGOs, CBOs, local government bodies and other related agencies.

The National Sanitation Strategy of 2005 was established by the previously mentioned policy. The strategy identified the lack of mechanisms for ensuring effective utilization of government subsidies at all levels. It has emphasized on sustainability of the service delivery and directs that the ownership of the facilities and the responsibility for operation and maintenance shall be that of the households and the communities. It also focused upon awareness promotion for increased mobilization of community resources which is essential for 100% sanitation coverage.

10.4.12 Issues and Challenges

Urbanization and Poverty

Urban sanitation remains a major challenge in Bangladesh as urban scenario is very complex and challenging. Due to high rates of urban migration, cities are unable to meet the demand for sanitation services especially in low income areas. In urban slums, population density is extremely high and in some areas, population density is 200 times higher than the Bangladesh's average density. Consequently, in most slums, space to construct individual household latrines is impossible. Although national figure for shared latrines is about 28% in urban areas, in slum areas about 80% of the residents use shared latrines. A significant proportion of slum dwellers also use drains, open fields or roadsides for defecation.

Although slums are found in most of the urban areas, the majority of the slums are concentrated in the City Corporations. The 2014 census of slum, identified 13,938 slums in urban areas of the country. About, 65.38% of those slums are found in the City Corporations with largest concentration in Dhaka North and South City Corporation (24.39%) areas. According to the BBS-UNICEF 2009 Multiple Indicators Cluster Survey, only 9% of the slum dwellers had access to improved sanitation facilities while the rest had access to unhygienic toilets only.

Hard to Reach Areas (HtR)

Despite significant progress in sanitation coverage nationwide, the sanitation sector faces challenges in terms quality of service and coverage in the HtR. In extreme areas, service level is deplorably poor while in very HtR service level is much lower than standard. Even in moderate HtR, service level is lower than standard. In HtR areas, only 35.8% families have improved sanitation facilities. Sanitation crisis in these areas result mainly from extreme poverty, poor infrastructure-road communication network in particular and vulnerability to various types of natural disasters (flood, cyclone, water-logging, etc.).

Climate Change

Floods pose major risks for sanitation facilities in urban areas. The main threat arises from the possible inundation of domestic and public toilets, especially in low lying areas. This would create many problems with damage to infrastructure and additional public health problems that may arise. Also, groundwater contamination may result from increased flooding, where untreated wastes are dumped. Thus, severe flooding may cause not only break in services, but also may distribute untreated waste including human excreta and its attendant health risks across entire neighborhoods and communities.

Technology Issues

Urban sanitation is mostly managed by households and is provided by various forms of improved latrine (as estimated 58%). The predominant household managed (onsite) sanitation options are different forms of pit or pour flush latrines with direct or offset pit and septic tank system with or without soak pit. Utility managed (offsite) sanitation is dominated by sewerage. Except for a small portion (20%) of Dhaka city, the entire country is covered by onsite sanitation facilities. Onsite sanitation technology suffers from problems related to emptying and disposal of pit contents. Septic tanks are also not properly designed and maintained. Septic tanks and pits are not desludged regularly to keep them functional. These are occasionally emptied manually and dumped into the nearby drainage system, low lands, surface waters and into the open environment. With the increase in urban population and the coverage of population by onsite sanitation system, volume of faecal sludge will increase significantly in the coming years. This may lead to serious environmental degradation unless faecal sludge collection and disposal systems are developed.

10.4.13 The Need for Integrated and Sustainable Wastewater Management

Wastewater is made up of different streams including urine, faeces, flushwater (black water), greywater and stormwater. These streams can be recycled for productive use. This, however, requires an integrated approach to wastewater management that recognizes the links between wastewater, the urban water cycle and city development as a whole. The conventional wastewater management is characterized by centralized technology and disposal oriented approach and focuses mainly on protecting human health and the environment. An integrated approach, on the other hand, reveals the benefits of recycling the different wastewater streams thereby encouraging a cyclical wastewater management process rather than a linear one based on disposal. To achieve this, alternative options are required. Quite a large variety of options are available to assist with the implementation of more sustainable wastewater management. These are alternatives to conventional wastewater management solutions, although each of them has the potential to be integrated into existing infrastructure. Followings are some of the options from the collection, treatment and disposal/reuse sectors of wastewater management (ICLEI European Secretariat, 2011b):

Collection:Urine Diversion Toilets

Treatment:Soil Aquifer Treatment

Treatment:Constructed wetlands

Treatment:Waste Stabilisation Ponds

Treatment:Biogas production

Reuse:Sludge reuse

Reuse:Greywater reuse

These are typically flexible, decentralized solutions which make use of natural systems such as ponds, wetlands and soils that provide multi-purpose benefits and are less likely to result in unexpected impacts. It is, thus, clear that wastewater needs to be more fully recognized within the overall water cycle, as one of the greatest untapped opportunities to enhance sustainable development. There is now a growing realization that the opportunities that effective wastewater treatment and reuse could bring to sustainable development could be achieved with a concerted effort and greater political will.

10.4.14 Urban Sanitation and Wastewater Management Strategies

Strategy WSS 7: Strengthening Governance Framework

Sub-Strategy WSS 7.1: Polluter pay principles

Polluter pay principles should be adopted asa philosophy for sector finance, and incorporated in legislative framework (sanctions). This should also be a basic enhancement mechanism against illegal dumping of faecal sludge.

Sub-Strategy WSS 7.2: NGO engagement

It must be noted that NGO's are participating at the development front of the sanitation sector. Governance principles where NGO engagement is accommodated or facilitated would be required at least in the short to mid-term perspective.

Sub-Strategy WSS 7.3: PPP encouragement

Private initiatives are required for further development of the sanitation sector: emptying of septic tanks, treatment of faecal sludge, resource recovery and marketing. FSM at present comes at a public cost which needs to be realized from beneficiaries gradually.

Strategy WSS 8: Institutionalize Cost Recovery Principles

In the sanitation sector cost recovery has not yet been suitably established. It is acceptable for house owners to pay for emptying their septic tanks. And in major cities (i.e. Dhaka) there is an arrangement where house owners pay for sewer connection. However, full service re-payment either by direct billing or through municipal tax levies requires further development.

Sub-Strategy WSS 8.1: Municipal tax development

Both in terms of executive mandate in the urban environment (storm water drainage, sewerage, solid waste) and regarding revenue collection, the institutional framework in Bangladesh needs to be strengthened. Even if environmental health services (continue to) be subsidized, it is relevant for (partial) household contributions to be applied. Evidence has shown that the introduction of these principles, enable and facilitate transition towards full cost recovery.

Sub-Strategy WSS 8.2: Flywheel fund considerations

Septic tank emptying constitutes an accepted cost. Safe environmental disposal of sludge represents a cost that can be 'avoided' by illegal dumping. Contrary to true cost economics, a premium could (temporarily) be awarded for sludge disposal at FSM locations. This temporary incentive may stimulate a flywheel towards sustainable practices.

Sub-Strategy WSS 8.3: Efforts for energy recovery

Energy and other resources may be recovered from sludge. While recovery will not cover the full expenses of FSM, it may reduce its cost and add to sustainable practice. The Government will encourage its application, and facilitate an enabling institutional context (permits, monitoring, licences and quality standards for recovered materials).

Strategy WSS 9: Increase Application of FSM

The ongoing sectoral initiatives need to continue with following sub-strategies:

Sub-Strategy WSS 9.1: Strengthening sectoral coordination

Sector co-ordination needs to be further developed (technical exchange, institutional mandate, registration and permitting on the application of recovered resources (like compost), guidance of further technology development).

Sub-Strategy WSS 9.2: Targeting financial sustainability

Cost recovery is presently insufficiently embedded. While resource recovery may generate some revenue, it is presently not enough to recover the cost of FSM. While there is an accepted practice where house owners pay for emptying of their septic tanks, the costs of suitable treatment are not presently recovered. Moreover, in an aim to 'save costs', septic tanks may not be emptied on a suitably regular basis, resulting in over flow to the environment. Cost recovery principles may be imposed through municipal tax, where everybody is paying, and where FSM services specifically may be subsidized from this tax revenue.

Sub-Strategy WSS 9.3: Enforce legislative provisions

Environmental legislation and enforcement needs to be increased. There is both a lack of technical/ institutional capacity, as well as a lack of social context, where environmental pollution needs to be reduced. Dumping of waste in any form should become socially unacceptable and punishable by legal enforcement.

Sub-Strategy WSS 9.4: Accelerate implementation of FSM

Presently FSM application needs to be subsidized. The social benefit in improving quality of life, protecting the environment, and safeguarding public health will outnumber the (subsidized) cost. While the need for increased FSM in urban Bangladesh has been advocated for many years, it is of importance that its implementation is accelerated and its actual use and operations is facilitated/encouraged by relevant Government agencies and development partners.

Strategy WSS 10: Urban Sewerage and Wastewater Treatment

Dhaka and other major cities proceed on planning and implementation of sewerage and wastewater treatment facilities.

Strategy WSS 11: Ensure Freshwater Supply and Wastewater Treatment to Enhance the Industrial Growth

Industries need to be a priority area for strategies towards environmental health and improved water quality. Sub-strategies for industrial water supply and wastewater treatment include:

Sub-Strategy WSS 11.1: Zoning

In clustering industries, services (including water) can be provided effectively and be dedicated towards particular needs. Environmental nuisance (noise, odour and traffic) can be contained and wastewater discharge can be treated collectively. Bangladesh will need to continue its effort to cluster industries, and proceed on imposing or incentivising existing industries to move to these clusters. BEZA and BEPZA are already playing important roles in this regard.

Sub-Strategy WSS 11.2: Enforce restrictions on water abstraction

Water abstraction should be primarily left to public water operators. Private abstraction must be discouraged, and pricing on these abstractions substantially increased. This strategy requires that public water supply is available and reliable. Meanwhile, regulated water abstraction permits, full metering and monitoring of industrial abstractions along with enforcement of restrictions is advised while taking the necessary steps towards available and reliable water supply by public water operators.

Sub-Strategy WSS 11.3: Enforce restrictions on wastewater disposal

Legislation on wastewater disposal needs to be made effective by intensified monitoring and effective sanctioning of defaulting industries.

Sub-Strategy WSS 11.4: Increase legislative capacity and capability

For effective monitoring and enforcement of regulations, increased government capacity and institutional capability needs to be prioritized.

Sub-Strategy WSS 11.5: Incentive programs towards good practice

Programs need to be developed where incentives are provided to industries in reducing water abstraction, in increasing water & energy (internal) efficiency, and in improving effluent disposal (reduced volume, improved effluent quality, (internal) re-use).

10.5 Solid Waste Management (SWM)

Management of solid wastes is a major problem for the City Corporations and Pourashavas of the country. These ULBs find it difficult to cope with the challenging task of collection, transportation and disposal of solid waste generated every day. The situation is compounded by rapid urbanization and rising per capita waste generation as well as unavailability of required open spaces for land filling. Lack of awareness of the people about safe disposal of solid waste and weak management systems of the ULBs are largely responsible for the accumulation of wastes in streets, open spaces, drains, canals and even stagnant water bodies causing serious health and environmental problems. Such a situation also creates problems for safe water supply as uncollected wastes pollute groundwater and surface water. While creation of solid waste continues to increase, capacity of ULBs to manage solid waste in an environmentally sustainable manner has not improved commensurately. Without improvement in efficiency and substantial financial support, significant changes in the management of solid waste cannot be expected. As result, this issue will continue to be a major hindrance to improving urban water management in the future.

10.5.1 Solid Waste Generation

Table 10.17 below shows the growth in solid waste generation in Bangladesh since 1991. It is quite clear that generation of solid waste in urban areas of Bangladesh has been increasing commensurate with increase in urban population despite the fact that the amount of solid waste generated per capita per day is lower compared to developed countries.

Table 10.17: Growth in Solid Waste Generation in Bangladesh since 1991

Year	Total Urban Population	Urban Population (%)	Waste Generation (kg/capita/day)	Total Waste Generation (tonnes/day)
1991	20,872,204	20.15	0.49	9,874
2001	28,808,477	23.39	0.50	11,695
2005	32,765,516	25.08	0.56	16,382
2025	78,440,000	40.00	0.60	47,064

Source: DOE, 2004; Waste Concern, 2005

There are however variations across the cities and towns within the country in terms of solid waste generation.

Table 10.18 presents information on solid waste generation in Dhaka city. Total amount of solid waste generated in 2005 was estimated at 3,200 tonnes per day by JICA (2005) while the amount was 4,866 tonnes per day according to Waste Concern (2005). BRAC Institute of Governance and Development (BIGD) estimated the amount of solid waste generated per day in Dhaka in 2015 as 6,110 tonnes (BIGD, 2015). The amount of solid waste generated per capita per day was estimated at 0.34 kg by JICA, 0.41kg by Waste Concern and 0.38 kg by BIGD.

Table 10.18: Dhaka Solid Waste Comparative Scenario: BIGD and other Studies

Waste (tonnes per day)	Composition of Waste	Results from Different Studies				
		JICA (2005)	Waste Concern (2005)	BIGD	City Corporation (2015)	JICA Projection 2015
Source wise Generation	Domestic	1950		3070.71		
	Business /commercial	1050		1983.92		
	Street	200		1055.83		
	Others					
Total Generated		3200	4866.50	6110.47		4624
Collected by City Corporation		1400			4653	
Per Capita Waste Generated		0.34	0.41	0.38		
Collected Waste as Percentage of Generated		43%		75.98%		

Source: BIGD, 2015

Table 10.19 and **Table 10.20** present per capita waste generation in other six City Corporations and six Paurashavas respectively in 2012. For City Corporations, the amount varied between 0.16 and 0.34 kg/capita/day while in the case of Paurashavas the amount varied between 0.19 and 0.36 kg/capita/day indicating that the pattern of solid waste generation was more or less similar across City Corporations and Paurashavas.

Table 10.19: Waste Generation Rate of Six City Corporations

City Corporations	Waste Generation Rate (Weighted Average)	
	Kg/hh/day	Kg/capita/day
Barishal	0.80	0.16
Gazipur	0.88	0.20
Narayanganj	1.29	0.29
Sylhet	1.36	0.28
Chattogram	n.a.	0.34
Rajshahi	n.a.	0.25

Source: CEGIS, 2012

Table 10.20: Waste Generation Rate of 6 Paurashavas (Class A)

Paurashava Name	Waste Generation Rate (Weighted Average)	
	Kg/hh/day	Kg/capita/day
Mymensingh	1.50	0.29
Cox' Bazar	1.19	0.29
Nawabganj	1.66	0.32
Dinajpur	1.69	0.36
Patiya	1.13	0.24
Jashore	0.86	0.19

Source: CEGIS, 2012

An analysis of the composition of solid waste shows the overwhelming dominance of food waste. **Figure 10.5** *shows that food waste accounts for around 80% of the solid waste in Barishal, Gazipur, Narayanganj and Sylhet City Corporations.* **Table 10.21** presents the composition of household waste in Dhaka. Organic waste accounts for about 97% of the household waste. About 72% of organic wastes are vegetables, fish and meat while about 28% of organic wastes are paper, plastic and polythene.

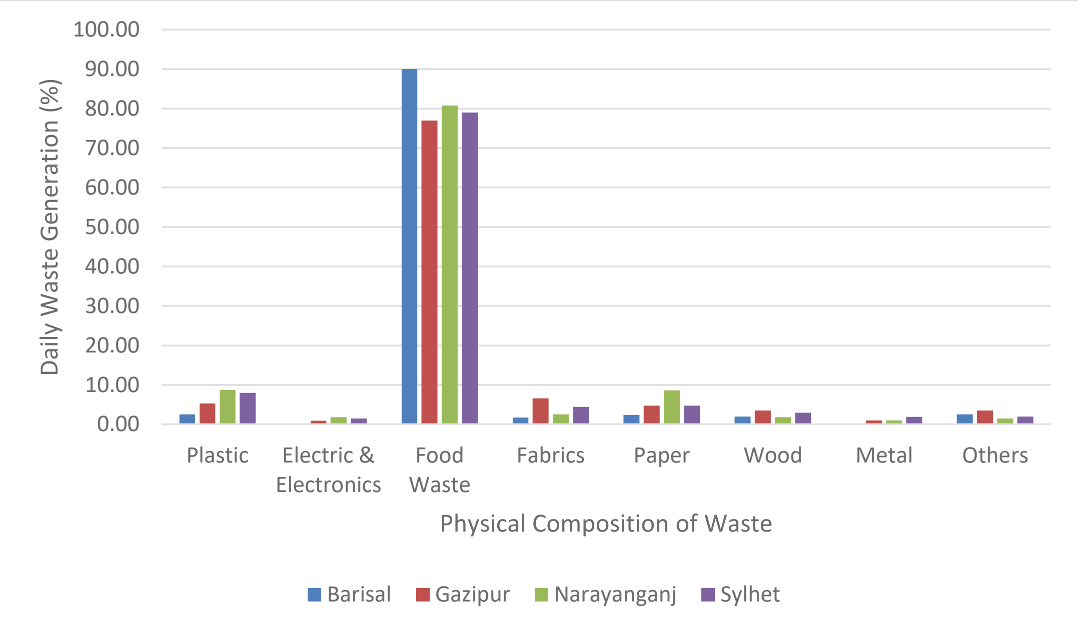


Figure 10.5: Physical Composition of Household Waste in 4 City Corporations

Source: BIGD, 2015

Table 10.21: Households' Waste Generation (daily): Volume and Composition

Volume of Waste	Total Waste Generated (kg): 1,058.79 Average per Capita Waste (kg): 0.377	
Types of waste	Organic	Inorganic
Total waste	1,028.2	30.1
Percentage of total waste	97.15%	2.85%
Average per capita waste generated (kg)	0.366	0.011

Source: BIGD, 2015

10.5.2 *Solid Waste Collection and Disposal*

Collecting and disposing huge quantities of solid waste generated daily in urban areas is indeed a daunting task for the urban local governments. It requires organizing the staff for collection, arranging transportation and funding ways of disposing the waste collected. Figure 10.6 shows the waste collection and disposal process in Dhaka city. The waste collected from households using house to house waste collection system is disposed in demountable containers. In some areas collected waste from households is disposed in open concrete/ brick bins or dustbins. The waste collected through street sweeping is heaped at various points and then transferred into dustbins/ containers. The containers and the waste from dustbins/ transfer stations are transported to the disposal point by waste transportation vehicles.

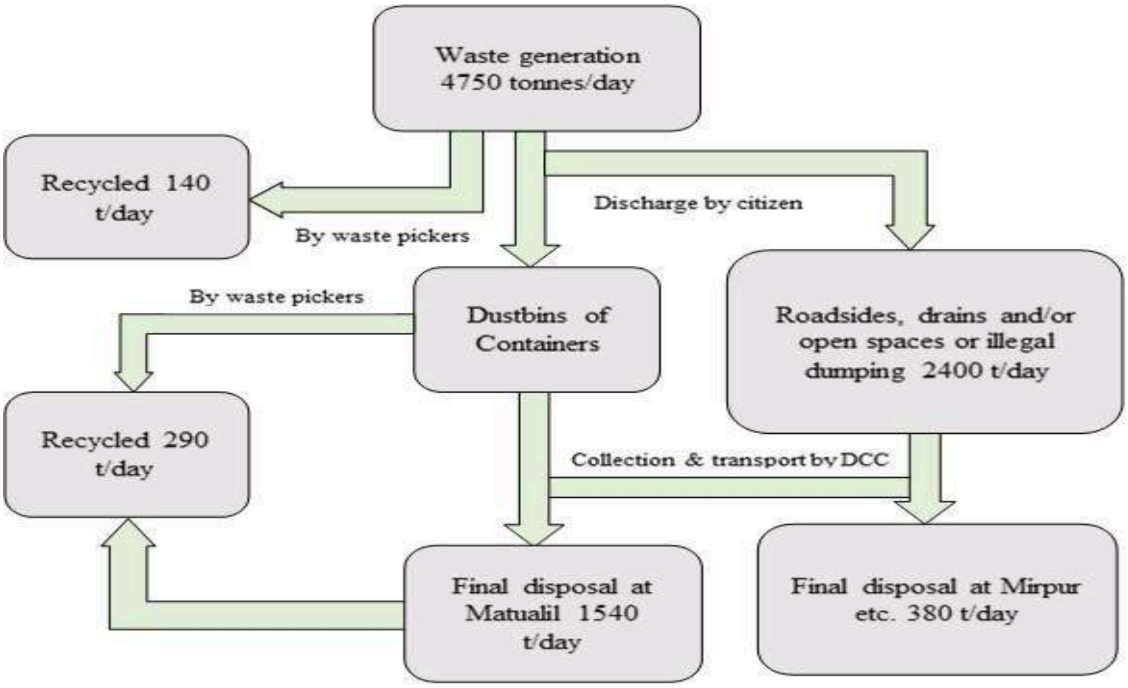


Figure 10.6: Waste Collection and Disposal Process in Dhaka City

Source: Report on Solid Waste Management Project by JICA & DCC Experts, 2005

Waste collection efficiency, defined as the proportion of generated waste collected and transported to disposal site, varies widely across cities and towns. In Dhaka waste collection efficiency was 43% in 2005 which increased to about 76% in 2015 (
Table 10.18**).** Waste collection efficiency in six other City Corporations and six Paurashavas are presented in **Table 10.22** and **Table 10.23**. Barishal and Rajshahi City Corporations perform much better than other urban areas. Waste collection efficiency of Barishal is about 100% while it is about 74% for Rajshahi City Corporation. For other City Corporations waste collection gap (proportion of waste not collected) is quite high and varies between 44% to 51%. In case of Paurashavas waste collection rate varies widely. Dinajpur Paurashava collects only 11.25% of the waste while Mymensingh collects about 85% of the waste. Such variations in waste collection efficiency actually reflect the financial and management capacity of local government bodies.

Table 10.22: Waste Collection Efficiency of City Corporations

City Corporation	Daily Total Waste Generations (m.Tonne)	Daily Total Waste Disposed at Landfill Site (mil. tonne)	Collection Gap (mil. ttonne)	Collection Efficiency (%)
Barishal	54.0	60	60.0	100.00
Gazipur	35.4	18	-17.4	50.84
Narayanganj	86.9	39	-47.9	44.88
Sylhet	147.2	66	-81.2	44.84
Chattogram	1049.91	490.5	-559.5	46.72
Rajshahi	194.60	144.5	-50.10	74.25

Source: CEGIS, 2012

Table 10.23: Waste Collection Efficiency of A-Class Paurashava

A class Paurashava	Daily Total Waste Generations (m.Tonne)	Daily Total Waste Disposed at Landfill Site (m. Tonne)	Collection Gap (m. Tonne)	Collection Efficiency (%)
Cox's Bazar	39	21.07	-18	54.02
Dinajpur	72	8.16	-64	11.25
Jashore	39	18	-21	4.15
Mymensingh	79	67.2	-12	85.06
Nawabganj	64	7.7	-56	12.03
Patiya	14	1.78	-12	12.71

Source: CEGIS, 2012

10.5.3 Service Cost and Revenue Generated

City Corporations and Paurashavas carry out waste management activities as obligatory functions. These activities take up a significant proportion of total budget of these local government bodies. Waste Management Cost (WMC) varies quite significantly across City Corporations and Paurashavas. **Table 10.24** presents waste management cost per tonne for four City Corporations while **Table 10.25** presents waste management cost per tonne of waste in six Paurashavas. There are significant variations in WMC amongst City Corporations as well as Paurashavas. WMC in Barishal and Gazipur City Corporations is twice the WMC per tonne in Narayanganj and Sylhet City Corporations. In Paurashavas the WMC is lower but the variation is quite large. In Mymensingh WMC per tonne is Tk. 0.3 thousand/day while in Nawabganj it is Tk. 1.2 thousand/day.

Table 10.24: Waste Management Cost Analysis of Four City Corporation Areas

City Corporation	Total Yearly Budget- Fiscal Year (2012-13)	Daily Waste Management Budget (Tk/day)	Daily Waste Generation at the Base Year (mil. Tonne/day)	Waste Management Cost (Tk/tonne/day)
Barishal	34,700,242	95,069	53	2,000
Gazipur	23,000,000	63,014	35	2,000
Narayanganj	36,000,000	98,630	84	1,000
Sylhet	40,000,000	109,589	135	1,000

Source: CEGIS, 2012

Table 10.25: Waste Management Cost Analysis of High Waste Generating Paurashavas (Class A)

Class A Paurashava (High)	Total Yearly Budget- Fiscal Year (2012-13)	Daily Waste Management Budget (Tk/day)	Daily Waste Generation at the Base Year (mil. Tonne/day)	Waste Management Cost (Tk/tonne/day)
Mymensingh	9,600,000	26,301	76	300
Cox's Bazar	8,300,000	22,740	35	600
Nawabganj	25,000,000	68,493	58	1,200
Dinajpur	7,600,000	20,822	68	300
Jashore	7,250,000	19,863	39	500
Patiya	2,725,462	7,467	13	600

Source: CEGIS, 2012

Solid Waste Management (SWM) cost of Dhaka South and North City Corporations (combined) is presented in **Table 10.26** below. SWM cost per tonne was 0.95 thousand Tk./day in 2004-5. It is estimated as 1.45 thousand Tk. per tonne/day in 2014-15, indicating an increase of about 52% in a decade.

Table 10.26: DCC North and South – SWM Cost per Tonne

	Unit	Actual (2004-2005)	Estimated* (2014-2015)
SWM O&M Cost	Million Tk.	487	2,467
Collected Solid Waste	1,000 tonne/	511	1,695
Tk./tonne	Tk./tonne	953	1,455

Source: JICA, 2005 & BDP 2100 Estimate, 2015

Solid waste management is a service that has low revenue generation. The service either generates no revenue or the revenue generated is not very significant. Revenue from this service mainly comes in the form of tax which is a certain percentage of the holding tax. The cost recovery in this service, therefore, is very low. **Table 10.27** and **Table 10.28** present the income from and expenditure for solid waste management in Chattogram, Rajshahi and Rangpur City Corporations and Patuakhali Paurashava.

Table 10.27: Income from Solid Waste Management

Local Government Unit	Total Waste Disposed (Tonne)	Income from Solid Waste Management (Million Tk.)	Income from Solid Waste Management	
			Tk. per tonne	Per capita income in Tk. per year
Chattogram City Corp.	490.5	202.87	1,133.15	61.60
Rajshahi City Corp.	144.5	28.08	532.47	35.31
Rangpur City Corp.	31.1	10.16	894.68	24.87
Patuakhali Municipality	10.84	2.65	670.27	32.20

Source: BMDF, 2012

Table 10.28: Solid Waste Management Expenditure

Local Government Unit	Total Waste Disposed (Tonne)	Expenditure for Solid Waste Management (Million Tk.)	Solid Waste Management Cost	
			Tk. per tonne	Per capita expenditure in Tk. per year
Chattogram City Corp.	490.5	465.00	2597.33	141.19
Rajshahi City Corp.	144.5	91.05	1726.41	114.47
Rangpur Municipality	31.1	16.64	1465.80	40.75
Patuakhali Municipality	10.84	14.97	3783.55	181.78

Source: BMDF, 2012

There are significant variations in from income and expenditure for solid waste management amongst these local government bodies. A comparison of **Table 10.27** and **Table 10.28** shows that per capita annual income from solid waste management is much lower than per capita annual expenditure for solid waste management. Per capita annual income in Chattogram City Corporation is only 43.63% of per capita annual expenditure for SWM, while in Rajshahi City Corporation, it is only 30.84%. The difference is even higher between Rangpur and Patuakhali municipalities. In Rangpur municipality, per capita income is about 61% of per capita expenditure for SWM, while in Patuakhali municipality, per capita income is only 17.71% of per capita expenditure on SWM. What is apparent is that per capita income from SWM is higher in City Corporations or large cities but per capita expenditure may be higher or lower irrespective of whether the local government unit is City Corporation or Paurashava.

10.5.4 Capital Investment Requirements

It has already been observed that solid waste collection efficiency is quite low in most of the urban centers under study. Except for Dhaka and Rajshahi, collection efficiency in the urban centers including Chattogram is around 50% or lower. In some urban centers, collection efficiency is less than 15%. Even in Dhaka and Rajshahi, around 25% of solid waste remains uncollected. Achieving 100% collection efficiency is obviously a daunting task and would require considerable investment.

The Study on Municipal Solid Waste Management (BMDF, 2012) estimated additional investment requirements for three City Corporations (Chattogram, Rajshahi and Rangpur) and one Paurashava (Patuakhali). The main objectives were to improve solid waste management system in these cities over the next three to five years so as to make the cities clean and healthy. Specific objectives were as follows:

- Institutional strengthening of solid waste management section of local government bodies;
- Improving financial performance by cost recovery;
- Promoting source separation of wastes;
- Improving waste collection and transportation;
- Promoting recycling and resource recovery;
- Promoting controlled final disposal of waste;
- Improving public education and awareness; and
- Promoting private sector participation in waste collection and treatment/recycling;

Table 10.29 presents the investment requirements for various SWM activities in four cities and towns in terms of US Dollars. Investment requirements for four cities vary depending on population size and local conditions. Total investment requirement for three City Corporations and one Paurashava is Tk. 1,815 million (US$ 22.68 millions). Per capita investment also varies between Tk. 330 and Tk. 940. Average per capita investment requirement for four cities combined is Tk. 396.

Table 10.29: Investment Requirements for Various SWM Activities

SWM Activities	Chattogram City Corporation	Rajshahi City Corporation	Rangpur City Corporation	Patuakhali Paurashava
	US$	US$	US$	US$
Human resource development	450,000	225,000	195,000	65,000
Source Separation	1,930,000	630,000	282,500	87,250
Achieving 100% collection efficiency	1,475,000	1,650,000	540,000	515,000
Developing controlled landfill	9,500,000	3,750,000	625,000	250,000
Establishing resource recovery centre	260,000	140,000	65,000	50,000
Total US$	13,615,000	6,395,000	1,707,500	967,250
Total Million US$	13.615	6.395	1.7075	0.96725
Total Million Tk.	1,089.2	511.6	136.6	77.38
Per Capita (Tk)	330	643	335	940
Average per capita investment requirement for four cities combined (in Tk.) = 396				

Source: BMDF, 2012

It was expected that the implementation of the programme would achieve the following:

Human resource development: The project would alleviate chronic shortage of properly trained professionals and other staff in the conservancy section.

Source separation: This project would help to promote resource recovery of waste, reduce disposal of waste in landfill and assist to reach national goal for 3R. Reducing waste from landfill and recycling of waste will help to reduce GHG emissions.

Achieving 100% waste collection efficiency: The project would establish appropriate primary and secondary waste collection system in City Corporations/Municipalities and operationalize it. It will improve the waste collection efficiency by 100%, synchronize the both primary and secondary waste collection and replace open waste collection bin with closed containers. Improvement in secondary waste collection system will reduce the fuel consumption and thus reduce greenhouse gas emissions. Furthermore, pollution of water bodies will be minimized.

Developing controlled landfill sites: The project would establish appropriate procedures for the operation of waste disposal sites and train conservancy staff on operational procedure of controlled landfill. The project is in line with GoB's 3R strategy to eliminate open dumping of waste by 2015.

Establishing resource recovery centre: The project would help to promote resource recovery of waste, reduce disposal of waste in landfill and assist to reach national goal of 3R by diverting waste from landfill to recycling as well as assist to implement GoB's national climate change strategy for low carbon development in waste sector.

10.5.5 E-waste, Medical Waste and Hazardous Waste Management

Electrical and electronic equipment waste ("e-waste") contain hazardous materials such as lead, mercury, and hexavalent chromium which is highly hazardous for the environment. Not much is known about the extent of e-waste and hazardous waste generation and management system of Bangladesh as no inventory has been done yet on these issues. Though some initiatives were taken by some private sectors to know the generation rate of e-waste, in many cases the methodology of their study was not scientifically strong and clear. A number of informal sectors are active in the recycling process of e-waste. There are very few formal facilities in the sector of e-waste recycling. No separate policy/rules/acts exist for guiding the management of e-waste till date. Only the National 3R Strategy for waste management mentions the issue of e-waste management and suggests starting the practice of extended producer responsibility (EPR) in the country.

Besides, an inventory of hazardous waste management was published by Department of Environment, in 2010 where textile dying industries, hospitals and clinics, tannery, pesticides, fertilizers and oil refinery, etc were enlisted as possible sources of hazardous wastes in Bangladesh. Only recently (2011) a rule titled "Hazardous Waste and Ship Breaking Waste Management Rules, 2011" was gazetted. However, there is not much information on the generation and management of hazardous waste management in Bangladesh and the law enforcement is not so vigilant in this regard. Consequently, the environment, especially the surface water of Bangladesh is severely degrading.

10.5.6 Radioactive Waste Management

Radioactive wastes arising in Bangladesh comes from the use of radionuclides in medicine, industry, research and agriculture works. In Bangladesh, presently there are 15 Nuclear Medicine Centres (NMC) and one Nuclear Medicine Institute (NMI). Out of these 16 facilities, two are private organizations and rest belong to Bangladesh Atomic Energy Commission (BAEC). Radioactive wastes are produced from different sources such as nuclear medicine practices, industrial radiography practice, nucleonic gauge practices, radiotherapy practices and gamma irradiators, etc. All of these facilities have serious lack of radiation protection and waste management capacities.

However, radioactive waste emits radiation, which makes it a particular hazard for human health and the environment. Producers and users of radioactive materials must be sure that a waste management strategy exists prior to the start of waste generation. A well-developed waste management system includes the handling, pre-treatment, treatment, conditioning, storage, transportation and disposal of conditioned radioactive waste, as well as the release and discharge of decontaminated materials. The strategy should consider the entire sequence of waste management operations, with various regulatory, socio-political and economic issues taken into consideration. Regulatory arrangement to manage radioactive wastes in Bangladesh has been established through promulgation of Nuclear Safety and Radiation Control Rules-1997.

Rooppur Nuclear Power Plant in Bangladesh

Bangladesh and Russia have signed a contract for establishing Rooppur Nuclear Power Plant, Pabna in 2013. The Bangladesh Atomic Energy Commission (BAEC), Ministry of Science and Technology, is implementing the project. The Uranium-235, which would be the reactor fuel at the proposed plant, is one of the most common fissile nuclear fuels used in power production, manufactured as small round fuel pellets. A single pellet is less than an inch long, but is said to produce energy equivalent to a tonne of coal. Harmful radio-isotopes can build up to dangerous and fatal levels of radiation that, if not properly contained, can kill a person. According to the contract, Russia will take care of the burnt nuclear fuel and will dispose the nuclear wastage.

10.5.7 Issues and Challenges

Rapid Urbanization

The generation of solid waste will continue to increase with the increase of population and urbanization. There are more than 500 cities and towns in the country, which are hubs of rapid economic development and population growth (BBS 2014). These urban areas generate thousands of tonnes of waste from domestic, industrial, commercial, health care facilities that must be managed daily. The production of urban solid waste approximates 16,015 tonnes everyday which adds up to over 5.84 million tonnes annually. This is projected to reach 17.16 million per year by 2025. The overall waste collection situation is not at all satisfactory. Huge amount of the uncollected waste, a high proportion of which is organic, finds its way into roadside drains or canals or incidental spaces or in vacant plots in between settlements. This makes the urban living environment and creates hazardous problems of water logging in different areas and pollutes the local environment.

Climate Change

Climate change will also have a substantial impact on solid waste management practices, underlining the need for urgent action. The major threat of rising temperature will be to augment the role of decay of solid waste that is dumped on land without treatment and safe disposal. This will lead to increased emission of methane gas, which is 21 times more powerful than carbon dioxide in term of its impact on climate change. The main threat arises from flood and consequent inundation of landfill site which exposes risk of contamination causing various diseases such as diarrhea, dysentery, cholera, typhoid and so on. Also, groundwater and river water can be contaminated by polluted flood water.

Changing Composition of Solid Waste

As income and standard of living increase, waste also becomes diversified with larger shares of plastic and paper. In Dhaka city, percentage of plastic in solid waste has increased from only 1.74% in 1992 to about 4.1% in 2005. Thus, there has been a 28.13% increase in the growth of plastic as a solid waste.

Apart from plastic, electric and electronic wastes (e-waste) are also rapidly growing forms of waste, which pose a health hazard to human beings as they contain metals such as mercury, cadmium and lead. UNEP (2005) estimated that e-waste from used computers in emerging economies (such as India) would increase by 200 to 500% in 2020. In Bangladesh, also e-waste from used computers and mobiles is likely to increase manifold during the next few years.

Waste Management in Urban Slums

Most of these slums are deprived of proper waste collection services. In fact, urban slum areas are the worst victims of inadequate provisions of public health services due to their illegal settlement and high density of population in limited areas. Most of the slum households dispose garbage in open spaces. An ADB study (ADB, 2008) found that in Dhaka slums, only 25% of the households use the designated places for garbage disposal, while about 58% of the households throw garbage down into the water through gaps in the floors of their houses or into any nearby open spaces. Exposure of slum dwellers to improperly disposed wastes makes their living condition and health status even worse.

10.5.8 Solid Waste Management Strategies under the BDP 2100

It is now acknowledged that conventional SWM is not sustainable and too costly. It is a centralized management approach, characterized by poor efficiencies, undesirable health impacts, environmental problems and undesirable social consequences (such as informal communities or waste pickers working in unsafe working condition). Integrated Solid Waste Management (ISWM) is the preferred alternative to conventional SWM. The ISWM refers to "the strategic approach to sustainable management of solid waste covering all sources and all aspects, including generation, segregation, transfer, sorting, treatment, recovery and disposal in an integrated manner, with an emphasis on maximizing resource use efficiency" (UNEP, 2016).

While there is no disagreement about the ISWM hierarchy, management methods need to be selected carefully as the local conditions, needs and means of local governments may vary. Other important factors that may influence the selection of management methods include environmental policies and regulations, availability of markets for composts and recyclables, and the process or technology for handling various types of wastes. Effective waste management, therefore, would depend on selection of appropriate management methods.

BDP 2100 has two strategies related to solid waste management as outline below.

Strategy WSS 12: Integrated Wastewater and Solid Waste Management

The conventional SWM is now a centralized management approach, characterized by poor efficiencies, undesirable health impacts, environmental problems and undesirable social consequences (such as informal communities or waste pickers working in unsafe working conditions). Therefore, Integrated Solid Waste Management (ISWM) would be the preferred alternative to conventional SWM.

Sub-strategy WSS 12.1: Strengthen institutional capacity

- Enactment of Solid Waste Management Act specifying waste management standards, practices, institutional structures, etc.
- Roles and responsibilities of each level of government should be clearly identified and proper coordination mechanism should be developed.
- As the local governments are primarily responsible for SWM, it is necessary to ensure that they have the authority and required resources to implement wastewater and SWM.

Sub-strategy WSS 12.2: Increase community participation

Community participation in all phases of waste management is essential for implementation of ISWM. A sustainable community-wide education and partnership program will play a significant and long term role in reinforcing the importance of waste reduction, re-use and recycling. The local government authority should work with community, non-governmental organizations and other stakeholders in order to understand and respond to community priorities in solid waste management. This will include facilitating two-way communication, in which information and ideas are exchanged and public awareness programs conducted.

Sub-strategy WSS 12.3: Cost recovery and private sector involvement

- The local authority can generate revenue through implementation of 'Polluters Pay' Principle. The authority can apply user charges to recover a portion of the costs of solid waste management services from waste generators.
- Private sector has the capacity to bring additional and much needed finance to the waste management system. For this it is necessary to identify the services to create viable and profitable businesses. Steps, therefore, should be taken to develop procedures and administrative arrangements necessary to implement participation of the private sector in waste management.

Sub-strategy WSS 12.4: Increase technical capacity with technology

Technical capacity needs include (but not limited to) the following aspects:

- Knowledge of the factors in siting and design considerations of collection and disposal facilities.
- Conduct waste characterization studies
- Standards, compliance and enforcement techniques
- Developing waste minimization and diversion programs
- Assessing waste treatment and recycling technologies

Sub-strategy WSS 12.5: Land use planning

Wastewater and solid waste management should be recognized as an integral part of land use or urban development planning. Land use or urban development plans should incorporate the objectives of solid waste management policy and address the issue of space requirements for carrying out various ISWM activities including space for collection and transfer stations, landfill sites, sites for recycling and energy production activities, etc.

Strategy WSS 13: Radioactive Waste Management

a) The national waste management policy should form the basis for legislation and regulation of waste management activities. The policy may state preference for one management option over another (e.g. storage for decay then disposal as nonradioactive waste, versus immediate disposal as radioactive waste) and define the funding and management responsibilities for the programmes and the legal/jurisdictional roles for various government departments.
b) Planning, implementing, managing and enforcing a waste management programme requires careful thought. Several factors must be taken into consideration in this regard:

- Care should be taken to minimize risks both to the natural environment and to the public health.
- Where it is not yet possible to undertake all of the management steps from waste generation to final disposal, it is advisable that steps be taken to avoid closing off later options, since some may require substantial additional cost and radiation dose penalties.
- If the dilute and disperse option for some aqueous and gaseous wastes is not appropriate, strategies incorporating confinement and concentration of the waste should be considered.
- The preferred processes should be considered taking into consideration the local availability of equipment and resources. This is especially true in developing countries, where highly sophisticated equipment may be difficult to obtain and maintain in a proper working condition.

c) Minimization of radioactive waste generation is a vital requirement that must be addressed at all stages of the design and operation of facilities.

d) Decay is the only natural way of reducing radioactivity. Since radionuclides have decay rates ranging from days to thousands of years, proper segregation of wastes depending on their half-lives, and separate treatment and conditioning of these wastes, is an important factor in the overall scheme of radioactive waste management.

10.6 Storm-Water and Urban Drainage Management

Apart from flooding, water-logging has also become a major problem of urban areas, especially in the big cities. The problem becomes quite serious during the annual monsoon with widespread and lengthy disruption of roads, telecommunications, electricity supply and water supply. In September, 2004 continuous rainfall for about 48 hours inundated most parts of Dhaka city. A record 341 millimeters of rainfall in the city on 12th and 13th September disrupted business and economic activities and forced the suspension of Dhaka's Stock Exchange. A report by Dhaka's Water and Sewerage Authority (DWASA) indicated that the heavy downpour affected 250 schools and 681 garment factories in addition to shopping malls, business centers and various other factories (Alam and Rabbani 2007).

Hazard potential of urban areas will also significantly increase due to climate change. Adaptation will require policies and investments to make urban areas resilient to the impact of climate change including loss of property, habitat and infrastructure. Formulation of effective adaptation measures, however, would require a better understanding of the factors responsible for flooding and water-logging in urban areas, urban drainage systems and their performances, and the issues and challenges that should be addressed to develop sustainable urban drainage systems in the country.

10.6.1 Causes of Water-logging

There are two types of city inundation namely urban floods and river floods. Urban floods are classified as the inundation in cities caused by drainage congestion and water logging. And river floods are classified as the city inundation caused by river floods. Urban flooding in the built-ip areas of Dhaka City is a major concern and a matter of serious discussion among the city dwellers. It causes unbearable sufferings for the people by creating difficult situation for traffic movement as well as unhygienic environment that has long lasting consequences. Following are the main reasons for urban flooding in Dhaka City:

- Increase in covered areas causing higher rainfall run-off volume;
- Unplanned and uncoordinated development of the city;
- Continuous filling of wet lands for expansion of the city both by the public sector and private organizations;
- Unauthorized and illegal occupation and destruction of natural drainage system and retention basins;
- Inadequate storm water drainage facilities;
- Clogging of drainage channels and sewer lines due to indiscriminate dumping of solid wastes and inadequate cleaning of sewers, catch pits, etc.; and
- High water level in the peripheral river system.

The disappearance of the natural drainage system is one of the main causes for water logging. Rapid population growth and unplanned development, unplanned land filling to develop new residential areas, uncontrolled and haphazard disposal of solid wastes and garbage into the existing drainage system, and encroachment on lakes, khals/canals and rivers with unauthorized construction are the main activities that can be linked to the disappearance of the natural drainage system.

10.6.2 Drainage Network

Drainage is defined as "the removable of unwanted water from human settlement". Unwanted water such as storm runoff, flood water from seasonal rains, and domestic wastewater (sullage) need to be removed from human settlements because of their potential impacts on health and well-being of the people. Such water, if not removed properly, would cause inconvenience, water-logging and health risks.

Drainage can be either natural or artificial. Many areas have some natural drainage which means the excess water flow to the lakes and rivers. Natural drainage, however, is often inadequate and hence artificial or man-made drainage is required. There are two types of artificial drainage: surface drainage and subsurface drainage.

Surface drainage is the removal of excess water from the surface of the land. This is normally accomplished by shallow ditches, also called open drains. The shallow ditches discharge into larger and deeper collector drains. In order to facilitate the flow of excess water toward the drains an artificial slope is maintained throughout the planned area. Subsurface drainage is the removal of water from the root zone. It is accomplished by deep open drains or buried pipe drains.

10.6.3 Drainage Network of Dhaka

In 1864, the Dhaka Municipality was formed. It became a Municipal Corporation in 1960 and in 1991 it got the status of City Corporation. In 2011, the City Corporation was split into two: North and South. The city has a population of 89,06,039 (BBS, 2014).

Natural Drainage System

Natural water bodies play an important role in the drainage system of any area. The water body performs the functions of water reservoir and the discharge sites of artificial drains. The natural drainage system can be divided into two types-Channel and Storage area. Dhaka had an extensive system of rivers, canals, lakes and ponds scattered and crisscrossing the city. Water channels like the Dholai Khal, the Gerani Khal, the Segunbagicha Khal or the Begun Bari Khal (**Table 10.30**) played an important role in the indigenous city life. These channels not only served as drainage networks but also served as good means of transportation. Khals and wetlands served as the backbone of the gravity drainage system of the city. But the pressure of urban development and consequent filling up of water bodies and flood plains drastically reduced the natural water retention and water carrying capacity and aggravated the problems of water-logging in the city.

Table 10.30: Characteristics of Major Khals in Dhaka City

Name of the Khal	Length (km)	Catchment Area (km^2)
Dholai Khal	4.0	16.8
Gerani Khal	3.4	6.7
Segun Bagicha Khal	3.5	8.3
Begunbari Khal	6.5	37.7

Source: Tawhid, 2004

Dhaka is surrounded by a number of rivers that include Buriganga, Tongi, Turag, Balu and Sitalakhya. In earlier centuries the city was criss-crossed by many drainage channels which carried away run-off to the surrounding rivers. According to Drainage Master Plan of Dhaka city (May, 2016) there are approximately 45 natural khals, 17 of which no longer exist., a total of about 142 km in length that are part of the khal system. Storm sewer lines covers about 140 sq km (40% coverage area) of Size of storm sewer lines are ranging from 0.6 m to 3.0 m in diameter made of brick and concrete. Dhaka WASA, however, has been able to bring the rest canals under its control. Eleven canals are being rehabilitated under the Removal of Water-logging Project Phase-2 while the rehabilitation works of eight canals are being carried out under a World Bank Project. With increased urbanization most of these canals have been filled up. Low-lying areas which work as retention areas for rain water are also becoming filled up with residential, industrial and other urban land uses. Consequently, drainage is impeded and many parts of the city become impassable or inaccessible after normal rains. Even after an hour long rainfall many parts of the city including low and middle class residences go under water because of poor condition of drainage channels, many of which have been encroached, filled, silted and blocked due to garbage disposal. With the expansion of the city, remaining open spaces and low-lying areas are likely to face intense pressure from private land development companies and the situation would become worse if protective measures are not taken to save these lands from further encroachment.

Man-made Drainage System

Surface Drainage

Dhaka North and South City Corporations are responsible for the surface water drainage of the city area. Surface drainage is the removal of excess water from the surface of the road. This is normally at the side of the road accomplished by shallow ditches, also called open drains. The roads are sloped toward the surface drain and the surface drain is connected with the storm drainage network. The storm water and other water that fall on roads are run off to the surface drain and enter the storm drains. The City Corporations have some 1,100 km. of surface drains. The responsibility of development, operation and maintenance of surface drainage system in Dhaka City lies with the two City Corporations.

Storm Water Drainage

All the Sullage and storm water are carried by the storm drain. Dhaka WASA (DWASA) is responsible for the storm water drainage of Dhaka city. The operation and maintenance of the storm water drainage system is organized by DWASA. For the better management of the city drainage system, DWASA divided the whole storm water drainage into 11 zones. Some 10 zones are within Dhaka city and one zone in Narayanganj city. Important components of storm drainage network are briefly summarized below:

- 22 open canals having width of 10 to 30 m and total length of approximately 65 km (Rabbi, 2001).
- 315 km. of underground pipes having diameter ranging between 450 to 3000 mm. (Rahman, 2004).
- 10 km. of box culvert of sizes between 2.5 m * 3.4 m to 6 m * 4.1 m.
- 3 storm water-pumping stations with capacity of 25 m^3/s, 22 m^3/s and 20 m^3/s at Rampura, Dholaikhal and Kallyanpur, respectively.

Bangladesh Water Development Board (BWDB) has also constructed one pumping station (capacity 44 m^3/s) at the northwestern part (Goran Chadbari at the outfall of the Degun khal into the Turag River) of the city. There are also 65 small pumps with individual capacities of 0.142 cumec, installed temporarily by DWASA to drain out storm water from various locations. Moreover, DCCs have constructed and maintains at least 130 km small diameter underground drains which carry storm water to the main sewer lines. RAJUK also constructs roadside underground drainage lines during the construction of new roads. The responsibility of development, operation and maintenance of drainage system in Dhaka City lies with the DWASA. But several agencies are working for development of the city drainage system, with little or no coordination among them.

10.6.4 Drainage System of Sylhet

Sylhet is a major city situated in the northeastern part of Bangladesh. It is located on the bank of the Surma River. It has a vast historical and cultural background, with diversified inhabitants of Garo, Khasia, Monipuri and Hazong populations. The District is surrounded by the Jaintia, Khasia and Tripura Hills. Sylhet region is well known for its tea gardens and tropical rain forests.

The Sylhet Municipality was formed in 1885 and then in 2001 it became a City Corporation. Population wise, it is the fourth largest City Corporation of Bangladesh. The total population of the city is 5,31,663 of which 54% are male and 46% are female. Total urban area is 41.85 km^2 of which 26.50 km^2 is under City Corporation jurisdiction.

The Surma River divides Sylhet city into two parts: northern and southern part. The topography plays an important role in the drainage system of Sylhet city. The northern side of Sylhet city is under the class of Tertiary Hills and the southern part is quite flat. The general topography of Sylhet city is undulating with elevations varying from 14.26 m, MSL to 9.26 m, MSL. Thus, the storm water drains from north to south and falls into the Surma River. The channel that originates from hilly regions are known locally as Chhara. In the northern part of Sylhet city area, there are mainly three individual drainage sub-systems: Malni Chhara, Baitha khal and Goali Chhara. All of the Chharas fall into the Surma River. In the southern part of the city area, there are only Ratner-Joynter khal system which drain towards south (low-land area) and a small-strip railway khal drains towards 'Barthkhola Haor'. Sylhet City is prone to flash floods from the northern hilly areas. So the catchment area of the sub-system is beyond the city area and up to the hilly region.

Table 10.31: Characteristics of Major Sub-System in Sylhet City

Name of the Sub-System	Length of khal (km)	Catchment Area (km²)
Malni Chhara	23.6	16.26
Baitha khal	4.25	2.79
Goali Chhara	18.01	12.98
South Surma	2.46	9.56

Source: Tawhid, 2004

There are 17 tributaries of the Malni chhara sub-system and the combined flow drains into the Surma River. About 1.80 km^2 (around 15.5% area) of this system is vulnerable for inundation to a 50-year flood event (10.84m MSL) of the Surma River. In this system, some of the Chharas are encroached at different reaches leading to low conveyance capacity and as a result inundation is observed at these locations. Solid wastes are indiscriminately dumped into the Chharas, which choke the drains and further aggravates the drainage congestion and inundation.

In the Baitha khal system, there are five tributaries and the combined flow drains into the Surma River. About 0.20 km^2 (around 7% area) is vulnerable to inundation to a 50-year flood event (10.84 m MSL) of the Surma River. In the Goali Chhara system, there are 12 nos. of tributaries and the combined flow drains into the Surma River. About 1.7 km^2 (around 20% area) is vulnerable for inundation to a 50-year flood event (10.84 m MSL) of the Surma River. Encroachment in some reaches and indiscriminate solid waste dumping are the main causes of drainage congestion in both sub-systems.

In south Surma drainge sub-system, four individual Chhara water drain to the south through Jointar khal and 'Barthkhola' Haor which drains from north to south and fall into the Kushiyara River. This system is separated from the Surma River by an elevated road embankment and this system is not affected by the flood of the Surma River. About 1.1 km^2 (around 16.4% area) is vulnerable to inundation during pre-monsoon and monsoon rains. In some places Jointar khal is choked due to water hyacinth and indiscriminate solid waste disposal. Water could not drain from Barthkhola Haor to south due to obstruction created by housing development (residential area) and inadequate (narrow) section of Jointar khal.

Besides the natural drainage channel, there are 60 km of pucca drains and 105 km of kucha drains along the major roads. The drains carry storm water from the urban areas into the Chhara/Khals.

10.6.5 Drainage System of Rajshahi

Rajshahi is a divisional town and the City Corporation is the fifth largest of Bangladesh in terms of population. Initially, Rajshahi Municipality was established in 1876 as Rampur Boalia Municipality with 7 wards and with only a population of 10,000. The municipality was transformed into a fully functional municipal corporation on 13th August 1987. The municipal corporation area extended from Horgram Bazaar in the west to Rajshahi University of

Engineering and Technology in the east covering 6.64 square miles containing a population of 56,883. Later, the municipal corporation of Rajshahi was upgraded to a City Corporation in 1991. It has an area of 97.18 km^2 (87.06 km^2 excluding the water areas). The total population of the City Corporation is 448,087. Analysis shows that within the City Corporation area there are 54% urban or builtup area, 12% waterbodies, vegetation 11.24% and 3.6% road. The slums cover only 1.27% area. The urban area extends beyond the City Corporation areas. The urban area has increased from an area of 18.5% in 1970 to 54% by 2010 (CEGIS, 2015).

The city is located in the bank of the Padma River and surrounded by Pabna District in the north. Rajshahi is also known as high 'Barind' area and is generally elevated with maximum of elevation 18.3 m MSL.

The total length of drainage network is 136.27 km, among them primary drain is 46.80 km, secondary drain is 44.69 km and tertiary drains is 44.78 km. About 41.6% city area have no sufficient drainage system (Rahman and Rahman 2012). Wastewater and rainwater cannot flow through the drains smoothly. Most of the drains are broken or earthen. Most of the tertiary drains are filled up by soil and different types of wastages, obstructing drainage flows. Moreover, the population is increasing and several slums have sprung up blocking the drainage system. Recently, the drainage systems have been improved in two phases covering about 60% of total city area.

10.6.6 Drainage System of Rangpur

The Ghagat River is flowing from north to south and then west to east direction. There are some khals inside the city area which carry storm water into the Ghagat River. There are 235 km drains in the city. The drainage problem at this stage is not so acute but may get worsen if in the city is not developed with proper planning. Many canals are already encroached in numerous places. Moreover, the Ghagat river has already silted up which can create drainage problems in the future.

10.6.7 Drainage System of Barishal

Barishal District is criss-crossed by numerous rivers and tributaries. The city lies along an offshoot of the Arial Khan River, called the Kirtankhola River.

Barishal Municipality was formed in 1876 and it was upgraded to a City Corporation in 2000. The total population of the city is 339,308 of which 52% are males and 48% are females, covering an area of 58.05 km^2 (BBS, 2014).

The existing drainage facilities in Barishal City are very inadequate, which mostly discharge into the nearby canals, low-laying areas and finally into the Kirtonkhola River. Major city areas are not subject to direct flooding from the Kirtonkhola River. However, synchronizing effect of intense rainfall and high tide of Kirtonkhola River causes drainage congestion to relatively low-lying areas.

The causes of internal drainage problem are due to encroachment of water bodies and natural drainage system, inadequate drainage, absence of sufficient drainage outlets, lack of proper maintenance of the existing drainage system and finally due to the disposal of solid wastes into the drainage paths.

The major drainage channels in the City are Jail Khal, Amanotganj Khal, Bater Khal, Sagordi Khal, Gurgo Khal, Napitkhali Khal, Chandmari Khal and Lakutia Khal, which drain the entire city to the Kirtonkhola River. These khals carry storm water runoff as well as untreated wastewater to the peripheral river. Natural drainage system drains the city in a southeastwardly direction to the Kirtonkhola River. At present there are about 600 km of pucca drains and 450 km of katcha drains.

10.6.8 Drainage System of Chattogram

Chattogram is the second largest city in Bangladesh. The city is bounded by hills and forests to the north, the Halda River valley to the northeast, the Bay of Bengal to the west and the Karnaphuli River to the southeast. Initially, in 1984, the Chattogram Municipality was established and received the status of a City Corporation in July 1990.

Chattogram City Corporation covers an area of 155.40 km^2 with a population of 2,581,643 (BBS, 2014). Chattogram is situated about 15 km upstream of the river mouth at the confluence of the Karnaphuli River and the Bay of Bengal. Annually on an average 3,000 mm of rainfall is observed, of which the major amount of about 2,400 mm occurs during the monsoon. The temperature is between 80^{o} C to 34^{o}C (BMD).

The City Corporation area includse 18% builtup area, 13.46% agricultural land, 16.38% rivers and waterbodies, 12.42% settlement area with homestead vegetation, 10.43% forests, 3.26% industrial area, 12% open space (including parks and playgrounds), 2.08% barren land and 0.84% slum area.

Drainage system of Chattogram consists of natural and artificial drains. Natural drains are open channels (khals and rivers). Khals and rivers are natural water bodies that serve as storm as well as sanitary sewers with a total length of about 144 km. Major khals include the Chaktai, Chakti diversion, Mohesh Kali, Rajakhali and Mirza khal, all eventually fall into the Karnaphuli River or the Bay of Bengal. Mohesh Kali khal contributes to draining the western and southern area of the city. Chakti khal contributes to draining the eastern and central part of the city. The catchment area is large and inflow is too high for Chakti khal to accommodate the total flow. Therefore, Chattogram City Corporation has developed the Chakti diversion khal to reduce the burden on the Chakti khal.

The artificial drains consist of tertiary, secondary and primary drains of various sizes which flow into open channels like Khals (or canals) and rivers. These are described below:

Primary drains: Primary drains are artificial drains usually constructed along major roads with a total length of around 70 km. Primary drains are the main source of discharge from secondary drains which ultimately fall into khals.

Secondary drains: Secondary drains flow into primary drains and usually run alongside local distributor roads. The structure is typically comprised of masonry and/or concrete, and collects discharge from tertiary drains. The total length of secondary drains is around 90 km.

Tertiary drains: Tertiary drains are constructed running parallel to access roads. The total length is around 130 km.

10.6.9 Drainage System of Khulna

Khulna is the second port city of Bangladesh. By size of population, Khulna is ranked third. The Municipality of Khulna was established in 1884 and the Khulna City Corporation was created in 1992. It has an area of 50.61 km^2. The total population of the city corporation is 6,64,728 (BBS, 2014). The temperature ranges between 12.5°C to 35.5°C and the annual average rainfall is 1,605 mm. The land use pattern of Khulna has been substantially influenced by the flow of the Rupsha and the Bhairab Rivers. As a deltaic plain, the land is flat and poorly drained. The whole metropolitan area is approximately 2.5m above MSL (ADB, 2010). At downstream of Khulna City, the Rupsha River meets the Kazibancha-Pussur River that travels more than 100 km and then falls into the Bay of Bengal. Tidal flow from the Bay has daily, seasonal and annual variation. The effect of this tidal flow is observed throughout the system.

There is about 667 kilometers of drainage network in Khulna City Corporation area, of which about 638 km is pucca including the covered drains, and 28 km katcha. The existing drains in KCC areas discharge water into the nearby khals, rivers, low-lying areas and beels. There is no underground storm water drainage system in Khulna City. Concrete box and pipe culverts are used for road crossings only. The existing drainage facilities in the fringe and semi-core areas are inadequate and unsatisfactory. The major part of the KCC areas in the town is not subject to direct flooding from the Bhairab-Rupsha River, but the low-lying areas situated on the western and southern part are flooded during heavy rain and tidal effect during monsoon season. According to the drainage Master Plan of (Survey to Mitigate Water Logging Problem of Khulna City, 2011, Khulna City Corporation) KCC the manmade drains have width ranging from less than 0.1 meter to 9.0 meter. Within city 155 km pucca drains have width less than 0.5 meter. About 1.16 km of pucca drains have width greater than 5 meters.

There are 6 regulators and 8 sluice gates to drain out storm water from KCC area. At Alutala a 10-vent sluice gate serves as major drainage function of the Khulna City. There are four regulators that drain out storm water into the Rupsha River and the other two regulators drain water into the Khudir Khal, the upstream part of the Mayur River.

10.6.10 Operational Performance and Maintenance of Drainage Systems

Operation and maintenance of Dhaka's drainage system is very poor which is often linked to the problems of water-logging in the city. Operation and maintenance of the drainage system is affected by inadequate maintenance of natural canals and storm water and surface drains, lack of cleaning equipment, inadequate budget and staffing, lack of proper monitoring programme, and poor coordination among the institutions responsible for operation and maintenance of the drainage system of the city.

Clogging of surface and storm water drains with solid waste is a major reason for frequent water-logging in Dhaka city. Every year about one meter of sludge is deposited in Dhaka's khals and box culverts. Further, rainwater carries the uncollected solid wastes into the drainage system that slows down the rainwater runoff from the affected areas. Lack of awareness of the people further aggravates the situation. They often use the khals and drains for dumping garbage. As a consequence, discharge capacity of drains, khals and box culverts is reduced drastically. The problem is compounded by the lack of capacity of WASA and DCCs in terms of financial resources for routine cleaning, availability of vacuum machines, remote-controlled excavators, etc.

Usually, pumping stations are used to pump out the storm water from inner side of the encircling embankment of Dhaka City. But there are only three storm water pumping stations located at Rampura, Dholaikhal and Kallyanpur. Dhaka WASA has the responsibility for operation and maintenance of these pumping stations. These are very much insufficient in respect of demand for timely pumping out of storm water.

In Chattogram reason of long duration water logging situation in the city is mainly due to inadequate drainage capacity. Lack of enough drains and their reduced water holding capacity helps in creating drainage congestion due to heavy rainfall. The width and depth of almost all the drains have decreased from their initial width and depth at the time of constructions mainly due to encroachment and dumping of garbage. As the width and depth of the drains decreased the water carrying capacity of the drains is also decreased. The water carrying capacity of primary drains decreased to about 28 m^3 to 31 m^3 from their initial capacity of 45 m^3 at the time of construction.

The capacity of secondary drains decreased to about 15 m^3 to 18 m^3 from their initial capacity of 27 m^3 at the time of construction while water carrying capacity of tertiary drains decreased to about 4 m^3 to 7 m^3 from their initial capacity of 9 m^3.

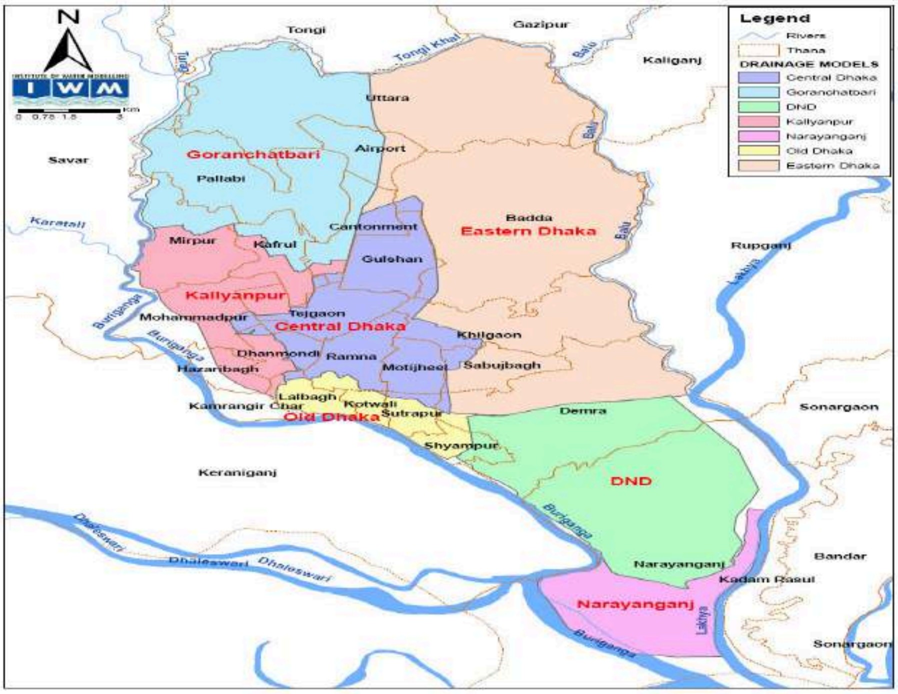
One of the biggest challenges for Chattogram City Corporation (CCC) in managing the drainage system is to deal with the illegal occupation of the canals. Many of the primary canals have disappeared and several secondary canals are either completely or partially occupied. The occupiers are very powerful and several attempts to reclaim the natural canals, especially the Chaktai Khal, which is the backbone of the natural drainage, have not been successful.

In Khulna City Corporation (KCC) area, the existing drainage network is not adequate to meet the present need of the city. Most of Wards have less than the desired drainage length. According to KCC Drainage Master Plan (2011), three Wards have maximum drainage coverage while one Ward has no man-made drains. In most of the other Wards the drainage coverage is very low. It has been identified in the KCC Drainage Master Plan that the capacity and gravity of most existing drainage channels is not sufficient to carry out the excessive rainwater. In natural khals the flow of water is hampered due to inadequate drainage section, absence of inlets and outlets and lack of proper maintenance of drainage structures. Water logging occurs at many places. There are katcha drains in KCC area that have no outlets.

Besides the divisional cities and city corporations, there are district and upazila level cities/towns where storm water and urban drainage management is a growing challenge. LGED has developed Master Plan of 240 Municipalities where drainage master plan is also a part. Implementation of the master plan along with the drainage master plan will make these cities habitable in the future and maintain their potential for future growth. There is a need for developing approaches for restoring the natural drainage canals and constructing new drains and canals.

10.6.11 Capital Investment Requirements

When the capacity of the natural drainage system shrinks due to the pressure of urban development the artificial drainage system needs to meet the drainage requirements of a city. This did not happen in Dhaka and the other cities. The man-made drainage system has not been able to keep pace with the rapid urbanization of the city. Even the capacity of the existing system cannot be fully utilized due to lack of proper maintenance. Dasgupta, et.al. (2015) carried out a hydrological modeling exercise to assess the capacity of the existing drainage system of Dhaka. For this purpose, Dhaka metropolitan area was divided into seven modeled zones- Old Dhaka, Central Dhaka, Kallayanpur, Goranchatbari, Eastern Dhaka, DND and Narayanganj (**Map 10.1**). The study has identified the deficit in the structural measures that have been adapted so far. On that basis the study recommended measures to address current adaptation deficit. The recommended additional investments include installing new permanent and temporary pump stations, increasing the capacities of existing pump stations, laying new drainage pipes, deepening existing water bodies, and installing automatic sluice gates to prevent backflow in box culverts. The study also analysed the impacts of climate change on the city's water-logging problem and identified adaptation deficit due to climate change.



Map 10.1: Zoning of Dhaka for Hydrological Study

Source: Dasgupta et al, 2015

Table 10.32 shows the total estimated cost of adaptation of structural measures for the five modeled zones. Structural measures excluded for rural portions of Narayanganj and Eastern Dhaka. Adaptation of non-structural measures was recommended for these areas. It was suggested that in Narayanganj all water bodies identified in the Detailed Area Plan (DAP) of Rajuk need protection; and khals and drains should be protected from solid waste. In Eastern Dhaka, planned land use as identified in the DAP must be enforced; water retention ponds require protection; and khals should be protected from encroachment and solid waste.

Table 10.32: Total Estimated Cost of Adaptation of Structural Measures for Five Zones

Modeled zone	Current adaptation deficit (Million Tk..)	Climate change deficit (Million Tk..)	Total cost (Million Tk.)	Damage avoided in 2050 (Million Tk..)	Cumulative damage avoided to 2050 (Million Tk..)
Old Dhaka	64.8	34.3	99.1	1,002	13,915
Central Dhaka	1,449.5	91.1	1,540.6	3,888	53,387
Kollyanpur	345.4	16.2	361.6	1,410	19,562
Goranchatbari	302.4	50.8	353.2	359	5,062
DND	544.6	1,105.4	1,650.0	352	4,868
Total cost	***2,706.7***	***1,297.8***	***4,004.5***	***7,011***	***96,794***

Source: Dasgupta, et al. ,2015

In addition to Drainage Master Plan and existing projects, a total estimated cost of Tk. 4.0 billion would be needed to meet the current adaptation deficit and also meet the adaptation measures to address climate change. The table shows that once the current adaptation deficit of approximately Tk. 2.7 billion is addressed, the added cost of closing the climate change gap would require another Tk. 1.3 billion. Central Dhaka would require the largest investment to meet its current adaptation deficits, at about Tk. 1.4 billion, while Old Dhaka would require the least, that is, Tk. 65 million only. All this investment would help to avoid damage totaling Tk. 7.0 billion in 2050 while the cumulative damage saving between 2014 and 2050 would be around Tk. 96.8 billion.

Water Sector Development Plan (WSDP, 2011) estimated the investment requirements for improvement of urban drainage systems in different cities and towns of the country for short (2011-15), medium (2016-20) and long (2021-2025) terms. For this purpose, three scenarios were developed as shown below:

- *Scenario-1 (Base case):* which is the present sector condition characterized by low service level and low operating efficiency
- *Scenario-2 (Moderate):* moderate service level and moderate operating efficiency
- *Scenario-3 (High):* high service level and high operating efficiency

Physical targets of urban drainage for each scenario are shown in **Table 10.33** below:

Table 10.33: Coverage Percentage by Urban Drainage up to 2025

Planning Areas	Present	Scenario-1			Scenario-2			Scenario-3		
		Short Term	Med Term	Long Term	Short Term	Med Term	Long Term	Short Term	Med Term	Long Term
Dhaka	35	60	80	90	60	80	90	70	90	100
Chattogram	30	60	80	90	60	80	90	70	90	100
Khulna	30	60	80	90	60	80	90	70	90	100
Other City Corporations	30	60	80	90	60	80	90	70	90	100
Large Paurashavas	25	50	75	90	50	75	90	60	90	100

Source: WSDP, 2011

If the socio-economic and institutional conditions, and country economic trends are taken into account then Scenario-2 appears to be a more realistic and achievable option during the plan period (2011-2025). Total investment costs of urban drainage for this scenario were estimated at Tk. 180,472 million, out of which Tk. 40,485 million would be required for short term (2011-2015), Tk. 65,449 million for medium term (2016-2020) and Tk. 74,538 million for the long term (2021-2025).

10.6.12 Issues and Challenges

Rapid Urbanization and Urban Poverty

Rapid urbanization is a major challenge for developing sustainable urban drainage systems. With the growth of urbanization, the proportion of the land covered by impervious surface (roads, parking areas, roofs, driveways and pavements) increases, preventing the natural infiltration of rainfall into the ground. Often the remaining open ground cannot accept water as rapidly as it did in its natural state. The increase of built up areas thus causes obstruction to the natural water flow.

Bangladesh being mostly a flat country, drainage is an inherent problem. Moreover, concentration of heavy rainfall during the monsoons, the cities and towns are regularly flooded. The average annual rainfall is about 2,540 mm, of which about 80% falls in the monsoon period from May to September. The carrying capacity of the rivers is being reduced due to siltation, causing serious drainage congestion, especially in the coastal zone. Construction of drainage systems in the urban areas is expensive and has not kept pace with urban development. This problem is compounded by the fact that many natural canals are being blocked by construction or are being filled up for housing and other purposes.

Urban poverty also has significant impact on urban drainage system. Rapid growth of urban population creates pressure on the housing market. Increased demand for housing again creates pressure on the land market and the land value rises. As the housing cost increases within the central city, the poor people are forced to settle on marginal lands which usually serve as storage areas for rain water. Encroachment on these areas badly affects the natural drainage system. They also settle in risky areas such as hill slopes (as in Chattogram) which are vulnerable to land-slides due to hill-cutting. Land-slides resulting from heavy rains lead to increased sedimentation of downstream drainage. Squatter settlements may also develop on public open spaces or green areas which may increase rainwater runoff and hinder groundwater recharge.

Waste Management

Urban areas generate huge quantity of waste every day from various sources. The major sources of solid waste are residences, streets, market places, commercial and industrial establishments, and hospitals. Due to urban development, population growth, and consumption increase, the volume of solid waste generation in a city increases every year. At present Dhaka City generates about 6000 tonnes of solid waste per day, with a per capita generation of about 0.38 kg per day (BIGD, 2015). The composition of solid waste varies according to location, standard of living, energy sources and season. The quantity of waste generation increases during rainy season when many vegetables and fruits, especially mango and jackfruit, are available. Solid waste in Dhaka mainly consists of food, grass and plants, brick, dirt, paper and polythene materials.

Management of solid waste is the responsibility of the City Corporations and Paurashavas. These local bodies are not able to collect and dispose properly a significant proportion of solid waste generated daily. In Dhaka nearly 25% of the solid waste generated every day cannot be collected and disposed off. In some City Corporations and Paurashavas, more than 50% of the solid waste generated daily cannot be collected. Most of the uncollected waste is visible on the streets, open spaces and in the drains. Uncollected solid waste often finds its way into the drainage system with rain water, restricting its passage and thus slowing the evacuation of rainwater run-off from the affected areas. The clogging of storm-water drains and manholes with solid waste is a primary reason for frequent, localized flooding in Dhaka. Similar is the situation in other cities and towns of the country. Performance of the drainage system of a city, therefore, largely depends on how the solid waste generated every day in the city is managed.

Climate Change

As with water shortages and increased pressure on sanitation, the urban flooding hazard potential of urban areas will significantly increase due to climate change because the frequency and intensity of rainfall events are likely to increase. This will threaten the critical infrastructure that supplies the city dwellers with essential services such as electricity, water, waste disposal, transportation, telecommunication, etc. This underlines the need for addressing adequately the problems of flooding and water logging in cities and towns of the country.

Institutional Issues

Planning, construction and maintenance of the drainage system in a city may be shared by a number of agencies. In Dhaka, for example, development and maintenance of drainage system are shared by DWASA, DNCC, DSCC, BWDB, RAJUK and Cantonment Board. Lack of capacity and poor coordination among these agencies are often cited as one of the major reasons for poor performance of Dhaka's drainage system. Dhaka's two DCCs are responsible for development and maintenance of the surface drains and roadside inlets. DWASA, on the other hand, is responsible for development and maintenance of the underground storm-water drainage system. As the performances of surface drains and storm-water drains are dependent on each other, strong coordination among these authorities is essential.

In Chattogram also governance of drainage systems does not belong to any particular authority. Several authoritative bodies are responsible for managing the drainage system of the city. The core responsibility for storm water drainage and sewerage belongs to CWASA. However, CWASA has neither developed any sewerage system nor storm water drainage infrastructure till date. CCC is mainly working on the local and tertiary drainage development and construction and is also responsible to keep the drains clean. CDA's role is to incorporate drains in land-use and structural plans and allot space in city designs. The BWDB, another statutory body, is responsible to plan the flood management of Chittagon City Corporation and they are both involved in linking embankments with the drainage system. Lack of capacity and coordination among these authorities are also cited as one of the major reasons for poor performance of the drainage system in Chattogram.

Apart from institutional coordination, there is also lack of involvement of civil society – local communities, NGOs, private sector and academia in the planning, development and management of the drainage systems. The institutional arrangements are week and the management organization lacks incentives for giving better outputs. The organizations function more like bureaucratic organizations rather than customer driven organizations and lack a holistic view of their management.

10.6.13 Strategies for Sustainable Stormwater and Urban Drainage Management

Space requirements of natural drainage systems such as rivers, canals, lakes, wetlands and ponds limit urban development, while urban development disrupts and pollutes natural run-off regimes. Consequently, the development of cities is found to be associated with the destruction of natural drainage systems and construction of vast drainage networks designed to remove rain water from the urban environment as rapidly as possible. In recent years, there has been a shift in approach towards a sustainable storm water management. While the conventional approach to drainage is based on the perception that storm water is a "nuisance that should be removed", the approach to sustainable storm water management is based on the idea that storm water is a "resource that should be utilized". This underlines the importance of natural drainage systems side by side with man-made systems. The difference between a conventional approach and the alternative approach is shown in **Table 10.34**.

Table 10.34: Conventional and Alternative Approaches to Stormwater Management

Aspect of stormwater	Conventional approach – stormwater as a *'nuisance'*	Alternative approach – stormwater as a *'resource'*
Quantity	Stormwater is conveyed away from urban areas as rapidly as possible.	Stormwater is attenuated and retained at source allowing it to infiltrate into aquifers and flow gradually into receiving water bodies
Quality	Stormwater is treated together with human waste at centralised wastewater treatment	Stormwater is treated using decentralized natural systems such as soils, vegetation and ponds

Aspect of stormwater	Conventional approach – stormwater as a *'nuisance'*	Alternative approach – stormwater as a *'resource'*
	plants or discharged untreated into receiving water bodies.	
Recreation and amenity value	Not considered	Stormwater infrastructure is designed to enhance the urban landscape and provide recreational opportunities
Biodiversity	Not considered	Urban ecosystems are restored and protected through the use of stormwater to maintain and enhance natural habitats
Potential resource	Not considered	Stormwater is harvested for water supply and retained to support aquifers, waterways and vegetation

Strategy WSS 6: Strategies on Storm-Water and Urban Drainage Management

Apart from flooding, water-logging has also become a major problem of urban areas, especially the big cities. The problem becomes quite serious during annual monsoon with widespread and lengthy disruption of roads, telecommunications, electricity supply and water supply.

Sub-Strategy WSS 6.1: Develop Green Infrastructure

In recent years, there has been a shift in approach towards a more sustainable storm water management. In such cases, Green infrastructure such as interconnected network of waterways, wetlands, woodlands, wildlife habitats and other natural areas that maintain natural ecological processes, can be used to restore vegetation and green space in highly impervious city areas. When linked together through an urban environment, it facilitates storm water management by letting the environment manage water naturally. It can be a useful tool for the city to protect its natural water resources and storm water management systems from the impacts of development and urbanization. Necessary steps that must be taken to preserve the natural beauty and save water bodies, parks, lakes and urban greenery are as follows:

- Designate all ponds/water bodies in Detailed Area Plan Map and protect them according to the ecological importance and public interest.
- Stop housing estate, industries and other development work in wetlands through earth filling.
- Protect the ponds/water bodies as per regulatory framework of DAP.
- Strictly implement Wetland Conversation Act, 2000.
- Create public awareness about the importance of ponds and its role in culture fisheries, bathing and water reservoir for surface run-off during monsoon.
- Avoid water bodies during planning of roads, housing and industrial estates.
- Practice good architectural/engineering design during planning of housing estates, buildings and the intersections of main roads.
- Enhance plantation and gardening to increase the natural beauty of the city.
- Preserve the wetlands like ponds, beels, khals demarkating buffer distance of lakes.
- Avoid critical ecological areas and refuge sites from development works.
- Aware people for keeping some trees and bushes around the homesteads.
- Increase tree plantation in roadsides and homesteads.
- Restrict private land development activities in and around low -lying areas.

Sub-Strategy WSS 6.2: Rain Water Harvesting

Rainwater harvesting is an innovative alternative for water supply approach. It is a process involving collection and storage of rain water (with the help of artificially designed system) that runs off natural or man-made catchment areas e.g. roof top, compounds, rock surface or hill slopes or artificially repaired impervious/semi-pervious land surface. It reduces demand on existing water supply as well as run-off, erosion, and contamination of surface water. These include landscape use, storm-water control, wildlife and livestock watering, in-home use, and fire protection. A rainwater harvesting system can range in size and complexity. All systems have basics components, which include a catchment surface, conveyance system, storage, treatment and distribution.

Sub-Strategy WSS 6.3: Handling Drainage Congestion in Chattogram Port City

Recovering the natural canals and khals of the city for ensuring excess rainfall water drainage into the Karnaphuli River and the Bay of Benal and controlling the mouths of these canals and khals to prevent inflow of water surges during high tides and strom surges by establishing sluice gates with appropriate mechanical devices.

10.6.14 Integrated Approach to Solid Waste Management

A sound system for managing solid waste disposal is an important determinant of the satisfactory performance of a city's drainage system. Lack of awareness of the people about safe disposal of solid wastes and weak management systems of the Urban Local Bodies are largely responsible for the accumulation of wastes in streets, open spaces, drains, canals and even stagnant water bodies causing serious drainage, health and environmental problems. To adequately address the issue of solid waste management, an integrated approach is recommended that focus on community participation in waste management, along with a recycling strategy to reduce the need for primary and secondary solid waste collection.

A National 3R (Reduce, Reuse, Recycle) Strategy was passed in 2010 establishing a 3R Wing at the MoEF to implement waste prevention activities, and an inter-ministerial committee to coordinate activities across ministries. To stimulate private sector investment in waste recycling and treatment plants, the strategy calls for the government to provide tax holidays, soft loans, and land to site the facilities. It also calls for research and development of resource-efficient products and processes that minimize chemical and energy waste. The strategy proposes public grants for educational and research institutions; and tax incentives, green industrial parks, and business incubators for industry.

Collected waste is usually disposed of in land fill sites, which operate as open dumps. Only a very small proportion is currently being recycled by scavengers who sift through wastes and identify items that can be sold to used-material merchants. This informal system appears to offer great benefits not only to the merchants selling used products but also to the recycling industries by supplying needed raw materials. Quite a good number of recycling plastic industries can be found in Dhaka which depends in this informal system for the supply of raw materials.

Another area that has been attracting attention in recent years is composting of organic materials. Such materials constitute the major share of the solid waste. With a simple technology this huge waste can be transformed into quality natural fertilizer. It effectively saves us from the adverse effects of chemical fertilizers and raises agricultural production in a very eco-friendly way. It is recommended that there should be no more dumping of solid waste in the low lying areas as is practiced presently causing huge pollution, filling out low lying natural water retention areas and so forth. Instead, entire solid waste management should focus on recycling and composting of such waste to capture above benefits. Estimates suggest that up-to one-half of wastes could be handled this way. Government support for recycling through imposing user fees for waste disposal, encouraging composting, and formalizing the function of scavengers, can lead to considerable savings in the cost of processing solid wastes.

Another major factor is the need for institutional coordination. Storm water management is hugely influenced by many urban development activities. Due to such activities, natural landscapes are being converted into buildings and paved surfaces. The linkages between storm water management and other urban management sectors are described below:

Roads and transport: The construction of roads expands the area of impermeable paving causing an increase in surface runoff. Roads are also a source of stormwater pollutants such as oils, heavy metals and sediments.

Waste management: Urban waste can block drainage channels creating localised flooding. Pollutants from land-fill sites can also be dispersed through stormwater runoff.

Housing: New residential developments create an increase in impermeable surfaces through roof area and paving. This alters the hydrological characteristics of the site resulting in larger volumes of rainfall runoff that need to be managed. Also, piling waste liquids are discharged to local drains and as the sediments build up this causes blockages in the drainage system.

Economic development: Construction sites, quarrying and certain types of industry produce pollutants and high levels of sediment that are dispersed into receiving water bodies through stormwater runoff.

Parks and recreation: The management of parks and gardens impact on stormwater quality through the diffusion of fertiliser and pesticides as well as sediments and organic matter.

Various types of organizations are involved in urban development activities as mentioned above. In Dhaka, for example, development and management of drainage system is shared by DWASA, DCCs, BWDB, RAJUK and Cantonment Board. In addition, quite a large number of public agencies and ministries are involved in urban development and management activities that significantly influence stormwater management of Dhaka. Cooperation among these organizations is essential for effective performance of Dhaka’s stormwater management.

10.7 Institutional Reforms in Urban Water Management

Integrated urban water management requires strong institutions with well-defined responsibilities, financial autonomy, solid service delivery capacity, sound investment decisions and accountability to the residents. Financial autonomy and accountability are inter-linked. Basic urban services like water supply, sanitation and waste management for a rapidly growing urban population requires considerable financial resources for O&M as well as new investments. There are several areas where institutional reforms are needed to allow the implementation of an effective integrated urban water management strategy.

10.7.1 Multiple Agency Service Coordination

Integrated urban water management requires strong coordination between the multiple service providers. Collaboration between managers and planners from these organizations is necessary to identify solutions that achieve synergies between urban and landscape design, water management, ecological protection and social enhancement. The cooperation between different urban development and management sectors not only increases the likelihood of Water Sensitive Urban Design solutions being successfully implemented but also paves the way for increased integrated planning in urban development as a whole. Achieving such cooperation, however, is not that easy. Efforts were made in the past to coordinate activities of various organizations through high-powered committees. These efforts were not successful. Experts now believe that formation of city government and bringing the organizations involved in service provision and urban development under the city government would be necessary to achieve the needed coordination for sustainable water management in big cities.

10.7.2 Involving Local Stakeholders in Urban Water Management

Effective partnerships between local governments and the private sector can generate considerable benefits. Private companies, informal sector enterprises, CBOs, and NGOs can provide urban services, mobilize finance (or voluntary labour), introduce innovative technologies and undertake infrastructure development activities. For involving the private sector in urban water management activities supportive legal framework should be developed and institutional setting should be ensured. Private sector actors with whom partnership arrangements can be made include the following:

Community-based Organizations (CBOs)

These organizations are formed when neighbourhood residents get organized and join forces to improve local security, housing quality, basic utilities, social services and neighbourhood environment. Municipal-community partnership (MCP) has now emerged as an innovative institutional model. MCPs are particularly suitable for delivering specific goods and services, e.g. sanitation, refuse collection, drainage improvement, environmental maintenance, etc. MCPs should be developed as part of an overall municipal strategy.

Non-governmental Organization (NGOs)

Unlike CBOS, non-governmental organizations usually originate outside of the communities with which they work. NGOs may be understood as a "third system" between the public and private, concentrating their support at the community level while at the same time mediating between the community and the government. NGOs are effective agents for building local awareness, for mobilizing community action, strengthening CBOs, etc. In the context of vast needs, limited capacity and constrained financial resources, the local governments should recognize the role of NGOs as partners in urban development and management activities.

10.7.3 Strengthening the Role of Private Sectors

The challenge for providing the range of urban water management services to a rapidly growing urban population in an environment of already yawning supply gap calls for a strategic rethinking of supply options. ULBs alone cannot handle the daunting task. A strong role of the private sector is necessary. There is already an increasing presence of private provision of rural water and sanitation services. The scope for private provision of urban water and cleaning services is large.

Private sector role can take various forms. These include informal workers at the community based waste management services, small-scale enterprises as well as large-scale business firms that may be entrusted with the task of operating or developing water and waste related infrastructure facilities. Because of their ability to introduce innovative ideas in management, supply investable resources and adopt cost-effective technologies, participation of the private sector organizations in urban water management activities could bring about the desired improvement in the sector.
The private role can take various forms. For commercial activities like supply of water, private enterprise can be spurred through proper regulatory policies and water concessions. For sanitation and waste management, where full cost recovery can be difficult, it can be a public private partnership where private supply is funded by public resources financed by property taxes and service charges.

10.7.4 Cost Recovery Policies

Given the large magnitude of unmet and growing demand, the financing constraint in the national budget will remain strong. Good international practice shows that the application of the beneficiary pays principle is of fundamental importance to finance adequate amount of basic urban services including water supply, sewerage and solid waste. Typically, water supply is financed through cost recovery. The cost recovery should be determined on the basis of full O&M and cost capital cost. Within this broad principle, some degree of cost subsidy for the poor may be possible. Also, implementation of capital cost recovery principle may be spread over a number of years. For sewerage and waste management, direct cost recovery may be difficult. These services may be funded through a well-designed property tax combined with limited service charges collected as a part of the property tax bill.

Chapter 11
Investment Planning, Financing and Implementation Strategy

Chapter 11 : Investment Planning, Financing and Implementation Strategy

11.1 Background

As discussed in **Chapter 5**, Bangladesh's long term socio-economic performance would critically depend on how it manages the effects of climate change and other environmental challenges. It was indicated that in the absence of proactive adaptation to mitigate the adverse impacts, Bangladesh economy may lose about 1.1% of GDP every year through loss of physical assets and economic activities and the consequent loss of income. It was also noted in that chapter that the adaptation measures will require massive amounts of investment in new projects and will also require spending of sizable resources to properly operate and maintain the existing infrastrutures.

Bangladesh currently invests insignificant amount (0.8% of GDP) in water related projects. Due to lack of maintenance and inadequate investment in upgrading existing projects, much of the investments made in the water sector in the form of embankments, polders and to improve inland waterways navigation are not in good shape. Significant new investments are required to upgrade the existing delta-related infrastructure to withstand the challenges arising from the shifting river estuaries and the unfolding climate change induced future challenges. As discussed in **Chapter 5**, total spending on interventions through new projects and maintenance of new and old projects will require about 2.5% of GDP per annum. In current prices and using the prevailing GDP, total required spending on BDP 2100 related interventions calculated at about US$ 3.5 billion in FY2017 which will increase to US$ 29.6 billion by FY2031.

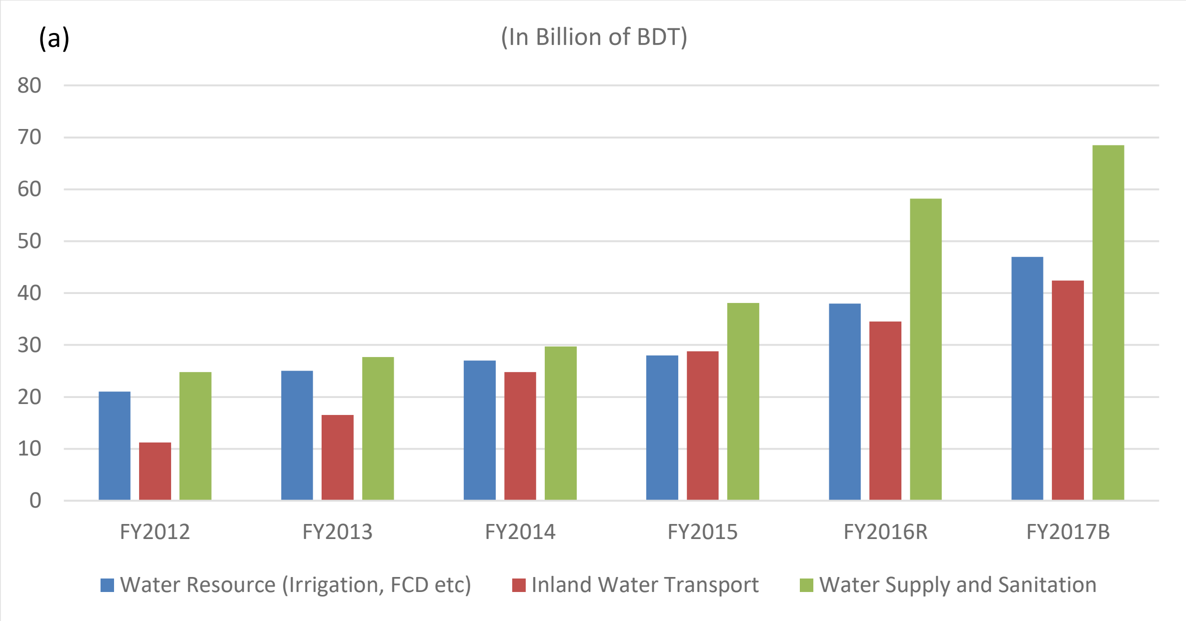
This Chapter analyzes the scope for mobilizing such a large amount of resources for financing the BDP 2100 related investments, how such a large investment program should be planned to realize the best possible outcomes, and the related implementation strategy for the BDP 2100.

11.2 Macroeconomic Outlook and the Delta Specific Investment Plan

Bangladesh strives to become an Upper Middle Income Country (UMIC) by FY2031 and eradicate extreme poverty from the country by that year. These goals have a solid macroeconomic foundation with stable real GDP growth of around 7%, solid track record of macroeconomic stability, declining inflation, high level of foreign exchange reserves (more than 8 months of import payments) and strong overall balance of payments outlook. At the same time, it has to overcome a host of challenges in order to sustain and further accelerate the growth momentum and poverty reduction efforts. The economy suffers from acute infrastructure gaps (in power, transport and land, in particular) and inadequate levels of investment by the private and public sectors. Impacts of Climate Change in the form of rising sea level, increasing salinity in the coastal districts and host of other challenges in hotspots like river systems and estuaries, Barind and drought prone areas and Haor and flash flood areas will also require special attention and adaptation measures in the form of BDP 2100 Investment Plan (IP). Growing population as well as industrialization pressures in the urban centres and the resulting water and sewerage problems also call for higher investment in the context of BDP 2100 IP.

The BDP 2100 policy option analyzed in depth in **Chapter 5**, which is consistent with the above economic objectives and with the 7th FYP, indicates that the gross domestic investment rate would need to increase to an average of 41% of GDP during FY2021-41 in order to offset the adverse effects of climate change and sustain economic growth at 8% plus per annum until FY2041. As in the 7th

FYP, much of the increase would need to come from the private sector. The role of public sector investment would essentially be to support private sector expansion and crowd-in private investments in the domestic economy.



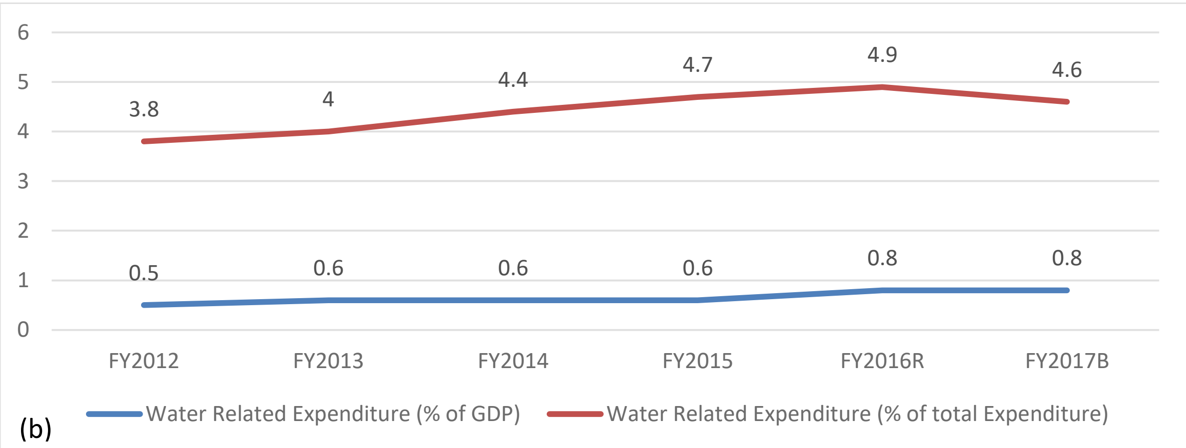


Figure 11.1: Water Related Expenditures

Source: Ministry of Planning and Budget Documents of Ministry of Finance, Bangladesh, 2015

Water related spending in Bangladesh in recent years ranged between 0.6-0.8% of GDP (**Figure 11.1 (a)**). The BAU policy option of the present time, implicitly includes similar amounts of water related resource allocations of about 0.8% of GDP, which are to be executed through the BWDB, Dhaka WASA and Chattogram WASA, and LGED for small irrigation projects. Water related expenditure as percent of total budgetary spending have increased in recent years and stood at 4.9% of total budgetary spending in FY2016 (**Figure 11.1 (b)**).

As discussed in **Chapter 5**, significant downside risks posed by climate change and environmental shocks in delta hotspots, if not addressed through investments in climate change and other forms of adaptations, would severely limit the growth prospects. Faced with these difficult challenges and without proper adaptation against these risks, Bangladesh will not be able to become an UMIC by FY2031. Total amount of spending in climate change and other environmental and water related projects and maintenance is conservatively estimated to be about 2-2.5% of GDP per annum. Realization of the Delta Plan Policy Option —and thereby achieving the objectives of UMIC status and eradication of absolute poverty by FY2031 is predicated upon this 2-2.5% of GDP spending on BDP 2100 IP and O&M of water and climate change adaptation related projects. However, increasing public spending on water related projects by more than 3 times in relation to GDP to 2.5% would be extremely difficult and will require creative financing arrangements, including involvement of the private sector.

Given that the estimated resource requirement for adapting and mitigating the negative impacts of climate change at around 2.5% of GDP and current allocation of 0.8% for the water sector and disaster management purpose, the estimated resource gap is thus 1.7% of GDP. The key question – how will this resource be financed? Although the current tax effort in Bangladesh is lowit is expected to rise by 4 to 5 percentage points of GDP over the Seventh FYP period and increase further over the long term. It is anticipated that with increased tax effort, the demand for public sector resources by other sectors (especially in transport logistics, power and social sectors) would also continue to rise leaving relatively modest amounts for the water sector. Good practice experience from other deltas show that a substantial part of water investments can be funded through a well-structured cost recovery policy based on the beneficiary pays principle. In Bangladesh, application of this will take time, but this policy must be pursued vigorously. Additionally, it is thus suggested that a significant part of the resource gap estimated for the water sector would need to be financed from the private sector and the global funds for climate adaptation.

Bangladesh has had a solid track record of expenditure control and debt management. It has consistently adhered to prudent fiscal and debt management strategies under which fiscal deficits have been contained within 3.5-4.5% of GDP. While this conservative approach has served Bangladesh very well during 1970s through to 2000s, it is time to re-evaluate certain aspects of the strategy. Total debt has come down from 45% of GDP in FY2005 to 34% in FY2015, which is entirely attributable to a decline in foreign debt. In particular, the level of low-cost foreign debt has declined to only 13% of GDP in FY2015, and likely to have declined further in FY2016. Financing of the fiscal deficit has been excessively tilted to high cost domestic borrowing while the foreign aid pipeline now exceeds US$ 23 billion. These issues will also be taken into account in developing the BDP 2100 IP financing strategy.

11.3 Climate Change Impact Assessment and Investment Requirements

As described in **Chapter 5**, a consistent macroeconomic framework has been used to generate the delta scenarios. The analytical framework for BDP 2100 has been developed to quantify economic impacts of climate change by linking the real side (i.e. economic variables) to the environment or climate change parameters. Using this framework, an attempt has been made to capture all possible environmental risks which Bangladesh might be facing and their impacts on all major economic indicators are estimated for FY2016-31 period. The two policy options considered in this exercise are along the following lines:

- *The first* option outlines the policy environment of the present situation where there is no Delta Plan to offset the economic impact of intensified environmental and climate change, and accordingly it is denoted as BAU policy option .
- *The second* option is the BDP 2100 policy option, requiring strong climate change and other delta related adaptation measures to offset the negative consequences of climate change and achieve higher and sustainable growth trajectories, thereby ensuring the government's long term objective of achieving UMIC status by FY2031.

Per capita real GDP: Incorporating environmental loss and subsequent loss in income due to environmental hazards provides a dire scenario compared to the baseline. Without any change in the implementation of adaptation and mitigation measures per capita nominal GNI would reach US$ 4,858 in FY2031, which would be significantly below the entry level threshold of UMIC.

Employment: New job creation depends on economic expansion. As a result of lower economic expansion the level of unemployment would rise at a faster rate. Additional unemployment in the country would increase to 10.3 million in FY2031. Almost one third of this additional unemployment would generate from the Coastal Zone because of its environmental vulnerability.

Poverty: In the BAU Policy option, the head count poverty ratio would be about 4 percentage points higher than the BDP 2100 Policy option by 2030. The key reason behind the higher poverty incidence in the BAU Policy option is lower per capita income growth. Most importantly, Bangladesh might not be able to eliminate extreme poverty by 2030 in the BAU Policy option, whereas this will be comfortably secured under the BDP 2100 Policy option. The analysis also suggests that urban migration would increase more under the BAU Policy option, as additional people would become unemployed in disaster prone areas and migrate to urban centers.

Investment Requirements: Aggressive investment policy is required to counter the negative environmental challenges. With appropriate investments and policies to counter the impact of climate change and associated natural disasters, Bangladesh can become an UMIC by FY2031. It is estimated that additional investment of about 1.7% of GDP each year will be required for the purpose of adaptation against climate change and other environmental impacts (**Table 11.1**).

Table 11.1: Delta Investment Requirements (% of GDP)

Investment Components	FY2016	FY2020	FY2025	FY2031
Total Delta Investment (Water and water-related) of which:	0.8	1.8	2.5	2.5
Additional Public Investment	--	0.5	0.7	0.7
Public Investment (Baseline)	0.8	0.8	0.8	0.8
Total Public Investment (Water	0.8	1.3	1.5	1.5
Maintenance cost (Recurrent Budget)	0	0.3	0.5	0.5
Private Investment	0	0.2	0.5	0.5

Source: BDP2100 Projections, GED, 2015

Accommodating this size of investment (about 2.5% of GDP) in the government budget will not be an easy task, despite the envisaged increase in the overall size of government spending. Out of the 2.5% of GDP, only about 0.8% of GDP is currently accommodated in the budget. About 0.5% of GDP will be needed to maintain properly the existing investments in the water sector. At present operations and maintenance (O&M) is the most neglected part of water sector spending and in most cases once existing embankments/polders are near the point of collapse, projects are undertaken to rehabilitate those infrastructures through ADP. Primary focus of water investments is on undertaking new projects or rehabilitation of old projects while not paying much attention to regular maintenance of existing facilities. Thus, explicit provision has been made for O&M of water related projects in the BDP 2100 IP and administrative arrangements will also be made through proper restructuring of the water governance to ensure appropriate focus on O&M of existing and future projects with a view to extending their productive life and enhancing operational efficiency of all existing and new projects.

Although the overall budget size will increase by about 10 percentage points to reach 25% of GDP by FY2031 there will be strong pressures for increased resource allocation for various social sectors like education, health and social protection (**Figure 11.2**). In particular, consistent with the thrust given in the 7th FYP, allocations in terms of GDP for education, health and social expenditure will be almost double. Significantly increased budgetary allocations through ADP (excluding BDP 2100 IP) will also be needed for infrastructure investment in power, highways/roads and bridges, and railways. Although there may be some scope for involving the private sector for some of the BDP 2100 IP projects, it is also true that BDP 2100 IP related expenditure would need to be mostly funded through the budget.

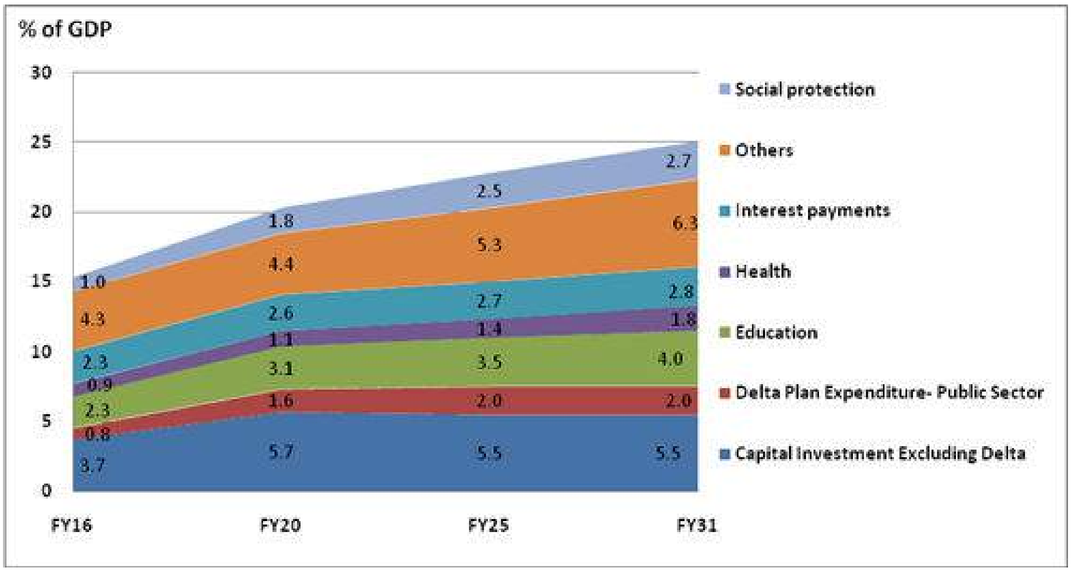


Figure 11.2: Public Expenditure Composition in BDP 2100 Policy Option

Source: BDP 2100 Projections, GED, 2015

Based on these considerations, the BDP 2100 IP envisages that out of the total 2.5% of GDP required, some 0.5% of GDP could be funded by the private sector under various initiatives discussed below and about 2% of GDP would need to be executed through the public sector. Out of this 2% of GDP financed from the Budget, about 0.5% of GDP would need to be spent on O&M activities and the remaining 1.5% of GDP should come under the BDP 2100 IP. It may be noted that at present O&M is very much neglected and the actual amount may not even be more than 0.1% of GDP. The practice of not maintaining adequate delta related investment leads to rapid deterioration in the quality of infrastructure and leading to complete rebuilding of the same at much higher costs. Thus, for quality maintenance of new and old infrastructure, dedicated funds will be made available in the amount of about 0.5% of GDP under the BDP 2100 IP over time. This component of BDP 2100 IP spending will come under the recurrent budget of the national government.

Currently, about 0.8% of GDP is spent on water related projects which is a part of the ADP and may be considered as a part of the BDP 2100 IP. This amount will almost double in relation to GDP to 1.5% of GDP under the BDP 2100 IP by FY2025 and sustained at this elevated level thereafter. Allocations for O&M must also increase significantly to ensure proper O&M of existing and future projects. The increased allocation for O&M under the BDP 2100 should be part of the recurrent expenditure or revenue budget and should be financed entirely out of the government's internally mobilized resources. Fiscal sustainability requires that all recurrent outlays including O&M spending should be part of recurrent budget and not to be funded through public borrowing.

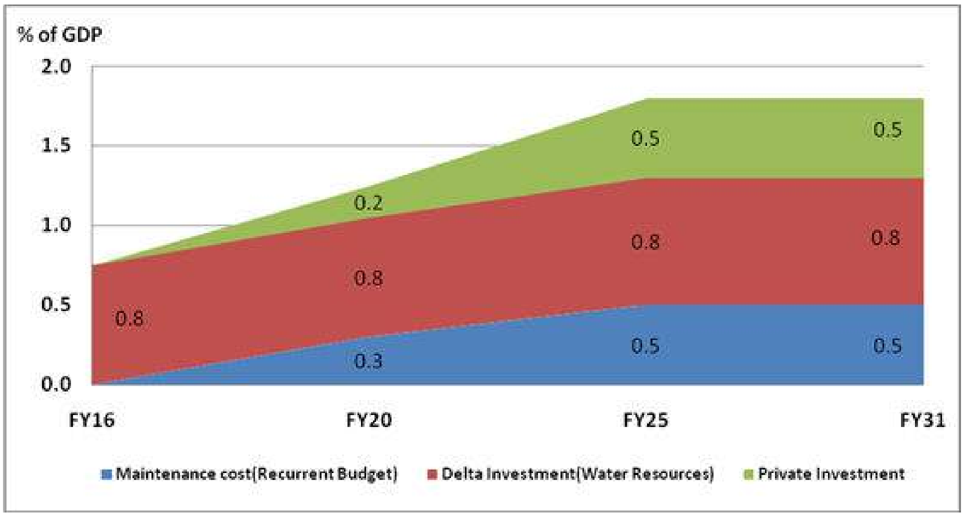


Figure 11.3: Sources of BDP 2100 Investments (% of GDP)

Source: BDP 2100 Projections, GED, 2015

The fiscal framework, prepared in the context of the BDP 2100 which is also consistent with the 7th FYP macroeconomic and fiscal framework, indicate that if properly executed the much higher level of BDP 2100 IP spending can be accommodated within the revised frameworks in a sustainable manner. The fiscal framework has been updated taking into account the fiscal outturns for FY2016, the first year of the 7th FYP and the budget for FY2017. The fiscal framework does not call for additional revenue mobilization since the revenue mobilization targets under the 7th FYP are already quite challenging. It also lowers both the revenue and expenditure targets under the 7th FYP in view of the shortfall in revenue experienced in FY2016 and the lower ADP spending due to slower implementation of projects.

The fiscal financing strategy for BDP 2100 IP envisages that all allocations for O&M will be accommodated within the overall government budget for recurrent outlays (in the revenue budget). In the remainder of the 7th FYP period, since the increase in revenue budget is envisaged to be 2.8% points to 12.2% of GDP, the estimated 0.2% of GDP in additional O&M spending can be accommodated within the growing size of the overall recurrent budget. Over the longer term (through FY2031), since the increase in revenue budget will be additional 6% points to 15.4% of GDP by FY2031, it would be easier for the government to accommodate the 0.5% of BDP 2100 IP related O&M spending in the recurrent budget.

Table 11.2: Fiscal Framework for Delta Investment Financing during FY2016- FY2031

Fiscal Year	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025	FY2026	FY2027	FY2028	FY2029	FY2030	FY2031
Fiscal Indicators:	**(As % of GDP)**															
Reveneu and Grants	10.5	11.8	12.6	13.9	15.2	15.9	16.3	16.7	17.1	17.4	17.8	18.2	18.6	19	19.3	19.8
Total Reveneu	10.3	11.4	12.2	13.4	14.7	15.4	15.8	16.3	16.7	17.1	17.5	17.9	18.2	18.6	19	19.4
Tax Reveneu	9	9.4	10.2	11.3	12.6	13.2	13.7	14.2	14.5	14.9	15.3	15.7	16	16.4	16.8	17.2
Non-Tax Reveneu	1.3	2	2	2.1	2.1	2.2	2.2	2.2	2.2	2.1	2.2	2.2	2.2	2.2	2.2	2.3
Grants	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Total Expenditure	15.3	16.4	17.2	18.8	20.3	21	21.4	21.9	22.3	22.8	23.2	23.6	23.9	24.3	24.7	25.1
Reveneu Expenditure	9.4	9.9	10.4	11.4	12.5	12.7	13	13.4	13.6	13.9	14.2	14.4	14.7	14.9	15.2	15.4
Development Expenditure	5.9	6.5	6.8	7.4	7.8	8.3	8.4	8.5	8.7	8.9	9	9.1	9.2	9.4	9.5	9.7
Overall Balance (Incl. grants)	-4.7	-4.6	-4.6	-4.9	-5.1	-5.1	-5.1	-5.2	-5.2	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4	-5.4
Financing	4.7	4.6	4.6	4.9	5.1	5.1	5.1	5.2	5.2	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Net External Financing	1.1	1	1	1.2	1.4	1.5	1.5	1.6	1.7	1.8	1.8	1.8	1.9	1.9	1.9	1.9
Domestic financing	3.6	3.6	3.7	3.8	3.8	3.7	3.7	3.7	3.6	3.7	3.7	3.7	3.6	3.6	3.6	3.6
Assumptions:	**(As % of GDP)**															
Total Delta Investment through Budget	0.8	0.8	0.8	1.3	1.6	1.6	1.7	1.8	1.9	2	2	2	2	2	2	2
Current level of investment in DP type projects-Baseline	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Recurrent budget (Domestic Resource Mobilization)	0	0	0	0.2	0.3	0.3	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
New Delta Plan related spending	0	0	0	0.4	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7
External Fund	0	0	0	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Grant	0	0	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
External Source including Climate Fund	0	0	0	0.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Domestic borrowing	0	0	0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Source: BDP 2100 Projections, GED, 2015

The public spending plan envisages an additional BDP 2100 IP related spending of up to 1.2% of GDP over the long term (FY2031) since the amount that the government is currently spending (about 0.8% of GDP) on water management is not adequate for adaptation in the face of climate change and other environmental impacts. Some 0.5% of GDP will be for O&M and will be included in the current spending plan of the government. Total public investment will accordingly increase by 0.7 percentage point to 9.6% of GDP. The envisaged expansion of the size of public investment over the medium and long term will enable the government to undertake BDP 2100 IP spending without cutting the planned large scale infrastructure projects in the priority power and transport sectors.

The financing plan for BDP 2100 IP related public sector spending amounting to about 2% of GDP at its highest point will be financed along the lines outlined in **Table 11.3**. Since about 0.8% of GDP is already being financed out of the government budget; so the required additional funding will amount to 1.2% of GDP. Expenditures related to O&M (0.5% of GDP), would need to be financed out of the recurrent budget with domestic revenue to ensure sustainability of the whole operation and also recognizing the fact that development partners are generally not supportive of financing O&M spending through donor funding. This leaves an additional 0.7% of GDP. The financing strategy is that additional externally financed BDP 2100 IP spending would amount to 0.5% of GDP when the Delta Plan is fully operational. A small part of this external financing may be secured in the form of grants and the rest as concessional loans with very limited impact on external debt servicing burden for the country.

Table 11.3: Sources of Public Sector Financing for the BDP 2100 IP

Components:	FY2019	FY2020	FY2025	FY2031
	(As % of GDP)			
A. Total BDP 2100 related spending through budget(B+C+D)	1.2	1.5	2.0	2.0
B. Current level of investment in Delta Plan type projects--Baseline	0.8	0.8	0.8	0.8
C. Recurrent budget(Domestic Resource Mobilization)	0.1	0.2	0.5	0.5
D. New BDP 2100 IP related spending (E+F)	0.2	0.4	0.7	0.7
E. Foreign Financed (Including Climate Fund)(a+b)	0.2	0.3	0.5	0.5
a. Grant	0.05	0.1	0.1	0.1
b. External Source including Climate Fund	0.15	0.2	0.4	0.4
F. Domestic borrowing	0	0.1	0.2	0.2

Source: BDP 2100 Projections, GED, 2015

Government believes that the fiscal plan accommodating the increased spending envisaged under the BDP 2100, as outlined above, is sustainable. While fiscal deficit excluding grants may exceed the 5% of GDP in certain years, the fiscal deficit (including grants)—i.e., the debt creating deficit will still be limited to 5% of GDP or below over the medium and long term. Total public debt to GDP ratio would accordingly increase by only 6 percentage points to 42.98% of GDP over the 15 year period through FY2031.

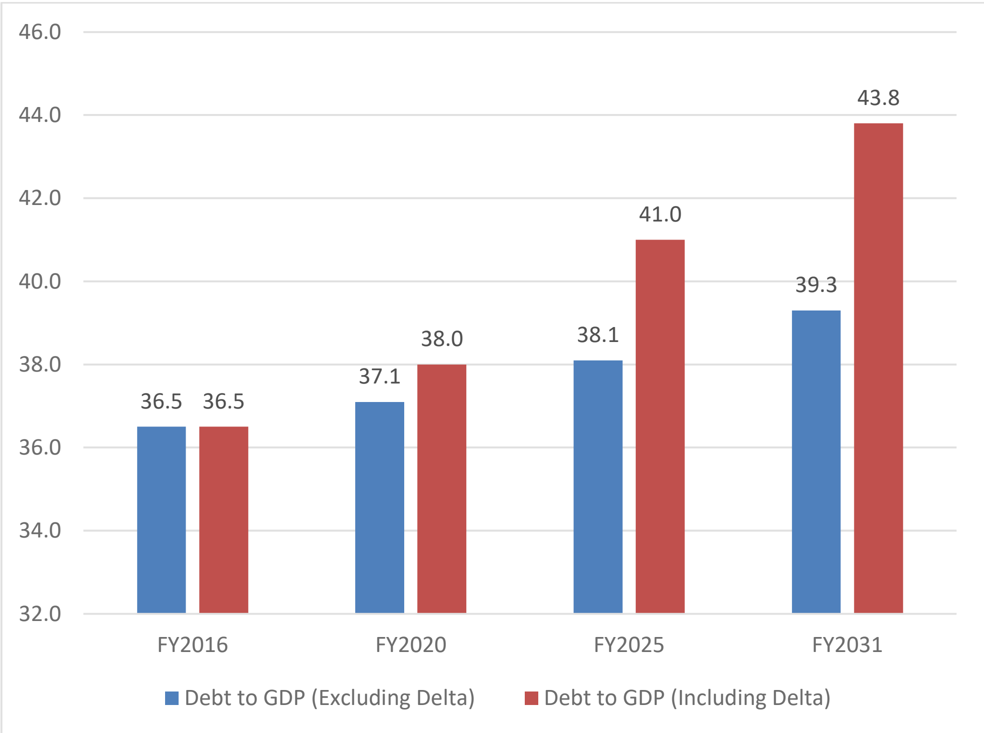


Figure 11.4: Debt Dynamics of Bangladesh

Source: BDP 2100 Projections, GED, 2015

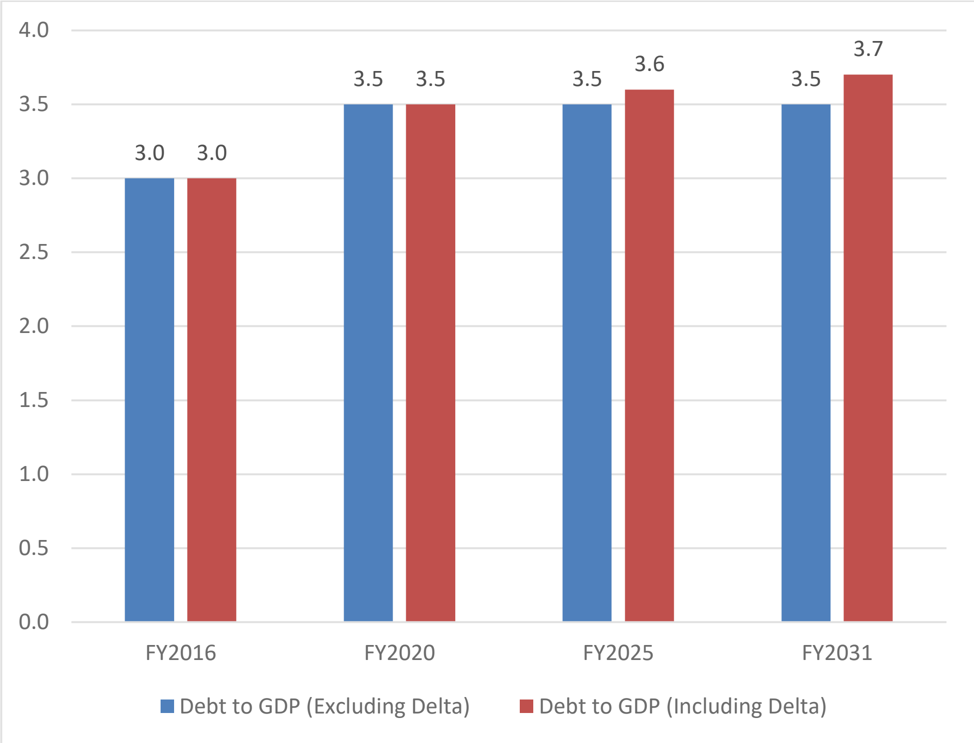


Figure 11.5: Debt Services in BDP 2100

Source: BDP 2100 Projections, GED, 2015

In preparing the financing plan for the BDP 2100, care has been taken to minimize the stress on domestic money market with a view to avoid crowding out of the private sector credit. Accordingly, effort has been made to ensure that much of the additional financing requirement is mobilized from external sources. As shown in **Figure 11.2**, there will be very limited recourse to additional domestic financing of the budget for implementing the BDP 2100 compared with the BAU policy option without the BDP 2100 spending. In the current global environment, there are plenty of low-cost private foreign financing sources available. Additionally, there are many sources of multilateral and bilateral official financing for projects associated with climate change adaptation at concessional terms and in the form of grants. Bangladesh will make best efforts to access such financing available under various international climate change and other initiatives. As a result, the debt servicing will not change (**Figure 11.5**).

11.4 Current Patterns of Resource Allocation and Estimated Resource Gap

Expenditure patterns by the budget lines for the main ministries/sectors over the last five years and the budget for FY2017 (i.e. FY2012 – FY2017) have been summarized in **Table 11.4**.

Table 11.4: Public Sector Allocation for Delta-related Programmes

	FY2012	FY2013	FY2014	FY2015	FY2016 (RB)	FY2017 (B)
Total expenditure (% of GDP)	14.4	14.5	14.0	13.5	15.3	17.3
of which: Water resource development	0.5	0.6	0.6	0.6	0.8	0.8
Agriculture	1.4	1.6	1.3	1.1	1.1	1.2
Of which: Water Resource (Irrigation, FMDI, etc.)	0.2	0.2	0.2	0.2	0.2	0.2
Social security and welfare	0.9	0.8	0.8	0.7	1.0	1.0
Of which: Relief and Disaster Management	0.4	0.4	0.4	0.3	0.4	0.4
Transport and communication	0.9	1.0	1.1	1.3	1.5	1.9
of which: Inland Water Transport	0.1	0.1	0.2	0.2	0.2	0.2
Local government and rural development	1.0	1.2	1.1	1.2	1.2	1.2
of which: Water supply and sanitation	0.2	0.2	0.2	0.3	0.3	0.3
	(% of Total Expenditure)					
Agriculture	9.6	11.3	9.2	7.8	7.0	6.7
Of which: Water Resource	1.4	1.4	1.5	1.4	1.4	1.4
Social security and welfare	5.9	5.8	6.0	5.5	6.4	5.8
Of which: Relief and Disaster Management	2.8	3.0	3.1	2.3	2.9	2.3
Transport and communication	6.2	7.2	7.6	9.3	10.1	11.0
of which: Inland Water Transport	0.7	0.9	1.3	1.4	1.3	1.2
Local government and rural development	7.2	8.1	7.7	8.7	8.1	6.9
of which: Water supply and sanitation	1.6	1.6	1.6	1.9	2.2	2.0
Total Investment in Water Resources	3.7	3.9	4.4	4.7	4.9	4.6
Nominal GDP	10552	11989	13437	15158	17296	19681

Source: Various Budget Documents, Ministry of Finance, Bangladesh

In the summary presentation, only total allocations by major ministries are provided without the explicit allocations for the water related investment and environmental disaster mitigation. Investment allocations for water development/management projects in the agriculture, transport and communications, LGRD, and MoEF have been derived by reviewing the ADP allocations for all the ministries. Water and environment related sectors consist of water resources, inland water transport and water supply and sanitation, environment and forest projects, and disaster management. A review of the budgetary allocations indicates that the total allocation for environment and water resource development has been increasing over time and reached a high of 0.8% of GDP in FY2016. It is also worth noting that almost half of the total allocation for social security and welfare is on account of relief and disaster management (0.4% of GDP), which may be considered as the recurrent cost of adaptation due to floods and cyclones. Total budgetary allocation for water resource management and development and relief and disaster management accounts for 1.2% of GDP in FY2016.

As against this reality, the BDP 2100 Policy Option projections suggest the need for a major push in increasing resources for water and other delta-related investment spending that amounts to a three-fold increase in total BDP 2100 IP from 0.8% of GDP now to 2.5% of GDP by 2021. Furthermore, the pattern of investment allocation across the delta sectors indicated in **Table 11.4** appear uncoordinated and not well-linked to achieving the core objectives and targets of the BDP 2100. A major downside is the absence of an O&M strategy for the water sector. It is obvious that a major change is needed in strengthening resource mobilization for the BDP 2100 and ensuring that the BDP 2100 IP is well coordinated and linked with the achievements of the major goals and objectives of the BDP 2100.

11.5 Innovative Financing Arrangements and Financial Mechanisms

11.5.1 Categories of Potential Funding and Financing Arrangements

In **Figure 11.6**, the relation between the funding needs for water services, potential funding arrangements and financing mechanisms are illustrated. First, the investment and annual revenue budget needed for O&M of the relevant water service needs to be specified: (a) based on budget funding arrangements and (b) to recover both investment and annual O&M costs of the relevant water services.

The first potential set of funding arrangements (a) consists of pricing mechanisms: optimising user charges and payments and billing systems in order to recover the costs (as much as possible aimed at full cost recovery). This is often easier for drinking water provision (where specific individual users or consumers can be identified) compared to water resources management (where it can be harder to identify specific individual users or consumers) and where externalities (such as lives saved, health benefits, etc.) are more prevalent. Cost optimization can be part of the possible options in the first set.

The next set of potential funding arrangements (b) is in the area of institutional arrangements. Examples can be the setting up of dedicated funds fed by taxes, special levies or reallocation of existing government budgets. Public Private Partnership models or scope extension adding income from other functions (such as land reclamation or urban development) can be part of these options.

After the funding model is chosen, the financing mechanisms consisting of a set of financing instruments (private equity, loans, public grants, etc.) can be determined. The mixture or public finance (such as government or donor grants) versus private repayable finance (equity, loans) depends on the funding (cost recovery) pattern and structure. The more private is revenue, the higher the possibilities for private finance. Moreover, this financing structure will be different in the development, implementation and operational phases of water services (depending on the risk-return pattern in each phase).

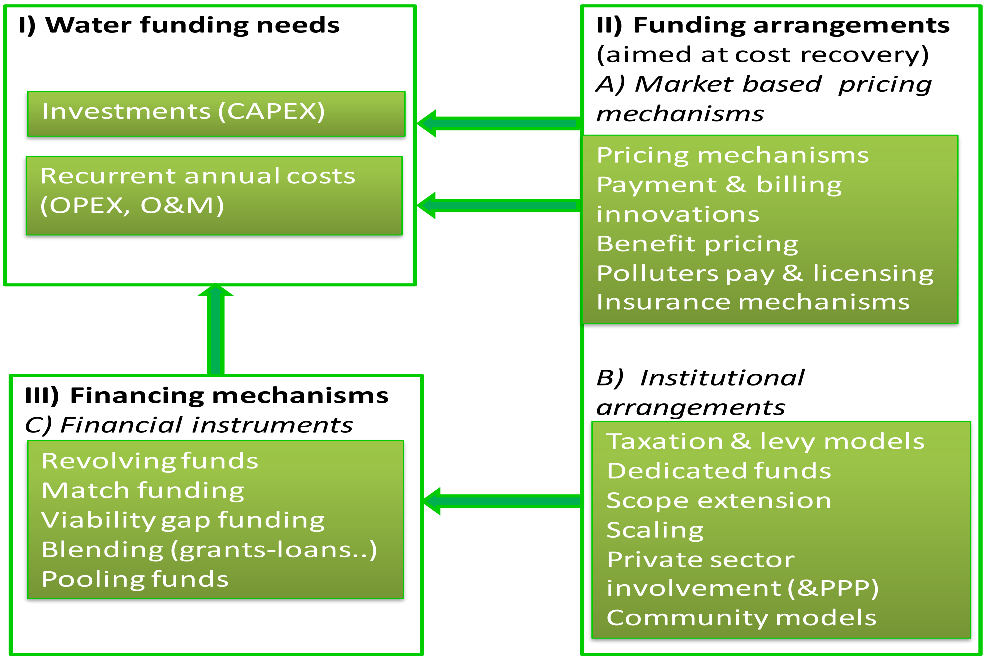


Figure 11.6: Funding Arrangements and Financing Mechanisms

More than 40 cases on funding and financing arrangements have been investigated from about 30 countries all over the world (including some cases already in place in Bangladesh). The international practices show a number of examples which might also be relevant for Bangladesh; a few examples are mentioned below.

11.5.2 International practices for funding and financing arrangements

Flood protection and water security

In a number of countries, *dedicated funds* have been set up to allocate resources for specific purposes in the climate or water sectors. Recently, especially in the field of climate change a number of funds have been established earmarking financial resources for specific aims and types of projects. Examples are the Green Climate Fund or the Sustainable Water Fund or in the Netherlands the *Delta Fund*.

In countries such as UK or Nigeria examples are found of *Public Private Partnership (PPP) models* for flood protection. Often scope extension - combining water protection with land reclamation or urban development - is used to tap into new revenue streams. This could be most relevant in the medium and long term for Coastal Zones and Urban Areas Hotspots. In the UK, PPP models with availability payments[33] for flood protection infrastructure have been started.

[33] An availability payment contract is a contract in which a payment for performance of the concessionaire is agreed irrespective of demand. This is an option in projects that generate no revenues from users or inadequate revenues to cover full cost of construction and ongoing operation.

Water availability and river transport

There are interesting *water pricing systems in irrigation* from Israel, irrigation PPP model from Morocco and a combined system from South Africa. Some of these private irrigation schemes and water pricing models could be relevant for application for new irrigation projects in Bangladesh.

Water supply and sanitation

In this sector, a range of market based arrangements has been found that aim to improve cost recovery:

- Optimal tariff setting (gradual increase scheme tariffs in Senegal, block tariffs in Fiji, etc.);
- Smart metering and innovative payment and billing systems (cases from Africa);
- Innovative leak detection in order to reduce non-revenue water (Mozambique);
- Introduction of benefit charging and polluters pay principle (water extraction in the Baltics);

Apart from market based arrangements a number of institutional developments are interesting:

- Small scale plug and play water purification stations operated by private sector (rural areas or peri-urban areas);
- Community or private operation of small drinking water operations (rural areas Haiti);
- PPP and privatization (Manila Water, Chile, Netherlands PPP Wastewater Treatment).

Finally, a number of innovative financing instruments have been investigated based upon principles of revolving funds, blending grants and/or guarantees with repayable finance and pooling.

Based on the above, a summary table is presented with a selection of international practices.

Table 11.5: Selection of international practices on Innovative Finance for Water

Water sub-sector & funding category	Practice title	Innovative financial aspects
Flood Protection		
Institutional arrangements	1% 'extra penny' tax – USA	To ensure funding for infrastructure and storm water projects, an 1% additional sales tax is imposed.
	Pevensey Bay PPP – UK	The Pevensey Bay Sea Defence is a sea defence project funded as a Public Private Partnership (PPP). The Agency signed a PPP contract with PCDL a special purpose company.
	Eko Atlantic – Nigeria	The plan in Lagos is to combine flood protection together with residential, commercial, financial and tourist developments. Commercial developments (land sales) can be used to cross subsidise the flood protection measures.
	Delta Fund - Netherlands	A dedicated multi-annual fund for investments and maintenance of flood protection and fresh water supply related to the national Delta Program. The fund is fed from Ministry budget and other resources.
Market based mechanism	Flood RE – United Kingdom	Flood RE is an industry owned insurance pool in the UK for flood risks (damage insurance scheme).
Water availability & navigation		

Water sub-sector & funding category	Practice title	Innovative financial aspects
	El Guerdane Irrigation system PPP – Morocco	The El Guerdane PPP irrigation project consists of private design, construction and operation of irrigation infrastructure in an area of 10,000 ha. Farmers co-finance (8% of investments) and pay a single amount to be connected to the irrigation system and additionally a fixed price per cubic metre of water they use.
	Danube Black Sea Canal - Romania	Ships navigating the canal pay a fixed tariff to the ANC, a Romanian national company which operates under the Ministry of Transport and Infrastructure. Tariffs depend on the capacity of the ship and the number of days the canal is used.
Water supply & sanitation		
	Cost recovery water supply - Fiji Islands	Cost recovery will be improved through a commercial approach to management and billing. Costs will be reduced through reduction of water losses (leakages, illegal tapping, etc.). The water supply and sewerage agency will recover the cost by an optimized tariff system.
	Viability gap funding of PPP Kolkata Salt Lake Water Supply And Sewerage Network – India	Salt Lake Water Supply Project is a combined water supply and sewerage project. The project was implemented under a Built-Operate-Transfer (BOT) PPP arrangement with viability funding, provided by the central government's scheme.

Source: BDP 2100 Analysis, GED, 2015

Potential pathways for Bangladesh are presented below based upon the lessons from the international practices.

11.5.3 Lessons Learned from International Practices

Market based instruments

The dominant finance and funding instruments within the international practices of market based mechanisms are based on cost recovery and several forms of benefit charging, all aimed to improve the financial performance of the water services delivery. What is clear is that especially for flood protection projects governments always play an important role, whereas in the other subsectors more mixed arrangements can be seen. Important recurring lessons learned from practices regarding market based mechanisms include:

- Political will, government commitment and leadership;
- Registration systems and water metering are important conditions;
- Sufficient and fair monitoring is in place;
- Proper stakeholder communication and participation; and
- Sufficient and realistic charges and incentives.

Institutional arrangements

Internationally, there are many cases involving private actors and private capital in water service delivery. The fact that PPP take up a large share of the cases indicates that PPP is widely recognised as a promising contracting or funding arrangement in the water sector, both in developed and developing countries. Scope extension projects are innovative arrangements which extent the provision of water services by including revenues from non-water services such as land development, land reclamation, transport, urban development, and energy production.

Consequently, private stakeholders are more and more involved in institutional arrangements that seek additional funding sources and revenue, especially in the scope extension and PPP arrangements. Governments are still involved in these projects, but often take on the role of process facilitator, rather than process driver. Development Partners (DPs) and NGOs also engage in scoping by aiming for integrated development approaches.

Securing the involvement of private capital is the main recurring theme throughout the lessons learned from different institutional arrangements. Cooperation with private partners can lead to significant (public) cost reductions and efficient management. However, the downside of cooperation with private actors is that private actors do exactly what they are paid for, but no more than that. Lessons learned therefore additionally include:

- Strong monitoring mechanisms, sound performance indicators of quality specifications, and robust contracts;
- Active multi-stakeholder engagement as well as capable and solid governance;
- Sufficient demand for the project's additional revenue sources (land demand, toll road traffic, urban development, tourism, etc.).

Financing mechanisms

Financing mechanisms aim to attract more private finance in the water sector through innovative financing mechanisms aiming at reducing risks or losses, decrease transaction costs and diversification of risks. Mechanisms include viability gap funding, match funding, revolving funds, blending instruments and pooled funds. The main actors in these arrangements are aid and development banks, private banks, governments, and (local) NGOs. The (local) NGOs, take the role of connecting the funds to local actors. These often use micro-credit like mechanisms to ensure sustainable development projects. Key lessons learned from international practices related to institutional arrangements include:

- A sufficient level of private sector and financing expertise is required to develop and sustain blending and pooling mechanisms.
- Government or donor grants or guarantee mechanisms are often important in order to attract private finance.

Specific lessons from the Netherlands and the UK

In the Netherlands semi-public drinking water companies and a set of regional water boards operate regional drinking water & sewerage systems and regional water management systems at full cost recovery level based upon a system of water tariffs and levies. The Netherlands aims to ensure strategic, long term expenditures on flood protection and water supply by the realisation of the Delta programme, the Delta Commission and a specific Delta Fund. The Delta Commissioner's task is to promote development through supporting and coordinating implementation and financing of Delta programmes. The Delta Fund has been established to ensure that in the long run sufficient funds are available to ensure realization of necessary national measures regarding flood protection and freshwater supplies in the Netherlands. The Delta Fund has its own budget, which is an independent part of the national budget. In section 12.2, **Box 12.1** the Dutch system is discussed in more detail.

In the UK system, the burden of drinking water and sanitation services for the public budget is minimised. Private water utilities and sewage companies are full cost recovery based and can attract capital from private banks or capital markets. A lesson from the UK is that private operations of water and sewerage can be efficient, but needs a proper regulator. This is a system where Bangladesh could aim for in the long run after improving financial performance of water utilities in the next decade(s).

11.5.4 The Green Climate Fund (GCF)-A Potential Major Source of Funding for Climate Change Adaptation

The GCF has been established with the objective to mobilize climate finance to support scaled-up mitigation and adaptation action in developing countries. It was first mentioned in the Copenhagen Accord in 2009 and was formally established one year later during the COP 16 held in Cancun, Mexico. In 2011, the GCF adopted its governing instrument, in which it recognized its objective to 'promote the paradigm shift towards low emission and climate-resilient development pathways by providing support to developing countries to limit or reduce their greenhouse gas emissions and to adapt to the impacts of climate change'[34].

The Fund has identified 5 investment priorities which will deliver major mitigation and adaptation benefits:

- Transforming energy generation and access
- Creating climate-compatible cities
- Encouraging low-emission and climate-resilient agriculture
- Scaling up finance for forests and climate change
- Enhancing resilience in Small Island Developing States (SIDS)

Adopted as an operating entity of the Financial Mechanism of the UNFCCC and confirmed in this function for the Paris Agreement, the fund has the ambition to channel a significant portion of future climate finance from both the public and private sector.

With US$ 10.2 billion of climate finance pledged to the GCF and US$ 5.9 billion confirmed as of January 2016, the GCF and its funders still have a long way to go to get close to the climate finance target of US$ 100 billion annually. The fund has however come a long way since its conceptualization in 2009 – it has found its home in South Korea, defined its scope of activities and its mission, developed proposal templates, investment criteria and approval procedures, initiated readiness programs and accredited 20 international and domestic entities through which disbursements can be channeled. Just before the COP in Paris, the GCF approved funding for the first set of eight projects for a total of US$ 168 million. The fund is ready to scale-up its funding allocations and intends to award up to US$ 2.5 billion in 2016.

[34] http://www.greenclimate.fund/who-we-are/about-the-fund/governance

The outcome of Paris is relevant to the modus operandi of the GCF as it reiterates the key role the fund is to have in a post-2020 framework, highlighting the fund as a key provider of predictable financial resources (**Box 11.1**). The Paris Agreement and the accompanying decision provide additional provisions on finance those are relevant to the GCF, including on funding ambitions, its contributors, earmarking of funds and its subsequent accounting and reporting.

Box 11.1: Green Climate Fund for Climate Change Adaptation in Developing Countries

Green Climate Fund and the Paris Agreement

- The Paris Agreement and the supporting Decision include provisions on finance that both directly and indirectly relate to the role and operation of the Green Climate Fund (GCF).
- The Agreement emphasizes the GCF's role as a key provider of predictable financial resources in the post-2020 framework.
- The introduction of a floor of US$ 100 billion annually on the level of climate finance going forward post-2025 acknowledges that climate finance needs to be further scaled-up.
- A roadmap to achieve this funding level is expected to introduce clarity on Parties' pledges, supporting the GCF in making future funding decisions.
- Development of modalities for the accounting of financial resources and the requirement to provide biannual reporting will introduce further transparency to the funding and operating of the GCF.
- Developed countries are to continue taking a leading role in mobilizing climate finance, which is already reflected in the contributions made into the GCF to date.
- Funding is to be balanced between mitigation and adaptation initiatives, acknowledging the importance of sustainable development co-benefits and prioritizing action in Least Developed Countries (LDCs) and Small Island Developing States (SIDS).

Funding ambitions

The Paris Agreement does not explicitly refer to the GCF and the amount of funding that it is to mobilize. The text recognizes however that 'the Financial Mechanism of the Convention, including its operating entities, shall serve as the financial mechanism of this Agreement' (Art. 9.8). The Financial Mechanism was established under the Convention (Art. 11) to formalize and streamline efforts to provide concessional financial resources to developing country Parties. Designated bodies – the operating entities – are entrusted to realize the goals of the Mechanism. The GCF, together with the GEF, are the two operating entities of the Financial Mechanism of the Convention and the Paris Agreement and as such represent the main channels through which future sources of international climate finance are expected to flow in the years to come.

The Paris Decision, serving as guidance for the implementation of the Paris Agreement and pre-2020 action, 'strongly urges developed country Parties to scale up their level of financial support, with a concrete roadmap to achieve the goal of jointly providing US$ 100 billion annually by 2020 for mitigation and adaptation' (para 115). The Decision furthermore mentions that prior to 2025 the COP shall set a new 'collective quantified goal from a floor of US$ 100 billion per year' (para 54). The reason both quantitative targets are missing from the actual Agreement is a pragmatic one – in doing so the COP has enabled the US President to adopt the Agreement as a 'sole-executive agreement' under the US law, without the requirement for the US Senate to approve.

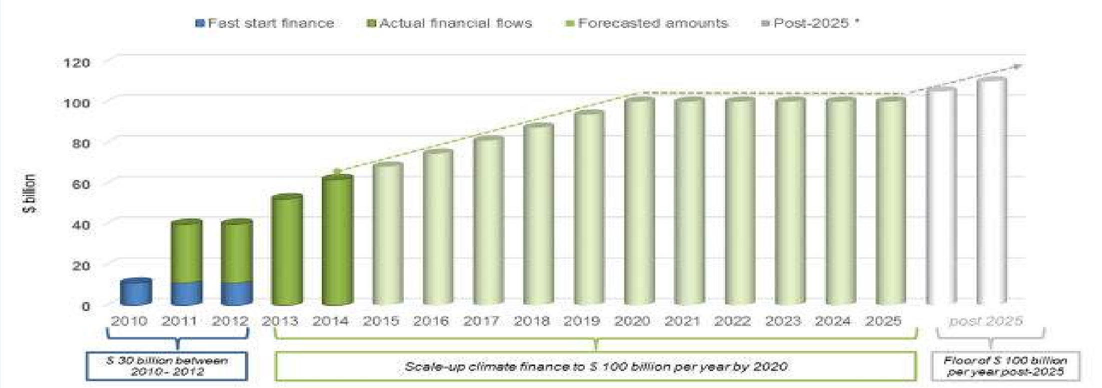


Figure 11.7: Overview of Current and Foreseen Climate Finance Flows

From the perspective of the GCF, while the annual target of US$ 100 billion is in itself not new, the introduction of a floor on the level of climate finance going forward post-2025 presents an acknowledgment that climate finance needs to be further scaled-up in order for the Agreement's objectives to be realized (see **Figure 11.7**). The GCF is explicitly recognized in the Decision as a key multilateral funding source that is to support the flow of 'adequate and predictable financial resources' (para 55). The urge to develop a roadmap for reaching the stated financing target by 2020 and beyond is also a significant development given the current ambiguity revolving around the magnitude and origin of future finance flows. More certainly and clarity on Parties' future funding pledges and its underlying terms and conditions will support the GCF in making funding decisions going forward.

11.5.5 Bangladesh Perspective

The GCF is split between two pots of funding: mitigation and adaptation. Half of the adaptation funding will go to LDCs. Upon request, governments can access grants or concessional loans for both adaptation and mitigation, and to finance the cost of overcoming policy barriers, address information gaps, and capacity constraints that impede local private sector activity.

The fund also seeks to minimise the transaction costs of working with SMEs by having accredited entities originate, approve, administer, and manage financing on behalf of the GCF through a programmatic approach. The accredited entities can be national, regional or international intermediaries that are accredited by the GCF for project management purposes and for the purpose of approving grants and loans.

11.5.6 How can Bangladesh harness its already established domestic financial innovations?

Bangladesh has had significant success in using its public sector intermediaries to incentivize the private sector, particularly in the renewable energy industry. The Bangladesh Bank launched an initiative that gives incentives to the financial sector to lend to SMEs and micro finance institutions (MFIs) aiming to invest in green technologies such as solar home systems, irrigation pumps, etc. The "policy guidelines for green banking," introduced by the Central Bank in 2011, requires every bank to allocate a specific budget to finance green projects. This includes direct or wholesale lending for renewable energy projects. Banks are expected to set achievable targets and strategies and disclose these in their annual reports. Banks are also required to establish a green branch in the second phase.

More recently, Bangladesh Bank has also established a US$ 200 million Green Transformation Fund (GTF) to help textile and leather sector firms to adopt environment friendly green technologies. The GTF established in January 2016 following extensive consultations with relevant stakeholders will provide funds at very subsidized rates to the textile and leather industries in order to increase water efficiency and reduce chemical pollution by these firms through adoption of better technologies and green practices.

Under these initiatives, compliant participating banks receive preferential treatment through a refinancing model that provides access to low-cost finance. Bangladesh Bank is one such example of a central bank, but national development banks of a few other countries are also investing to provide adequate and appropriate finance through green credit lines.

The Infrastructure Development Company Limited (IDCOL) is another example of a government-owned financial intermediary that channels donor and government finance to decentralized climate-friendly energy projects. IDCOL has supported the setup of more than 3 million solar home systems in Bangladesh, and its business model is now being replicated in several countries in Africa. The success of IDCOL lies in its one stop shop model. The model includes supporting the delivery of energy access projects, offering an end-to-end package that incentivizes market creation, delivery networks, access to capital, quality assurance, after sales service, training, and institutional strengthening support for partnering organizations and SMEs, etc.

These existing institutions and policies provide evidence of tried and tested models of how local financial intermediaries can be instrumental in promoting the participation of private sector actors in Bangladesh. Such entities can also become accredited GCF intermediaries, fitting with the fund's ambition to ensure country ownership and direct access. Accessing GCF funds directly through Bangladeshi organizations is an opportunity for more SMEs to access finance. However, a lot more needs to be done to ensure private enterprises fulfil their crucial role in the fight against climate change.

11.5.7 Bangladesh's Readiness

To access the GCF, the recipient countries have to ready themselves by meeting certain criteria and standards. Countries have to appoint a National Designated Authority (NDA) to operate the Fund and criteria based National Implementation Entity (NIE)/Multilateral Implementation Entity (MIE) to access to the Fund.

As of 6th February 2015, the GCF has received 96 initial NDAs or Focal Point Designations (GCF 2015), where Bangladesh has nominated its Economic Relations Division (ERD) of the Ministry of Finance as NDA or Focal Point, the apex body to facilitate access to the Fund.

Meantime, the NDA in Bangladesh launched an inclusive consultation process and short listed 14 national institutions considering them potential of being NIE/NIEs while meeting basic and specialized standards set by the GCF. The NDA also completed a 'self-assessment' process to identify strengths, gaps of the prioritized institutions. To help out the selection process Bangladesh Government, in close partnership with GIZ, appointed an international consultant who meantime completed 'one to one' meeting sessions with the potential institutions (UNDP Press release; 2015).

Following the self-assessment process, during 28-29 January 2015, country's NDA focal point, (Senior Secretary of Economic Relations Division of the Ministry of Finance) organized a consultation workshop titled "NIE Accreditation Process: Getting Bangladesh Ready for the Green Climate Fund". The workshop discussed the outcomes of the self-assessment process; discussed capacity/eligibility gaps of the positional institutions and explored required technical assistance to make Bangladesh ready for gaining access to GCF.

In fact, the requirement of establishing of NIE comes whenever the concept of direct access comes. While multilateral institutions (e.g. intermediaries) do play a major role in implementing other climate funds (e.g. Least Developed Countries Fund, Special Climate Change Fund) the GCF put significant concern to channel fund directly to the eligible countries. Hence, it is crucial for the country to "expedite the process" of selecting its national entity or entities and facilitate their engagement with the GCF.

11.6 Private Sector Involvement in BDP 2100

Delta management in Bangladesh has been predominately led by the public sector. With increasing needs of the country, and growing gaps in public expenditure, the role of private sector has become significant. In recent times there has been a growing realization that involvement of the private sector in infrastructure investments and operations, including in the delta management, needs to be increased if the country is to meet the demands it faces in establishing strong infrastructure facilities.

Bangladesh consists of large private sector entities who are already engaged in development of private economic zones, container terminals, carriers, cargo transport, ships and others. The sector covers a range of different markets and themes, coupled by enormous opportunities.

The Bangladesh economy has been growing at a rate of 6-7% in the last decade. Growth of the manufacturing and services sectors is increasingly altering the structure of the economy. This growth has been driven by the private sector through the continued robust performance of exports in the face of a global economic crisis, particularly textiles and apparel sector and remittances. In addition to this, the private sector has been engaged in large scale investments chiefly in Economic Zones (EZ), and other non-traditional sectors such as bottled drinking water markets. With a growing gap in public expenditure, there is a significant scope for private sector engagement through technology, financing and investment in the broader Delta Management scheme. This section details out the key segments that have a direct link with large scale interventions. These sectors, due to their characteristics, high levels of investment, present the strongest opportunities for private sector and possible long term PPP arrangements.

Dredging

It is revealed that there is significant levels of private sector engagement in dredging. Dredging has only received due importance from 2010. The proposal of BIWTA titled Capital Dredging on Inland Waterways was approved for implementation in two phases. The first phase concluded by December 2013, marked 24 routes for dredging at an estimated cost of BDT 4,201 crore (€440 million). The second phase, to be concluded in December 2018, planned to dredge 30 river routes at an estimated cost of BDT 7,271 crore (€770 million). With this significant pipeline of projects, it was estimated that at least 100 dredgers are needed. The government itself has approximately 18 dredgers, while the private sector has a total of twelve dredgers.

Flood Protection and Drainage

Flooding is a perennial problem and the urban areas are more prone to economic and human losses due to high density of population, commercial and industrial sites. Engagement of private sector, as contractors, in construction of flood embankments and urban storm sewerage are on-going. Operation and maintenance of embankments are neglected and often managed through very small scale operations. There is potential for private sector engagements for maintenance of embankments.

Water Supply

Water supply facilities used in rural water supply are: shallow tube well, deep set pump tube wells, deep tube wells, dug wells, pond sand filters, rain water harvesting, arsenic removal technology & iron removal technology. Private sector is already operating in providing these facilities.

Ship building

There are some 124 registered shipbuilding and repairing yards in various locations in the country. Much of these shipbuilding yards are engaged in building and repairing small inland and coastal vessels up to 3,500 deadweight tonnage (DWT), while several modern and internationally standard shipyards are building small-sized ships for exports.

During the past decades, local shipyards such as Ananda Shipyard, Slipways Limited and Western Marine Shipyards Limited, developed shipyards with the ability to manufacture ships of 10,000 DWT and they are expanding their facilities to upgrade to 25,000 DWT. Currently, About 7% of the 124 shipyards have the capability to entertain quality shipbuilding. With growth in the global economy and the domestic market it is expected that investments in shipyards will be robust in the near future.

Other Modes in Inland Waterways

Considering the facts of low land-man ratio and scarcity of land for further expansion of road networks in the country, IWT will gain importance in the coming years. A report by the Asian Development Bank (ADB) also stated that Bangladesh could raise its GDP by 1% and foreign trade by 20% if the inland water transport logistics systems are made efficient and competitive.

BIWTC currently operates 47 ferries in different routes, and ocean shipping performs 80% of the export-import trade. Inland ports have been inadequate and in poor condition, while rural landing facilities - pontoons and jetties – are scarce compared to the needs. The private sector plays a dominant role in the country boat sector and passenger and freight services on the main river ways, but the public sector has a virtual monopoly for ferry services. There is ample scope for private sector participation in providing ferry services.

Land Reclamation

Land reclamation is gaining high attention and is being discussed as a significant prospect for future exploration. There are promising opportunities for land reclamation within the geographical areas of Bangladesh port cities and other coastal and river areas, which are fast becoming centres of economic activity and can act as motors for national prosperity. While water resources, morphological and engineering aspects are crucial in the improved navigation and land reclamation processes, there is a heavy requirement realising potential economic benefits- this can only be achieved through active engagement of the private sector who can balance off the high costs against the ultimate economic utilisation and net revenues. Assessments in land reclamation opportunities reveal a strong linkage with economic zones (which ensure start of productive use of reclaimed land).

As of April, 2017, eight locations have been approved for economic zones sites, within which three are being privately invested by large private sector players in Bangladesh. The opportunities in land reclamation and EZ development are immense in Bangladesh, and there are strategic opportunities in engaging private sector both in the medium and long term.

Agriculture

Although agriculture is not a large market segment in terms of investment, it is still closely connected with water resources and is also the lifeblood of the economy. Private sector involvedment includes: seeds and irrigation, green house technology, storage facilities, agro-product processing, etc.

The private sector in seed business is comprised of multinational corporations as well as local companies, with more than 100 companies involved and over 5,000 registered seed dealers operating across the country.

To facilitate local seed production, the Government provides financial incentives in the form of government backed loans for research and development and a 5% incentive on agricultural produce. The seed producing companies are also eligible for funds from the Equity and Entrepreneurship Fund (EEF) provided by the Investment Corporation of Bangladesh. Under this fund, a project worth at least BDT 2 million may receive 49% financial aid if it invests the remainder from its own funds. Given the importance of the sector, for both food security and livelihood, Private sector engagement must continue and be strengthened to realise long term benefits. Mariculture, deep sea fishing and fish processing can be the potential areas for private sector investment through long-term PPP arrangements

Irrigation

Widespread availability of dry season irrigation facilities played a vital role in agricultural development. Currently, out of 8.42 million ha of cultivable land, 65% is irrigated. Agriculture uses more than 70% of all the fresh water extracted in Bangladesh. Farmers generally use manual labour or diesel powered pumps to divert the water from various water bodies to their farmlands. Diesel pumps can often require expensive diesel fuel and regular maintenance to run. One company that sells solar panels, recently started a pilot program aimed to alleviate the operational costs regarding the diesel powered irrigation schemes. Instead of diesel, its irrigations scheme is powered by solar panels. With a cooperative consisting of 83 farmers, this irrigation scheme has successfully run on renewable energy. They are now piloting five more of these solar powered irrigation programs in the northwestern region of Bangladesh. The Bangladesh Bank facilitates in the financing of renewable energy schemes with a BDT 2,000 million fund that private banks can avail at a 5% interest rate. Banks then provide loans for projects of such nature at 8-9% interest, which is lower than the normal bank interest rate.

11.7 Framework of Investment Planning

BDP 2100 has been formulated based on ADM principles. ADM is a process to develop alternative adaptive strategies, delta management plans and measures considering future uncertainties. The vision, goals, scenarios and strategies have been formulated in this regard, which are detailed out in **Chapter 5** and **Chapter 6**.

The translation of the formulated strategies into implementation level requires an Investment plan. A set of projects has been identified and selected based on the issues and challenges, delta vision, goals, future scenarios and preferred strategies.

The Investment Plan consists of a total of 80 projects: 65 are physical projects, and 15 are institutional and knowledge development projects. Its total capital investment cost is BDT 2,978 billion (US$37 billion). All projects can be started within the next eight years, though given the scale and programmatic nature of some investments, construction in some cases will extend over decades.

Development of the Investment Plan followed a rigorous, consultative, and inclusive process, using the principles of ADM. As part of the BDP 2100 formulation process, the General Economics Division (GED) of the Planning Commission asked over 20 agencies involved in work in the Delta to submit their priority investment projects. This generated 133 candidate projects with total capital costs of BDT 3,753 billion ($47 billion).

The candidate projects were screened, grouped, then sequenced following an ADM methodology. Candidate projects were included in the Investment Plan if their expected benefits exceed expected costs; if they contribute to at least one of the six BDP 2100 goals; and if they are compatible with the ADM approach. Of the 133 candidate projects, 80 met these criteria. The framework of the BDP 2100 Investment Plan is presented in **Figure 11.8**.

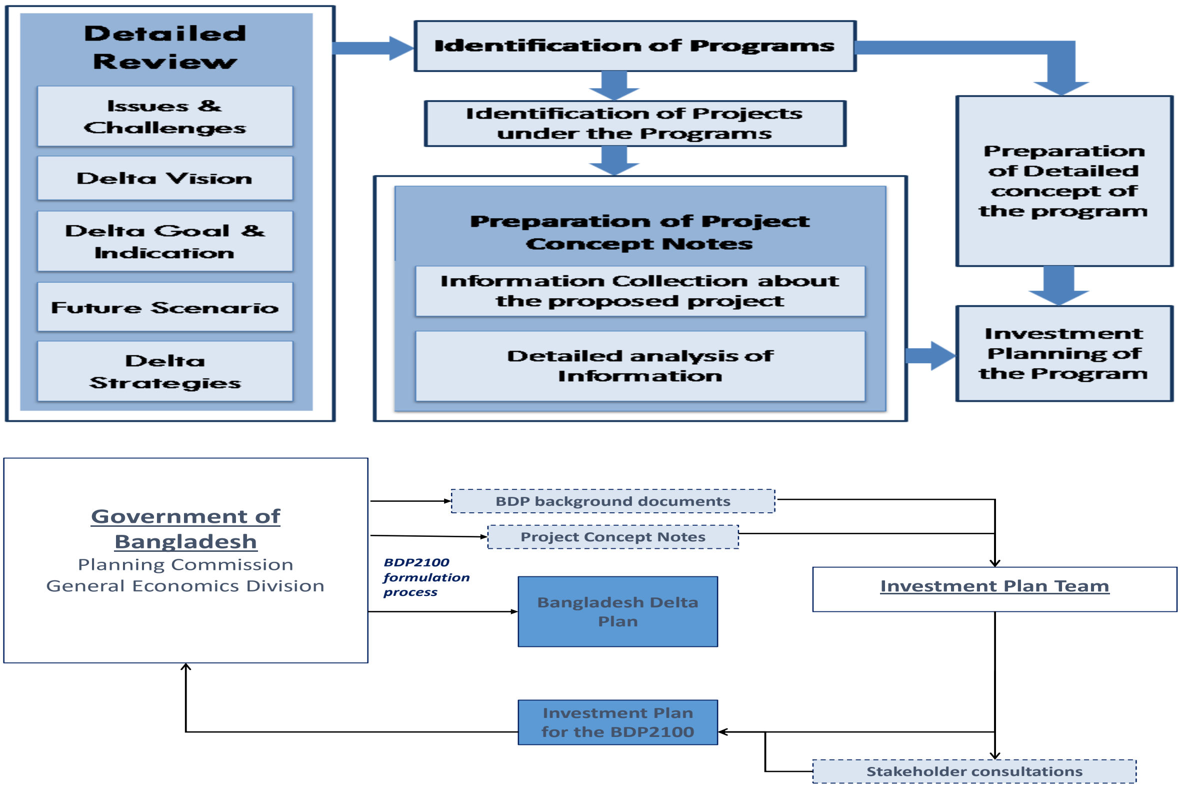


Figure 11.8: Framework of Investment Plan

Source: GED, 2015

As shown in **Figure 11.9**, the BDP 2100 IP aspires to reduce dependency on funding from Development Partners over time. This would be replaced by specific levies paid by beneficiaries and also increased contribtion from private financiers. Funding from GoB general revenues will increase slightly up to 2020 then gradually decrease up to 2030 and then remain steady after that.

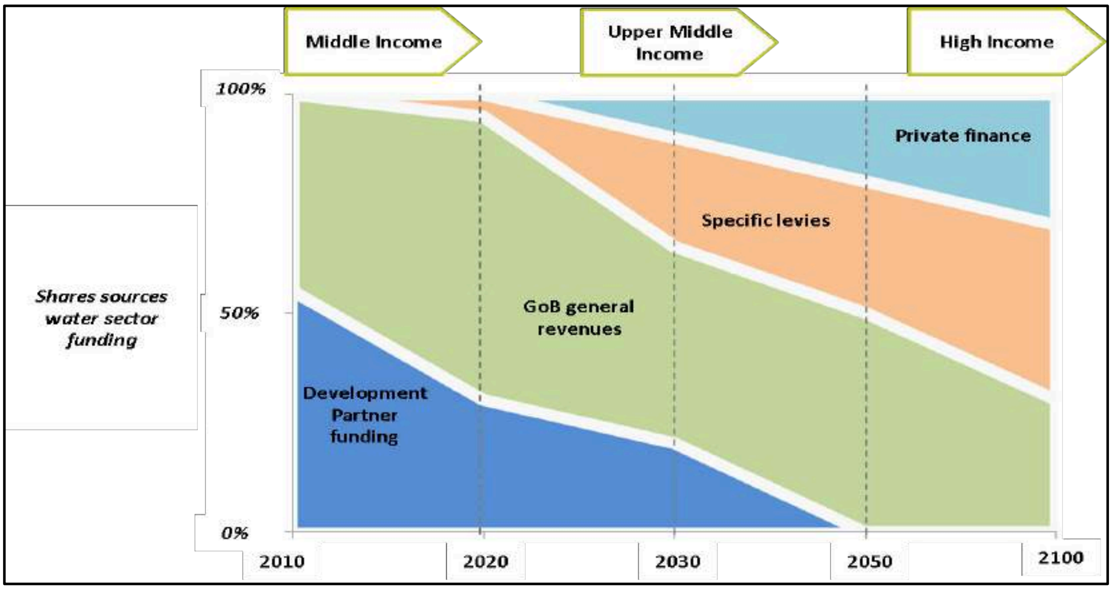


Figure 11.9: Aspirations for Composition of Water Sector funding in Bangladesh, 2010-2100

Source:GED, 2015

In the Water Supply, Sanitation and Health (WASH) sector specific levies (through a tariff system) already exist. Although currently cost recovery levels in this sector are low, as well as their service levels, WASH operators are gradually improving their business. Further improvements can be realized in the major cities (Dhaka, Chattogram). Both WASAs are gradually operating in a more sustainable way, significantly upgrading their service level (including drinking water quality) and applying more affordable (block) tariffs aimed at full cost recovery in a 10-years period. A Regulatory Commission is supposed to be established for regulating tariffs for drinking water and sanitation. In the short term, this process would also be started in cities where City Corporations are responsible for these services. Dependency on the GoB's budget for investments in this WASH sector will slowly come down as full cost recovery principles would be introduced gradually. In Paurashavas, where huge investments in water supply systems and sanitation would be realised, spread over a period of 15 to 20 years (aimed at fulfilling the SDGs for water and sanitation), full cost recovery targets will take much longer. After 2030, when in a number of cities WASH is technically and financially sustainable, the private sector will start to participate leading to a number of PPPs in this sector or even private entities. Such a development would mean that the central government grants funding responsibility might be faded out.

The same process might happen in the irrigation sector, in which large scale irrigation investment projects will implement sustainable operations in the next 10 to 15 years. This would be realised through PPPs and cost recovery principles being applied, based on tariffs to be paid by the farmers.

Another example is, for river operations and maintenance, a River Authority might be established to offer large contracts with private firms through PPP, and introduce a specific levy for dredging activities to be paid by all vessels using the dredged river system.

In summary, it is expected that due to a significant improvement in income status in Bangladesh, Delta Plan funding (and GCF funding) can slowly phase out in the medium term. At the same time, the GoB's Annual Budget could be increased significantly as % of GDP and would be better targeted, and as a consequence sufficient budgets would be made available for investments in infrastructure as well as for proper operations and maintenance. Due to higher average incomes, people and businesses would be willing to pay specific levies for specific services for flood protection tailored to the regional situation and charges for river maintenance to sustain the major inland waterways network. Next, participation of the private sector would become stronger through PPPs (in WASH operations, through huge maintenance contracts for flood protection, and through river maintenance).

Aspirations of water sector funding and a Bangladesh Delta Fund

The above outlined aspiration developments for water sector funding in Bangladesh can also be viewed from a slightly different perspective, representing the evolving composition of the proposed Bangladesh Delta Fund. An important addition is the distinction between capital and revenue budget allocations, in which the revenue component grows substantially over time. Resource allocation potential is shown in three stages: 2016 to 2030, 2030 to 2050 and 2050 to 2100.

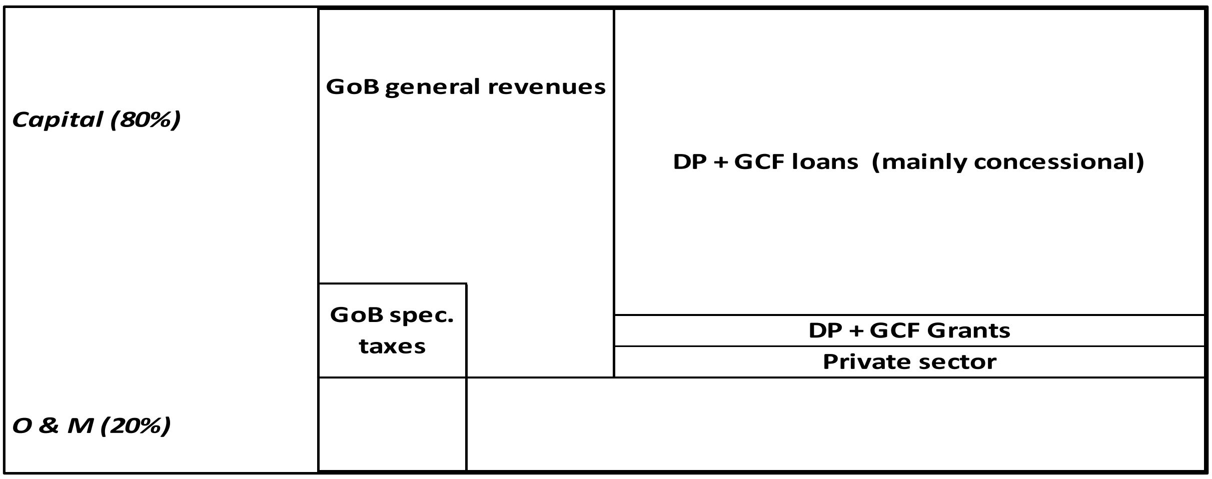


Figure 11.10: Resources Mobilization Potential for Water Sector Funding: 2016-2030

DP= Development Partner, GCF= Green Climate Fund

Source: GED, 2015

Figure 11.10 envisages a possible resource mobilization environment over 2016-2030 period. A division is made between investments on the one hand and operations and maintenance (O&M) of these investments on the other. Up to 2030, huge investments in BDP 2100 core sectors would be foreseen and therefore a large proportion of the total available budget of the Delta Fund would be allocated for these investment needs. Apart from the general budget, the majority of the funding would come from Development Partners, although their contribution is likely to decline in the coming decades. However, the upcoming GCF would fully compensate the gap through loans (mainly concessional) and grants. Involvement of the private sector would be still very low and specific levies hardly exist. The budget allocation needed for sustainable O&M activities would come from the general budget as development partners and GCF are generally not financing these activities. Apart from the general budget, only in the WASH sector, the revenues will be generated (through tariffs) to finance O&M costs of their facilities as well as a part of their capital investments.

In this period, Development Partners funding is expected to decline as Bangladesh consolidates its middle income status and Development Partners redistribute their resources to poorer countries. In addition, rich nations are likel to channel their climate adaptation funds increasingly through GCF. Development Partner share of financing the BDP 2100 investment budget declines from 50% in FY2015 to 17% in FY2030.

From 2020 onwards GCF finance will be a major share of the BDP 2100 budget, from 0.4% GDP (or 23% of BDP 2100 investment budget) to 0.5% of GDP (or 33% of BDP 2100 investment budget). The formulation of a GCF strategy and facility towards gearing BDP 2100 investment projects for GCF is an important pre-condition for reaching these ambitions.

From 2025/2030 onwards other public finance sources will need to increasingly play a role in funding BDP 2100 related investments. These other public finance sources will be composed of (public) revenues generated from beneficiary payment principles (water management levies, user charges for drinking water & sanitation, etc.). These public financial sources could be generated from different government budget accounts or public funds and at various levels: local, regional and national. Various financial instruments could be used such as budget support, domestic loans, public guarantees, etc.

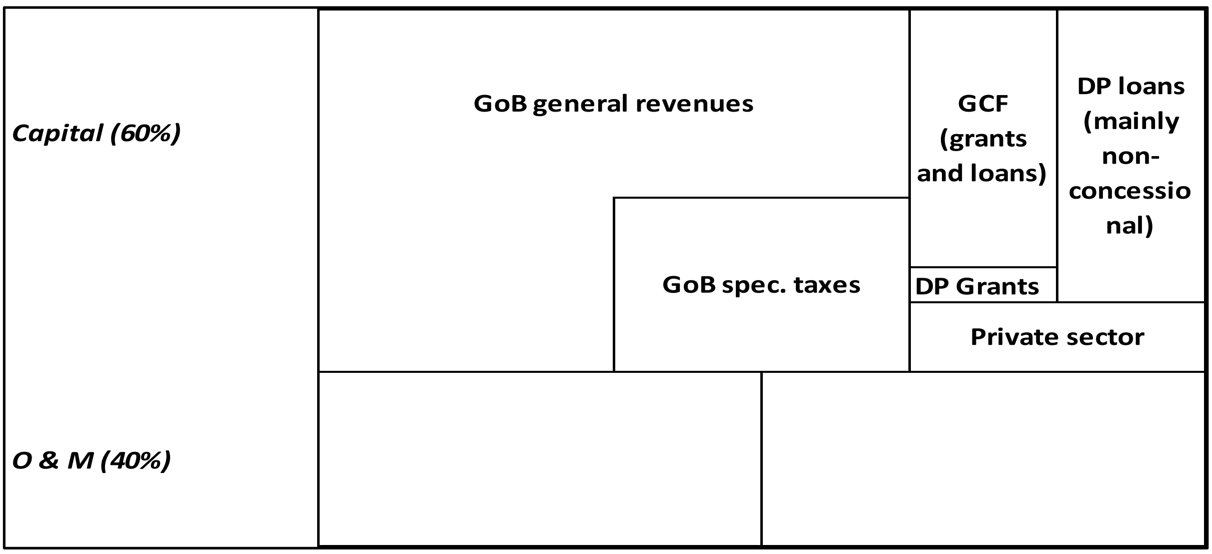


Figure 11.11: Resource Mobilization Potential for Water Sector, 2030-2050

Source:GED, 2015

In the second period (2030-2050) the envisaged composition will change significantly (**Figure 11.11**). Budget needs for investments relative to O&M activities would decline, because ensuring high levels of sustainability of expensive BDP 2100 measures is key. Development Partners contribution for funding investments would be declining further (and if still present mainly at non-concessional terms and conditions). GCF funding would also be declining and the GoB's contribution through general tax revenues as well as specific levies would increase. Private sector funding is expected to increase (through PPPs) based on positive institutional developments and lower risks. O&M activities (for regular annual maintenance as well as major overhauls every 5-10 years) with a significantly growing share in total budget needs, would need to be financed by the general budget and for a minor part by specific levies (e.g. through the introduction of a river maintenance charge). The WASH sector would have achieved full cost recovery by the end of this period and would be able to finance its capital and revenue expenditures.

After 2030, private sector funding should become increasingly important as source for funding of BDP 2100 related investments (**Figure 11.11**). The share could increase from 0.1% of GDP in 2030 to higher levels around 0.2% and 0.4% of GDP until 2050. Rolling out of PPP schemes and special financing instruments (revolving funds, etc.) should enable reaching these levels of private sector funding.

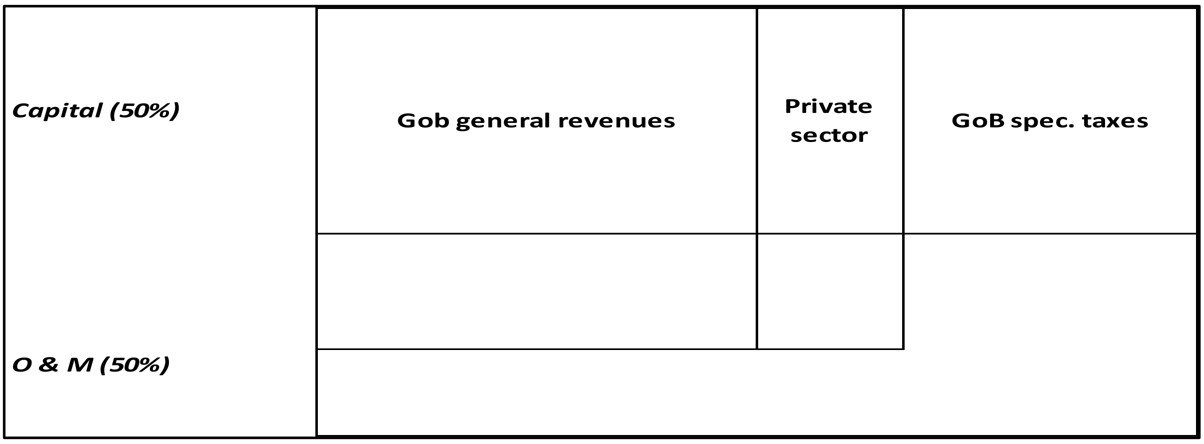


Figure 11.12: Resource Mobilization Potential for Water Sector, 2050-2100

Source: GED, 2015

Figure 11.12 shows resource mobilization potential for water sector over the very long term (2050 to 2100). It indicates budget needs for investments and O&M activities to be more or less in balance. By this time, most major infrastructural works would be already in place and require high maintenance. General budget as well as specific levies would be in place for both activities. Also the private sector's share in contributing to these activities would be substantial. The WASH sector has already achieved full cost recovery in the previous time period, and by the second part of this century the GoB would be able to levy a national water system tax, possibly customised at the local level, for flood infrastructure. Development Partners as well as GCF have completely disappeared, as Bangladesh would be a full-fledged middle income country aiming to develop into a high income country in the second half of this century.

In order to achieve the envisaged funding structure for the water sector a number of policy directions are necessary. These policy directions are shown per sub-sector in **Figure 11.13**.

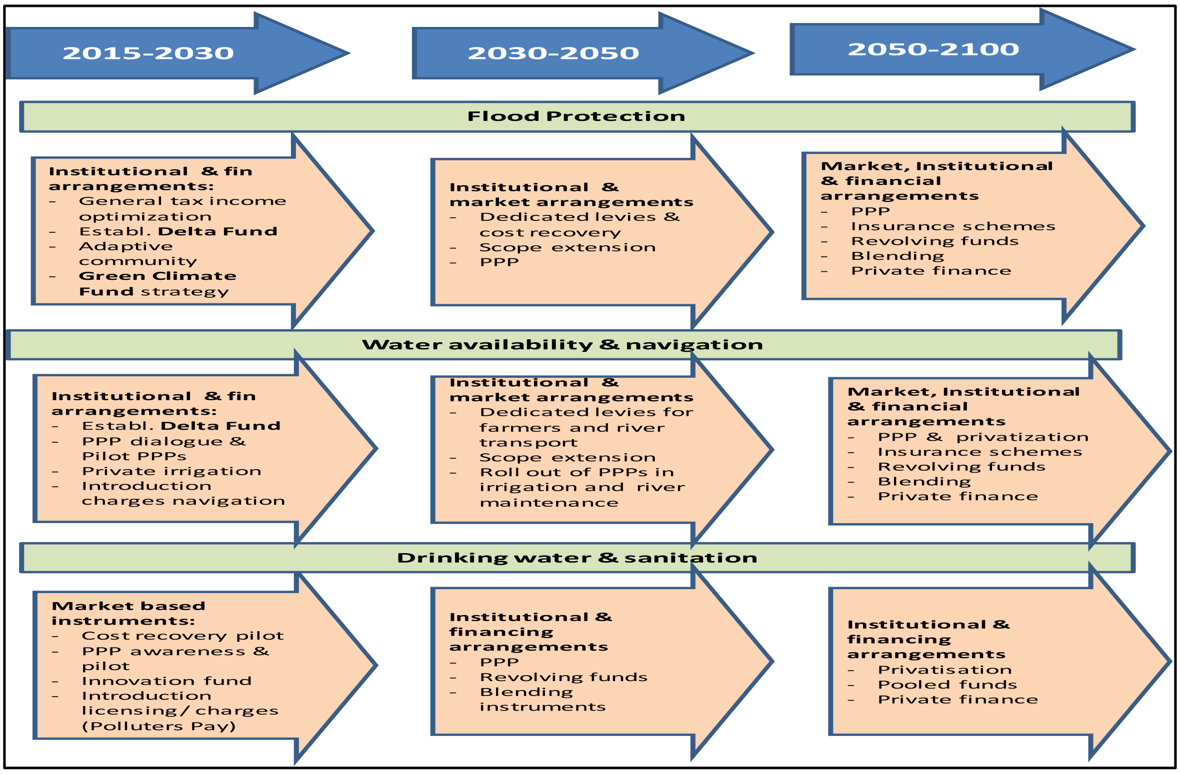


Figure 11.13: Directions and potential for the future funding and operation of Bangladesh water services

Source: GED, 2015

11.8 Resource Constraints and Resource Allocation

The water strategies developed in **Chapter 6** suggested that the list of water-related investment priorities is long. The list is all inclusive and is meant to be implemented over the longer term. Despite the projected significant increase in public sector investment under the BDP 2100 over the medium and long term, there will be need for prioritization of the investment plans and projects and outline a distribution of resources among competing priorities. Many of the investments will be heavily capital intensive. Additionally, implementation capacity constraints will limit the ability to design, prepare and implement large projects.

The current Investment Plan is the first such selection of projects to put the Delta Plan into action. It sets out the physical and institutional investments the Government will make to put the Delta Plan into effect. The current Investment Plan consists of a total of 80 projects: 65 are physical projects, and 15 are institutional and knowledge development projects. Its total capital investment cost is BDT 2,978 billion ($37 billion). All projects can be started within the next eight years, though given the scale and programmatic nature of some investments, construction in some cases will extend over decades.

Development of the Investment Plan followed a rigorous, consultative, and inclusive process, using the principles of ADM. As part of the BDP 2100 formulation process, the General Economics Division (GED) of the Planning Commission asked over 20 agencies involved in work in the Delta to submit their priority investment projects. This generated 133 candidate projects with total capital costs of BDT 3,753 billion ($47 billion).

The candidate projects were screened, grouped, then sequenced following an ADM methodology. Bangladesh is the first country in the world to develop a comprehensive investment plan for an entire delta using ADM.

The purpose of ADM is to ensure that the right investments are made at the right time. It aims to avoid both ‘too little, too late’ and ‘too much, too early’ by identifying tipping points when a change in approach is needed. Therefore, flexible approaches based around smaller interventions phased over time are often preferred to large one-off projects that cannot be changed once committed to. Projects aim to address climate conditions that can be realistically anticipated. Interactions between projects, land use, and water management are considered. Working in harmony with natural hydrological systems is generally preferred to large-scale attempts to alter such systems. Resources are used efficiently following cost-benefit analysis, and protection from water disasters is prioritized. Broad participation, investment in knowledge, and innovation are key.

Candidate projects were included in the Investment Plan if their expected benefits exceed expected costs; if they contribute to at least one of the six Delta Plan goals; and if they are compatible with the ADM approach. Of the 133 candidate projects, 80 met these criteria.

Delta projects are not just physical investments. There are major research, knowledge and institutional gaps that will require complementary capacity building investments. These gaps are discussed in detail in **Chapter 12, Chapter 13** and **Chapter 14**. The investment priorities will have to be converted into specific investment projects with identification of project components and detailed costing by components.

Table 11.6 provides some indicative magnitudes of the relative programme priorities based on the detailed investment programme done under the NWMP of 2001. The priorities of the NWMP are adjusted to reflect the emphasis of BDP 2100 and these are applied to total public investment estimates of the Delta Plan. The main adjustments are flood and river management, water management in dry season, environment and ecology, enabling environment and institutions according to priorities. Total amount of delta-related public investment in FY2016 prices is projected to be BDT 7.27 trillion for the period FY2019-31. This projection does not include budgetary spending on account of O&M in the amount of 0.5% of GDP per annum. Private sector investment in BDP 2100 related projects projected to be about 0.5% of GDP per annum by FY2031- is also not part of this projection.

Table 11.6: Indicative Composition of Public Investment under the BDP 2100 during FY2019-FY2031

(BDT billion; FY2016 Constant Prices)

Investment Components	Short term (FY2019-FY2021)	Medium term (FY2022-FY2031)	Total	% of Overall Investment
Institutional Development	42	322	364	5
Enabling Environment	20	125	145	2
Rivers and adjoining areas & Coastal Protection (including inland water transport)	255	2,291	2,546	35
Towns and Rural Areas	159	1,368	1,527	21
Major Cities (water supply, sanitation, flood control and drainage)	190	1,628	1,818	25
Disaster Management	23	195	218	3
Agriculture Water Management	40	251	291	4
Environment and Ecology	35	329	364	5
Total	***764***	***6,509***	***7,273***	***100***

Source: BDP 2100 Estimates (GED 2015) based on National Water Management Plan 2001/2004

Much of the public funding of BDP 2100 will go to flood protection, river erosion control, river management including river training and navigability, urban and rural water supply and waste management, as well as urban flood control and drainage. These are highly capital intensive investments. The priority accorded to flood control, river erosion, river management including training and navigability is obvious. These are amongst the highest priority investments in today's Bangladesh and can no longer be neglected in order to avoid the downside risks posed by natural hazards and climate change. Secondly, the back-log of demand for urban water, sanitation, waste management and drainage in major cities coupled with rapidly growing concentration of population and economic density in these areas suggest that this category will absorb at least a quarter of all Delta investments. Thirdly, the lack of water and sanitation services in small towns and rural areas suggest that the need to achieve the government's targets for safe water supply and sanitation for these areas will call for massive investments in these services. This category may absorb as much as 20% of total BDP 2100 investments upto FY2031. Public investment alone will not be enough. This is new area, in addition to agriculture water management, where the scope for private participation is large.

11.9 Concluding Remarks

Bangladesh's long term socio-economic performance would critically depend on how it manages the effects of climate change and other environmental changes. It is indicated that in the absence of proactive adaptation to mitigate the adverse impacts, Bangladesh economy may lose about 1.1% of GDP every year through loss of economic activity and the consequent loss of income.

It has been estimated that investment for adaptation to mitigation tasks would require about 2.5% of GDP per year. More specifically, total spending on interventions through new projects and maintenance of new and old projects will require about 2.5% of GDP per annum. However, currently Bangladesh has been investing only around 0.8% of GDP in water related projects. The key issue is how to bridge the resource gap. This chapter discusses several options including PPP and global climate funds.

As mentioned above, financing the BDP 2100 IP in the amount of 2.5% of GDP per annum will be challenging and will require new and innovative arrangements to encourage private sector participation in certain areas. It is also true that while there are areas where private sector may pay an important role, involving private sector in BDP 2100 financing will not be an easy task. Much of BDP 2100 IP investment including O&M expenses would need to be financed by the public sector. Accordingly, the Plan envisages private sector involvement in the total BDP 2100 IP operations of about 20% of the overall BDP 2100 spending, equivalent to 0.5% of GDP. In line with the global and regional experiences the private sector funds may be attracted to following few areas:

- Water treatment, supply, and sewage treatment
- Irrigation
- Dredging
- Land reclamation
- Inland water transport

An important but yet unexplored funding source could be the 'Green Climate Funds' agreed under the Paris Agreement. If Bangladesh can pursue her case effectively, there is a good possibility that Bangladesh may receive funds as large as US$ 2 billion per year from the 'Green Climate Fund'.

Chapter 12
Governance and Institutions

Chapter 12: Governance and Institutions

12.1 Introduction

Sound implementation of public policies and programmes depends upon the prevailing governance environment and underlying institutional arrangements. These requirements gain added significance when policies and programmes are cross-sectoral in nature and involve multiple line agencies. The BDP 2100 agenda is essentially cross-sectoral and implementation arrangements involve multiple line ministries, local government institutions, communities and the private sector. Clarity of roles, interdependence of actions and a coordinated approach are essential requirements of the institutional set up for BDP 2100 implementation. The stakes are high and so are the resource requirements. Yet, resources are limited and there are competing demands. How resources are allocated among competing demands, how trade-offs are made and how effectively programmes are implemented to get the best results from limited resources are major political economy issues that depend critically upon the prevailing governance environment and institutional setup.

Bangladesh is not alone in managing a delta plan. Globally there are many other delta experiences and Bangladesh can learn from these experiences with a view to avoiding their mistakes and adapting the positive experiences to the Bangladesh situation. Importantly, Bangladesh itself has a long experience in dealing with the delta issues and challenges. A critical review of these experiences, identifying areas of success and areas where there are major gaps can provide useful lessons for building the supportive institutional arrangements for the implementation of the Delta Plan.

Institutions are not static. They are dynamic in the sense that they evolve over time. Starting with a thoughtful design that involves pragmatic solutions based on the present socio-political realities of Bangladesh and working within the umbrella of the overall capacity constraints in public administration, institutional changes can further evolve as implementation progress is made. As noted earlier, in view of considerable future uncertainties the Delta Plan is essentially technical and adaptive in nature. This flexible approach to investment planning can also be applied to institutions. The challenge is to develop a basic minimum core arrangement now without which the implementation of the Delta Plan will falter.

Against the backdrop of the above, this chapter develops the structure of the basic core institutional arrangement that must underlay the implementation of the BDP 2100. The suggested institutional framework draws on the lessons of both international and Bangladesh experiences. It recognizes the socio-political environment of Bangladesh and suggests institutional set up that is realistic and will likely work in Bangladesh.

12.2 Lessons of International Experiences

Throughout human history river deltas have attracted people. Today deltas belong to the most densely populated areas in the world. Deltas provide food for their inhabitants because the soil in deltas is very fertile that supports agriculture. In addition, deltas allow easy access to fishing. Deltas often have large ports and harbours and therefore become hubs of industry and trade.

On the other hand, deltas, with land hardly above sea level or often below it, are quite vulnerable to natural disasters. Land subsidence can also be a threat. Studies indicate that subsidence or sinking is worsened by the impacts of human activity, such as upstream sediment collection caused by reservoirs, dams, accelerated sediment compaction, and control of river channels. Under these circumstances deltas are often subject to flooding and require frequent attention to their sea defenses. In the future, as a result of climate change and rising sea levels, this vulnerability will most likely become more acute and cause severe impacts on the natural processes in deltas. The lives of the millions of people living there will be affected dramatically.

There are an estimated 33 major river deltas prevailing worldwide. The Ganges- the Brahmaputra- the Meghna Delta (Bangladesh-India) is considered to be the largest in the world. Other famous large deltas are the Chao Phraya (Thailand), Danube (Eastern Europe), Fly (New Guinea), Fraser (Canada), Godavari (India), Krishna (India), Lena (Siberia), Mackenzie (Canada), Mahakam (Kalimantan), Mekong (Vietnam), Mississippi (USA), Niger (Western Africa), Nile (Eastern Africa), Orinoco (Venezuela), Parana (Argentina), Po (Italy), Shatt-el-Arab (Iraq/Iran), Volga (Russia),Yangtze-Klang (China), Yukon (Canada) and the Rhine-Meuse-Scheldt deltaic complex (Western Europe). Some 500 million people inhabit the delta areas of the world.

According to recent scientific studies of the 33 major river deltas, 24 are sinking due to flood-control efforts and other human-caused changes to the river systems. The combination of sinking deltas and rising seas will increase the damages caused by cyclones and other flooding events[35]. The inhabitants in these deltas are caught between land subsidence – caused both by dams and dikes upstream that hinder the natural flow of sediment to the delta as well as by groundwater extraction in combination with soft soils – and sea level rise caused by climate change. The study warned that the Chao Phraya River, which runs through Bangkok, Thailand, may be the worst affected by delta loss. Parts of the delta have sunk 1.5 meters below sea level. More than one-third of the Mekong delta in Vietnam, where 17 million people live and nearly half the country's rice is grown, could be submerged if sea levels rise by three feet in the coming decades. In North Africa, Egypt is particularly vulnerable to the effects of global warming. With a 3 feet rise in the sea level, much of the Nile Delta will be inundated, submerging the city of Alexandria, displacing more than 9% of the population and destroying some 6% of the GDP. On the border between India and Bangladesh at the Sundarbans islands, nearly 31 square miles of the Sundarbans have already vanished entirely. Millions of people on both side of the Sundarbans, in Bangladesh and India, will be displaced by a 3 feet rise in the sea level.

Armed with knowledge of these risks, authorities responsible for managing specific deltas have taken actions to mitigate these risks where possible or help the population adapt to these risks. These actions have emerged in the context of several institutional frameworks and approaches based on the specific delta profiles, issues and risks and the socio-political-economic environment of the concerned delta. Many of the institutional experiences have evolved over a long period time, sometimes in response to specific emergencies faced from climate change and natural environment, but also based on learning by doing. While not all positive institutional experiences are replicable in the specific form they have shaped in a particular delta, the organizing principles,

[35] "Sinking deltas due to human activities" by James P. M. Syvitski, Albert J. Kettner, Irina Overeem, Eric W. H. Hutton, Mark T. Hannon, G. Robert Brakenridge, John Day, Charles Vörösmarty, Yoshiki Saito, Liviu Giosan & Robert J. Nicholls in Nature Geoscience 2, pp 681-686, 2009.

the safeguards, the things that did not work, and the adaptive features of these experiences can provide useful insights for Bangladesh in developing its own institutions for the Bangladesh Delta management.

Some of the broad principles and features of the global institutional practices in delta management can be summarized as follows:

- **Integrated water management:** Perhaps the most notable institutional dimension emerging from global good practice experiences is the need for integrated water management. Water has multiple uses and competing demands can often create conflicts spatially as well as within a specific area. Depending upon the source of demand for water, responsibility for managing that particular demand might lie with a specific agency of the government. Consequently, more often than not, multiple public agencies are involved in managing water internally. Without an integrated approach to water management, the risks for conflicting policies, competing water development programmes and inefficient uses of water are high.

  Institutions of integrated water management have emerged in different forms in various river deltas. A good practice example of this integrated approach to water institutions is the Delta Programme in the Netherlands (**Box 12.1**). Through the Delta Programme the Dutch government not only signaled the top priority attached to water but it also instituted a holistic approach to water management. All aspects of water management including planning, investments, operations and maintenance, and research are handled by the Delta Programme and implemented in the framework of a highly decentralized water management agencies.

Box 12.1: The Dutch Delta Management

The Netherlands is located in a delta where the rivers Rhine, Meuse, Scheldt and Eems drain into the North Sea. Over the centuries floods have happened, caused by high river discharges, storms, and ice dams. In view of the changing climate, the probability of flooding has increased. As the socio-economic developments in the Netherlands have enabled the country to accumulate substantial income and wealth, the possible damage as a result of flooding has grown.

The Dutch have more than a thousand years of experience with flood mitigation and adaptation measures. Historically, the fight against floods basically involved a combination of dikes (polders) to keep sea/river water out and water pumps including those based on windmills to drain excess water from the dikes. The fight against flood and the adaptation measures grew bottom up with strong participation by the people most affected by the flood. So a rich tradition of participatory water management has prevailed in the Netherlands and is a striking feature of the Dutch Delta Management.

The devastating 1953 flood was a turning point in Dutch water management. The Dutch as a nation agreed that the risk of a similar flood even over a 1000 year plus was no longer acceptable. This culminated in the development of the First Dutch Delta Commission, the enactment of the Delta Law and the adoption of the Delta Plan. The plan aimed at reinforcing the water defenses and to shorten the coastline by closing estuaries with large dams. This huge project aimed at protecting the coast in a manner that reduced the risk of a disaster such as the 1953 flood to a probability of one in 3000 years.

A striking feature of the Delta Plan was the adoption of the Delta Works Programme as the engineering and technology response to realize the objectives of reinforcing and modernizing water defenses and shortening the coastline. The Delta Works is a massive, multi-billion dollar decades-long project to build and update the country's dams, dikes, locks, and sluices. Today, the Delta Works represents a coordinated engineering marvel. The American Society of Civil Engineers went so far as to deem the Delta Works one of seven modern wonders of the world. The project started in 1958 and completed some 40 years later in 1997, costing a total of US$ 15 billion. As a result of this project, Netherlands is now considered as the safest delta in the world.

Despite this solid progress with institutions (Delta Commission, Delta Law and the Delta Plan) and the implementation of state of the art flood prevention infrastructure through the Delta Works, the Dutch did not rest on these laurels and become complacent. Armed with the evidence of global climate change and the projected effects on the Netherlands especially in term of rising sea level, the Dutch government instituted the second Delta Commission in 2008. Based on its recommendations, it adopted the Delta Act in 2011, established the Delta Commissioner to manage the Delta Programme and set up the Delta Fund to provide annual funding on a long term basis. The new Delta Programme is a national programme in which the Dutch government, provinces, municipalities and water authorities work together in collaboration with civil society organisations, the business community and research institutes under the direction of the appointed commissioner for the Delta Programme (the Delta Commissioner). The Delta Programme is aimed at maintaining the Netherlands as a safe and attractive country. The current Delta Programme has three national programmes (fresh water supply, new safety standards for flood risk and reconstruction and development) and six regional programmes (the Coastal zone (mainly dunes), the Wadden Sea Area, the South Western Delta (Scheldt Delta), the Rhine and Meuse Delta, the lake IJsselmeer Area and the two major rivers Rhine and Meuse). The programme aims at supporting the Delta Decisions on five major issues related to water management in the Netherlands, by providing long term analyses that cover the period from 2015 to 2100.

The three Ds of the new Delta Programme: the Delta Act, the Delta Commissioner and the Delta Fund together constitute a most comprehensive and well thought Delta management programme. The three D's are essentially institutions for coordinating the efforts of a large number of water institutions working at the central level, at the provincial level, at the municipal level and at the level of water user authorities. The Dutch Delta management is heavily decentralized and the Delta Programme plays an essential coordination role with emphasis on research, modeling, long term planning, policy and regulatory support and financial assistance. The implementation of actual water investments and other programs are done by the decentralized agencies at the various levels.

Much of the funding for water programs come from the resources of the decentralized water institutions. Data available for 2010 show that a total of Euro 5.2 billion was spent on water programmes, of which Euro (€)1.1 billion came from the National Budget (21%); €2.6 billion (50%) from regional water boards; €1.3 billion from municipalities (25%) and €300 million from provinces (4%). Programmes supported at the national level are funded by the National Budget. With much of the capital spending required for flood safety out of the way owing to the Delta Works, yearly resources are needed for research, modeling, and maintenance and upgrading of individual infrastructures. To ensure that critical water programmes are adequately funded, the Delta Act established the Delta Fund, dedicated to finance the needs of the Delta Programme. Currently this amounts to about €1.0 billion per year, which is 0.15% of the Dutch GDP. This relatively small amount of money is ear-marked at the disposal of the Delta Commission and managed by the Delta Commissioner. Spending priorities are agreed consultatively with the participation of all decentralized water institutions, the national government and the parliament. These resources are mainly used for the national level projects but are also available for co-financing priority projects managed by the decentralized water agencies. Knowledge management and research gets a top priority in the Delta Programme that allows the Netherlands to remain at the cutting edge of climate change and water management technologies.

- **Regional water cooperation:** A second major lesson from the global delta experiences is the importance of water cooperation agreements among riparians. Many rivers originate in one country, travel through several other countries and finally drain out to the sea in another country. These rivers are a common resource for all riparians. More than half the world's population depends daily upon water resources shared by more than one country. Some 40% of the world's population lives in river and lake basins that comprise two or more countries and 90% live in countries that share basins. Yet adverse developments resulting from non-cooperative behavior of an upstream country could create havoc in terms of water shortages and or flooding for downstream countries. Rather than go to conflict and end up in a lose-lose situation, many delta countries sharing a common river have agreed to share the water as a common resource.

The usual approach is to take a river basin view and reach specific agreements about water rights and responsibilities among the riparians. Good examples include the Indus Basin Treaty (India and Pakistan); the Nile Basin Initiative (Egypt, Sudan, Ethiopia, Uganda, Kenya, Tanzania, Burundi, Rwanda, the Democratic Republic of Congo (DRC)); the Mekong Basin Commission (Vietnam, Cambodia, Laos and Thailand); the Niger River Basin Authority (Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger and Nigeria) and the Rhine River Basin Cooperation Agreements (Austria, Belgium, France, Germany, Italy, Luxembourg, Netherlands and Switzerland). There is no standard model of cooperation. Each of the agreement is specific to the needs and interests of the concerned riparian countries and the commonality of interests. Nevertheless, the Rhine River Basin Cooperation Agreement is the most comprehensive water cooperation involving multiple agreements and encompassing all water dimensions including navigation, water sharing for consumption, and water pollution control. In a way, this sets the global best practice example of water cooperation.

- **Institutions for internal water cooperation:** Similar to the role of regional cooperation, the cooperation between various actors within a country dealing with water and other aspects of the delta (land use, environment, biodiversity) is an extremely important feature of successful delta management. In water alone, managing multiple uses, shortages and trade-offs on the demand side and multiple agencies providing and or managing the water resources on the supply side must be involved in making decisions that take into account the private interests of each group of users and the social interest of ensuring sustainable use of clean and safe water. While integrated water management takes care of supply side coordination, on the demand side cooperation among users is necessary to manage water shortages, conflicts and trade-offs.

  Internal water conflicts arise in both urban and rural areas, although in developing economies rural water conflicts are more serious in nature. This is partly because local voices are not well represented in national institutions dealing with rural water issues. Consequently, rural water investments and allocations often tend to bypass the priorities and interests of communities. Two good practice examples of well-coordinated internal water cooperation are the Dutch delta management and the Spanish delta management (**Box 12.2**). In both cases, local water groups have emerged as important players in resolving water conflicts and trade-offs nationwide. More generally, active participation of user groups is an essential requirement for an effective delta management.

Box 12.2: Decentralized Water Management in the Netherlands

The Netherlands arguably is one of the most vulnerable deltas of the world in geographical terms. Yet, with determined efforts, it is now considered the safest Delta. A combination of sound planning, solid investment and good management based on decentralized water management has made this possible. Historically, water safety efforts emerged from the land-owners fighting for survival from recurring sea and river flooding. These land owners formed water management associations and funded investments from own resources. Over time as the country developed the role of state in flood safety and other water management expanded. Yet, this expanding state role preserved the historical decentralized approach and the result is the modern participatory flood control and water management institutions.

There are four main actors in water management: the national government; the provincial governments; the municipalities and the water boards (regional water authorities). While the relative roles and forms of the different actors have evolved over a 1000 years of experience, the roles at the present time are as follows:

1) National level: There are two main institutions. First, the Delta Commissioner oversees the Delta Programme and coordinates strategy, planning, knowledge management and core investment decisions. Second, the Ministry for the development of water and spatial planning (Rijkswaterstaat) is responsible for the following: Lake, river and coastal management; and maintenance and construction of dams and structures, large navigational waterways and inspection.

2) Provinces: Spatial planning, water management planning at the regional level, maintenance of provincial navigational waterways, inspections, permits for dike reconstruction.

3) Water boards "regional water authorities": Management of 55,000 kilometers of waterways, 18,000 kilometers of dikes, 360 sewage treatment plants

4) Municipalities: Sewer systems and some local waterways.

Clearly, while strategic planning as well as river and coastal management are the primary responsibility of the national government, the local water boards manage the bulk of the inland waterways. Not surprisingly, as earlier noted, these water boards accounted for about 50% of total water spending in 2010. These are indicative of the highly decentralized management of water and are a key factor for the successful management of the Dutch Delta.

- **Knowledge for ADM:** In view of the uncertainties of river course movements, sea behavior, climate pattern and climate change, adaptive delta planning is an essential element of effective delta management. This planning requires strong monitoring and evaluation of river courses, sea level rise, silt and sediment deposits, and climate behavior. Development of appropriate knowledge bank, research and modeling efforts, and data collection, storage and use are an essential element of adaptive delta institutions. There are several good practice examples of this, including the Dutch experience, the experience in Spain, and the several delta examples from the USA (e.g. the Mississippi Delta authority, the Colorado River Basin, and the San Francisco River Basin). Yet, arguably, the approach to knowledge management in the Netherlands is perhaps the most comprehensive approach.

- **Public-private partnerships:** Although in any typical delta the public sector takes the lead in managing the river delta in view of the public goods nature of the issues and challenges, good practice examples show the solid value of well-crafted public-private partnerships in delta management. These partnerships can take a range of shapes and involve many areas of delta management. The most obvious and common example is in the area of knowledge management, especially related to delta research. Another common example is water partnerships for pollution control. A third oft-seen example is operation and maintenance of water courses and polders/dikes by water user groups at the community level. At the institutional level, private provision of water in both urban and rural areas based on well-developed water markets hold the most promise in terms of mobilizing private resources for water services.

- **Coordinated approach to delta financing:** The adequacy of the financing arrangements is critical to the success of the implementation of the delta plan. This has several dimensions. First concerns the adequacy of total allocations. The second concerns the proper balance between the different components of the delta investment strategy: navigation; water supply management overall and by uses; investments for mitigation and adaptation (polders; dams; embankments; river training, etc.); operations and maintenance expenditures; and water cleaning and pollution control. A third issue is investment in adaptive delta management: water and climate knowledge bank; delta modeling and research; data collection, storage and use. A fourth issue is investment in delta institutions like water user groups; public-private partnerships; and stakeholder consultations.

  In a typical developing economy public resources are limited. Political economy considerations often short-serve the needs of preserving the delta that are a long term challenge while other priorities appear more near term. Some delta authorities have tended to address this financing constraint by creating a special dedicated fund for funding the needs of the delta strategies. The most notable example of this is the Delta Fund created by the Netherlands government to finance the delta programmes. This Fund was created in 2012 and is managed by the Delta Commission. Presently, this amounts to about €1 billion per year. This is a small sum of money in relation to the GDP of the Netherlands (0.15% of GDP) and about a quarter of the total spending on water in the Netherlands but it signifies a commitment by the government to protect core investments related to the protection of the Dutch Delta over a long period of time.

12.3 Existing Policy and Institutional Framework for Water Management in Bangladesh

Bangladesh has a long history of water management. Related water policies, regulations and institutions have emerged over time, partly in response to water-related natural hazards. Nevertheless, the main focus of water management has been the protection of agriculture. This is understandable in view of the dominant role of agriculture for food security and livelihood for the poor. One negative consequence of this primal focus has been the relative neglect of issues emerging from climate change, river transport, urban water, urban drainage and water quality issues including pollution of river and other water bodies. These later issues have now gained added significance in the context of integrated delta management.

Legal framework for water management: The legal framework for water management is provided by the Water Act 2013. This is a comprehensive Act and covers well all aspects of water management as an integrated resource. According to the Act, the main objective is to "make provisions for integrated development, management, abstraction, distribution, use, protection and conservation of water resources"[36]. Since the Act is of recent origin, the associated regulatory policies and institutions have not fully taken shape. But the Act provides a strong basis for moving forward.

The Water Act 2013 currently operates through the use of a number of operating principles defined by the National Water Policy of 1999 and the National Water Resource Management document of 2001 (adopted in 2004). The institutional responsibilities are as follows:

- The National Water Resources Council (NWRC) coordinates all water resources management activities in the country.
- The Executive Committee of the National Water Resources Council (ECNWRC) guides water management institutions at the national, regional, and local levels in the formulation and implementation of policies and plans for improved water management and investments.
- The MoWR formulates a framework for institutional reforms to guide all water sector related activities. It periodically reviews the mandates of all water sector institutions and redefines their respective roles, as necessary, to ensure efficient and effective institutions commensurate with changing needs and priorities.
- The WARPO is exclusive government institution for macro-level water resource planning. It acts as a clearing house for all water sector projects. It also serves as the Executive Secretariat of the ECNWRC.
- The BWDB implements all major surface water development projects and other Flood Management, Drainage and Irrigation (FMDI) projects with command area above 1,000 ha.
- The LGED implements FCDI projects having a command area of 1,000 ha or less after identification and appraisal through an interagency Project Appraisal Committee. Local Governments (Parishads) are the principal agencies for coordinating these efforts.
- The BIWTA is responsible for river transport including river dredging to maintain river navigation.

Progress with water policies and programmes: Bangladesh has 50 plus years of experience in managing water resources that is reflected in numerous water policies and water programmes. a chronological list of the major initiatives are provided in **Table 12.1.**

Table 12.1: List of Major Water Related Policies, Acts and Programmes

Policies/ Programmes	Responsible Agency / Ministry
The Embankment & Drainage Act 1952	Ministry of Water Resources
The IECO Master Plan (1964)	Bangladesh Water Development Board (BWDB)
The Marine Fisheries Ordinance (1983)	Ministry of Fisheries and Livestock
The National Water Plan I (1986)	Master Plan Organization (MPO)
The National Water Plan II (1991)	Master Plan Organization (MPO)
Floodplain Management Pilot Project	Ministry of Water Resources
Flood Action Plan FAP (1990/95) with 11 main studies and 15 supporting Components:	
FAP 1: River Training Studies of the Brahmaputra River	
FAP2: North West Regional Study	

[36] The Water Act 2013, Government of Bangladesh.

Policies/ Programmes	Responsible Agency / Ministry
The Embankment & Drainage Act 1952	Ministry of Water Resources
FAP 3: North Central Regional Flood Control/Drainage Study	
FAP 4: Southwest Area Water Resources Management Project (1993)	
FAP 5: South East Regional Study	
FAP 6: North East Regional Study	
FAP 7: Cyclone Protection Study	
FAP 8: Dhaka Town Protection	
FAP 9: Other Town Protection	
FAP 10: Flood Forecasting and Warning Project	
Protections and Conservation of Fish Act (Amended 1995)	Ministry of Fisheries and Livestock
National Minor Irrigation Development Project (1996)	Ministry of Agriculture
Environmental Conservation Act 1997	Ministry of Environment and Forests
National Policy for Safe Water Supply and Sanitation 1998	Ministry of Local Government, Rural Deveopment and Cooperatives
Meghna Estuary Study, Master Plan (1998)	Bangladesh Water Development Board (BWDB)
National Fisheries Policy (1998)	Ministry of Fisheries and Livestock
National Water Policy (1999)	Ministry of Water Resources
Guidelines for Participatory Water Management (2000)	Ministry of Water Resources (WARPO)
The National Water Management Plan (NWMP) (2001)	Water Resources Planning Organization (WARPO)
Action Plan for Solid Waste Management in 19 Towns	Department of Public Health Engineering
District Development Plan of WARPO (2005)	Ministry of Water Resources (WARPO)
The Coastal Zone Policy (2005)	Ministry of Water Resources
District Perspective Plan for Development and Management of Water Resources (2005-06)	Local Government Engineering Department
National Fisheries Strategy and Action Plan (2006)	Ministry of Fisheries and Livestock
Government Jolmohal Management Policy (2009)	Ministry of Fisheries and Livestock
The Master Plan for Haor Areas (2010)	Directorate of Bangladesh Haor and Wetland Development
Dredging Plan 2012	Ministry of Shipping
Sector Development Plan (SDP) for Water Supply and Sanitation Sector in Bangladesh (FY 2011-25)	Local Government Division, Ministry of Local Government, Rural Development and Cooperatives
The National Water Act (2013)	Ministry of Water Resources
Bangladesh Water Development Board Act (2013)	Ministry of Water Resources
Bangladesh Haor & Water Bodies Development Board Act (2014)	Ministry of Water Resources
National Shrimp Policy (2014)	Ministry of Fisheries and Livestock
Participatory Water Management Rules (2014)	Ministry of Water Resources

Source: BDP 2100 Technical Team Analysis, GED, 2015

This is an impressive list of policies and programmes covering most aspects of water management. Evaluation studies of implementation of these policies and programmes suggest some common issues and challenges.

First, in the area of policy, the most comprehensive policy is the Water Policy, 1999. It is a well thought out policy paper that provided guidance on regulations as well as institutions such as emphasizing the need for local level representation in water management. The main problem area is in implementation. Many of the recommendations have not been implemented, including participatory water management.

Second, the most ambitious project was the adoption of the Flood Action Plan, 1990-95 that was prepared with the help of the World Bank. The FAP involved 26 studies and pilot projects to be supported by 17 donors. The project was the first attempt to have a coordinated approach to flood management involving the government and the donor community. However, the project came under strong scrutiny and criticism on a number of weak links including weak institutional capacity and coordination, lack of involvement of stakeholders, inadequate impact assessment with possible negative effects on fisheries and the natural environment, and inadequate attention to operations and maintenance arrangements including financing. Consequently, the project was only partially implemented with the main focus on the studies.

Third, coordination of water investments have been attempted through a number of rounds of national water plans (NWMP 1986, NWMP 1991 and NWMP 2001 (adopted in 2004)). A common feature of these plans has been the development of ambitious investments plans that is not based on a realistic assessment of available resources and implementation arrangements. Additionally, these plans were all prepared by the MoWR and did not have the buy-in of all line ministries dealing with water resources. In the absence of a coordinating mechanism, the programmes have remained on the shelves and did not have much impact on actual investments by line ministries done through the Annual Development Programme (ADP) process. Inadequate coordination between water policies and programmes prepared by the MoWR and actual decisions in other water-related line ministries has been a perennial concern that led to the Water Act, 2013 and the establishment of the NWRC and ECNWRC.

Fourth, the plethora of specialized area studies done so far, such as the regional area studies, the individual city protection plans, the Master plans for Southern Area and the Haor Area, the District Water Development Plans, etc. many of them have remained in shelf, not putting into real practice as such. Significant implementation has not happened. This is a generic problem in Bangladesh, where many donor-funded technical studies are done with little or no serious government ownership.

Finally, most of the policies, studies and plans in water resources sector have tended to be done in piece meal with single line ministry involvement. They do not take a holistic approach to water as a cross-sectoral issue. Neither do they look at the demand side and/or based a careful assessment of their socio-economic impacts if these policies or programmes are adopted. The institutional aspects of water management tend to be side-tracked or weakly covered. Implementation capacity constraints are not well understood and integrated. Most importantly, the implications for resources and how they will be funded in the context of a tight budget constraint and conflicting priorities is seldom reviewed or discussed.

Legal framework for environmental protection: As in the case of water, a number of legislation and rules have been established to protect the natural environment. These are summarized in **Table** 12.2. The main issues are limited implementation capacity and inadequate application of these laws to integrated delta management. The capacity of the MoEF is required to be further enhanced in the areas of knowledge, data generation, implementation, monitoring and evaluation of the environmental laws and regulations.

Table 12.2: Legal Framework for Environmental Management

Sl	Act/Rules (Year)
1	The Bangladesh Environment Conservation Act (1995)
2	The Bangladesh Environment Conservation Rules (1997)
3	The Brick Burning (Control) (Amendment) Acts (2001)
4	The Clean Dhaka Master Plan (2005)
5	Noise Pollution (control) Rules (2006)
6	The Environment Court (Amendment) Act (2010)
7	Hazardous Waste and Ship Breaking Waste Management Rules (2011)

Source: MoEF, 2012

Policies and programs in other Delta-related ministries: As in the case of water, there is a range of policies and programmes related to delta management areas of climate change, environment, land, agriculture, fisheries and forestry. These are summarized in **Table 12.3**. A broad range of topics are covered here that are of relevance to proper delta management. As in the case of water, policies and programmes have emerged in isolation in individual ministries without proper integration with the different parts of the delta. The possible impact of each of these policies taken in isolation upon integrated water resource management has not been done. Implementation capacities are weak and implementation has been uneven.

Table 12.3: List of important Policies and Programmes in other Delta-related Ministries

	Policies and Programmes	Responsible Ministry
A.	*Agriculture, Fisheries and Livestock*	
1	Master Plan for Agriculture for the Southern Region (2012)	Ministry of Agriculture
2	National Agriculture Policy (2013)	Ministry of Agriculture
3	National Agricultural Extension Policy (2012)	Ministry of Agriculture
4	National Seed Policy (1993)	Ministry of Agriculture
5	Seed Rules (1998)	Ministry of Agriculture
6	National Integrated Pest Management Policy (2002)	Ministry of Agriculture
7	National Fisheries Policy (1998)	Ministry of Fisheries and Livestock
8	National Livestock Development Policy (2007)	Ministry of Fisheries and Livestock
B.	*Environment and Forests*	
1	National Environment Policy and Implementation Plan (1992)	Ministry of Environment and Forests
2	National Forestry Policy (1994)	Ministry of Environment and Forests
3	National Wetland Policy-Draft	Ministry of Environment and Forests
C.	*Land Management*	
1	National Land Use Policy (2001)	Ministry of Land
2	Jalmohal Management Policy (2009)	Ministry of Land

Source: BDP 2100 Technical Team Analysis, GED, 2015

Administrative arrangements for water management: Given the multiple dimensions of water supply and demand, cross-boundary water issues and multiple sources of water related risks and hazards, many government agencies are involved in the sector. However, 3 key ministries dominate in the actual implementation of water programs. These are: the MoWR; the Ministry of LGRD&C; and the Ministry of Shipping.

So far as water management is concerned, the MoWR is the largest and most important player. In recognition of this, the Water Act 2013 assigns the Minister of MoWR the all important role of serving as the chair of ECNWRC. Similarly, the secretariat role to the NWRC is assigned to the Secretary, MoWR and for ECNWRC the secretariat role is given to WARPO, which is a specialized agency of the MoWR.

Within the MoWR, the main implementation arm is the BWDB established in 1959 and mandated for managing of about 700 rivers of total approximate length of 24,140 km. The BWDB is the most significant water management organization in Bangladesh. It also handles a substantial amount of the budget expenditure in the water sector. The BWDB is responsible for preparing and implementing development projects related to flood control, drainage and irrigation, riverbank erosion, coastal development, and land reclamation. It is also responsible for the collection and dissemination of hydrological and hydraulic data and provides flood forecasting and warning information through the management of the Flood Forecasting and Warning Center (FFWC).

While the BWDB is the implementing arm of MoWR, the WARPO is the strategic and macro-planning arm. WARPO formulates policies, plans, strategies, guidelines, instructions, acts, and rules relating to the development and management of water resources. It has been involved in formulating the National Water Policy (1999), a Coastal Zone Policy (2005), the National Water Management Plan (2001/4), and the more recent Bangladesh Water Act (2013).

Additionally, there are a number of specialized institutions in MoWR that deal with specific areas of surface water management including coordination and research. The specialized institutions fall under three broad categories. First, there are institutions responsible for coordination of specific areas of water management: the Directorate of Bangladesh Haor & Wetland Development (DBHWD). The second relates to the coordination of policy dialogue and information on cross boundary water issues. The concerned institution is the Joint River Commission (JRC) that serves as the secretariat of the Ministry for dealing with cross-boundary water issues. The third relate to institutions that support policy through research. These include: the River Research Institute (RRI) that deals with physical and mathematical water modeling; the IWM which does mathematical water modeling; the CEGIS which provides integrated environmental analysis involving GIS, remote sensing, IT and database management.

As far as water supply and sanitation is concerned, the responsibility lies with the Ministry of LGRD&C. Much of the effort is focused on urban water supply and sanitation. There are very little institutionalized water and sanitation services in the rural areas. Piped water and sanitary toilet facilities are generally not available in rural areas. The main effort is to address rural drinking water safety concerns emerging from soil-based arsenic poisoning carried through tube wells and developing pilot rural sanitation schemes in partnership with NGOs.

Urban water and sanitation is provided through a range of institutional arrangements. They involve: Water and Sewerage Authorities (WASAs), city corporations, municipalities and DPHE. The four WASAs are: Dhaka WASA, Chattogram WASA; Khulna WASA and the Rajshahi WASA. Dhaka WASA has the largest urban water supply and sanitation program and its service has been extended to cover Narayanganj. Typically, WASAs have received substantial international assistance, are relatively well staffed and provide relatively high levels of service compared to the city corporations and municipalities. Many of the medium sized cities are experiencing very high rates of population and industrial growth. Yet, urban water and sanitation management institutions are desperately understaffed and receive only modest support from central organizations. Their capacity for planning and enforcement of the few regulations that exist and those that are planned is especially weak.

Efforts to decentralize irrigation and drainage management have led the government to distinguish between large and small schemes based on area of coverage of the schemes. Large schemes are those that encompass service for 1000 ha or more; small schemes are less than 1000 ha. The large schemes are managed by BWDB; the small schemes are managed by LGED. The aim is to eventually transfer the operation and maintenance (O&M) of these smaller schemes to the community organizations.

Inland water transport is the accountability of the Ministry of Shipping through the Inland Water Transport (IWT). The IWT has two major institutions: the Bangladesh Inland Water Transport Authority (BIWTA) and the Bangladesh Inland Water Transport Corporation (BIWTC). The BIWTA is responsible for river dredging, river maintenance, river port facilities and river transport regulations including safety standards. The IWTC is responsible for running the river transport facilities for cargo and passengers.

In the earlier days the Ministry of Agriculture (MoA) had responsibility for managing small scale mechanized irrigation facilities (deep tube wells) through the Bangladesh Agricultural Development Corporation (BADC) and the Barind Multipurpose Development Authority (BMDA). The BADC role has diminished as private provision of minor irrigation schemes emerged and largely took over the BADC role in irrigation. Overall, the MoA's role in water management has diminished over time.

12.4 Issues and Challenges in Integrated Water Management

The adoption of the 2013 Water Act and the formalization of the associated institutions (NWRC and ECNWRC) have in principle provided an adequate governance and institutional structure for integrated water management in Bangladesh. As noted above, by incorporating the NWPo, 1999, the National Water Act, 2013 also streamlines individual areas of responsibilities for water. The main challenges lie in:

- Properly implementing the provisions of the Act by making NWRC and ECNWRC effective institutions of inter-sectoral planning, financing, decision-making and coordination;
- Incorporating issues of climate change, environment, biodiversity, agriculture, fisheries, forestry, inland water transport and land management and their interaction with water to develop a comprehensive view of the delta issues and challenges; and
- Converting each of the related institutions of water, climate change and environment management, agriculture and land management, and inland water transport management into strong institutions with adequate technical skills including in the areas of economic management, financing, institution building, monitoring and evaluation and knowledge management.

All three factors are essential for having an effective institutional framework for Delta Management.

Fragmentation of tasks and agencies

There are a number of institutions responsible for water resources management in Bangladesh. At the ministerial level, a number of ministries/divisions namely MoWR, MoFL, MoA, MoS, MoLGRD&C are involved in water resources management. Among them, only the MoWR is the dedicated ministry in this area; the others, have multiple areas of responsibilities and accountability. Importantly, the number of individual entities under each ministry is large and diverse. The interests are similarly diverse and inter-ministerial coordination is a challenge. There is competition for government funding attention to O&M is highly deficient. Consequently, water is managed more as an individual service in each entity rather than an integrated service or input.

Administrative and technical capabilities of water institutions

The BWDB continues to follow a response-based approach rather than seeking a long term, sustainable solution to floods and erosion. The effectiveness has been limited by inadequate designs, insufficient maintenance, failure to address river erosion, and limited long term planning. Current management practices also need to be enhanced to deal with the dynamic nature of the river system and adapting to climate change. This has increased the vulnerability to flood disasters and undermined opportunities to safeguard economic development.

WARPO has been assigned the all-important role of macro water planning but its capacity to do this effectively appears inadequate. Much of the water research is on engineering and physical aspects of water flows and environmental impact. The economics of water management and related climate change in terms of effects on output, employment and poverty are not well researched. Issues of institutional reforms, investment requirements and financing options similarly are not well understood or analyzed in a coordinated manner. A national water plan was last prepared in 2001. The plan has not been meaningfully implemented and remains to be updated, reflecting both the capacity constraint in WARPO and also the slowness of institutional change in Bangladesh. So, it is obvious that converting WARPO into an effective macro water policy institution yet remains as a challenge.

Separation of implementation from regulation and (compliance) monitoring

A general principle that has become a global norm in water and sanitation is the separation of implementation from regulation and (compliance) monitoring, at least in so far as the functions are performed in the same geographical area. This consideration is missing in Bangladesh. For example, currently there is no organization with dedicated responsibility for groundwater management, and such expertise as exists is thinly scattered between DPHE, BWDB, BADC, etc. Resolving such a question would require, inter alia, considering what types of functions are to be assigned. Some form of abstraction licensing is required, at least in Water Stressed Areas. Currently there is no agency ideally suited in terms of skills, conflicts with existing functions and geographical spread to undertake the administration of licensing. In the context of the various new responsibilities that have been created under the Local Government and WASA acts, there may be a need to clarify the role and responsibilities of DPHE through the bye-laws to be established.

Capacity of water and other Delta agencies in handling WRM issues

The implementation of the NWA, 2013 and even the NWPo, 1999 has still a long way to go. In addition to the capacity constraints in water agencies, capacities are similarly constrained in other

Delta agencies (e.g. Ministries of Agriculture, Environment and Forests, Shipping, Land as well as Fisheries and Livestock). Capacity constraints in all Delta related institutions is a major constraint to implementing the NWA, 2013. Additionally, WARPO and similar institutions in other delta ministries tend to work in isolation. The coordination guidance from NWRC and ECNWRC for inter-ministerial institutions to work together is either missing or ineffective. This is an important challenge that needs to be addressed.

Community participation in water management

A key lesson from international delta experiences is the importance of community participation in water resources management. This is a major problem area for Bangladesh. Historically, Bangladesh has been pursuing a top down engineering approach to water management. Large water schemes such as polders and river embankments have been installed in many parts of the country with little or no community involvement. Participatory approaches by implementing agencies were simply add-ons with no sustainable gains. The results have been a concern of effectiveness from these major investments.

The Government has recognized this policy gap for a long period of time. The NWPo (1999) provides policy directions for community involvement in water management. The MoWR established an inter-agency task force to establish guidelines for participatory water management. The task force comprised of staff from BWDB, LGED, WARPO and professionals representing engineers, economists, gender specialists, agronomists, sociologists, resource planners and fisheries experts. The draft guidelines were circulated to professionals and stakeholders at a national workshop in May 2000. The guideline, known as "Guidelines for Participatory Water Management", was adopted as the official guidelines and is currently the basis for the Rule on Participatory Water Management (2015). Despite this effort the results are not encouraging. Effectively, there is very little meaningful participatory approach to water management. More effective approaches that go beyond specific projects and instead give local government institutions and associated communities a voice in water decisions at the national level are needed.

Research and knowledge agenda

Research and knowledge agenda that is critical input for ADM is not well organized in Bangladesh. The major research on delta related issues are done by only two ministries: the MoWR and the MoA. Both have dedicated research institutions. MoWR concentrates on water research and MoA on agriculture research including soil technology. Research agencies do their research based on their own interests. Joint or interactive research that is critical to understand the impact of climate change on agricultural productivity and vulnerability, for example, is not done. Importantly there is no concept of a delta knowledge bank. As a result, global research as well as local research done in the private sector including in universities on various delta issues are not well known or disseminated for policy use. Consequently, there is a huge knowledge gap on delta vulnerabilities, challenges, institutions, outlook and solutions that remains unaddressed.

Gap in Monitoring and Evaluation (M&E) of water and other delta issues

Another major gap is Monitoring and Evaluation (M&E) of water and other delta programmes. BWDB monitors the delta water resources projects through its Chief, Monitoring aided by two superintendant engineers but a comprehensive, dynamic and effective M&E is inevitable.

Furthermore, given considerable uncertainties associated with climate change, river course movements and behavior of sea and occurrence of natural disasters, ADM is necessary. The successful management of water as an integrated service and proper understanding of the progress, risks and vulnerabilities going forward is at the heart of developing appropriate responses in the context of ADM responses to these risks and uncertainties. Without a well-developed M&E system and a systematic approach to data collection, updating and research, ADM will be tough to implement. This is a significant institutional gap in Bangladesh.

Coordinated approach to adaptive planning of delta issues related investments

Another area of concern is coordinated approach to planning water investments, setting investment priorities and arranging financing. Considering limited resources in Bangladesh maximum efforts will be needed to establish the priority among the delta agenda, mobilizing appropriate resources and ensuring their best use in the context of the agreed delta strategies. Traditionally, line Ministries take the lead in advocating investment priorities and carrying those through the formal approval process by the Planning Commission (PC). Non-development budget (non-investment financing) is provided by the Finance Division on an annual basis based on a dialogue with concerned line ministries. More recently, efforts are underway to formulate multi-year budgeting and introduce programme based budgeting in the context of a Medium Term Budgetary Framework (MTBF). De-facto though, the budget funding remains an annual feature with no carryovers, the distinction between non-development and development budget still prevails. An attempt towards integrated water investment programming was made in the context of NWMP, 2001 that developed a medium term programme for water investment and capacity building in the context of achieving some well-defined strategic objectives. This was a significant step forward but the NWMP has remained mostly unimplemented. There was less commitment or buy in from the line ministries or the central planning and financial agencies. The NWMP also did not make any effort to identify the possible sources of finance or relate this plan to available resource envelope and realism of the investment plan.

Consequently, water investments remain fragmented based on priorities set by the concerned line Ministry. There is no effort to check out the consistency of the approved water investments against the targets of NWMP or any other integrated water investment strategy. Funding allocations focus on new projects and the balance between investment and O&M is not a policy factor in funding allocations. There is a long wish list of investments by each water-related ministries and competition over limited funding resources is an important factor in influencing the political economy of investment decisions rather than the potential contribution to addressing water benefits and mitigating or adapting to water risks and vulnerabilities.

Inadequate Public-Private Partnership

A final area of concern is the under-developed public-private partnership (PPP) in water investments. The government has a long standing interest in developing private participation in water management. The main success has been achieved in the area of providing mechanized deep tube wells in rural areas for irrigation. Private provision is also dominant in rural water supply, in terms of family- owned hand-pump tube wells to lift water for drinking and household use and sale of water by small scale private providers. In urban areas, organized water supply is undertaken by public entities (WASAs; city governments; pourashavas). As in rural areas, owner-installed mechanized water pumps and hand tube wells also exist in urban areas where piped water is either not available or available for only a limited number of hours.

In recent years the government has been partnering with donor groups and NGOs to provide piped water to rural areas and to improve sanitation services in the rural areas by building markets for rural sanitation. The piped water issue has become particularly important because of arsenic contamination in water extract from hand-pump based shallow tube wells. The limited experience with providing piped water is too early to call, but greater success has been achieved on the rural sanitation front. The Steps for Sustainable Sanitation Services (4S) project of the Water and Sanitation Program of the World Bank (WSP-WB) piloted the approach in 5 villages in 2009. Since then the approach has been expanded to many parts of rural Bangladesh in collaboration with small scale sanitation entrepreneurs and microfinance institutions.

On the whole, there is a large untapped potential to augment private water supply in urban and rural areas for household use, for commercial use and also for irrigation purposes. Establishment of well-functioning water markets where private provision of water and sanitation in both urban and rural areas and for trading irrigation water can function alongside with public supply can be an important way to expand services to unserved areas and augment financial resources in the water sector.

12.5 Reform of Governance and Institutions for Adaptive Delta Management

Establishing effective governance and institutions for ADM is obviously a huge challenge. The adoption of the NWA, 2013 is however a major positive step forward in providing the legal framework for establishing the required institutional arrangements. It is a solid starting point that can be modified appropriately in light of good practice international experience to serve the needs of the Delta Plan. In this regard, Bangladesh can also learn from the experiences of other delta countries, especially from the experience of the Netherlands that arguably has moved the farthest in establishing a well-thought and effective delta governance and institutional framework.

Implications of the Dutch Delta management for Bangladesh Delta: The Dutch experience illustrates the best lessons of international delta management. However, in adapting the Dutch experience, care has to be taken to recognize the sharp differences in socio-political-economic environment of Bangladesh. The major differences are:

- Bangladesh is a country with around 160 million people as compared with only 17 million in the Netherlands.
- Per capita income in Bangladesh is about US$ 1751 (2018) while it is US$ 52,000 plus in the Netherlands.
- The poverty rate in Bangladesh is 22.3% in 2017. Although poverty rates are not comparable because the poverty threshold in Netherlands is almost 20 times higher in nominal dollars and 7 times higher in purchasing power parity terms, even so poverty estimates in Netherlands are much lower, ranging from 2.7% (long term poor, i.e. percent of household below low-income threshold of €1810 per month in 2011 prices for a family of 4 members for four years) to 10% in 2014.
- Bangladesh still is dominantly a rural-agrarian economy with 70% of the population in rural areas and 44% of employment in agriculture. Currently, agriculture accounts for about 14.74 % of the GDP and 58% of the value-added are from crops. Netherlands is primarily an urban

industrial economy with 90% of the population in urban centers. Agriculture accounts for only 2.8% of GDP and 1.5% of total employment.

- Netherlands has a heavily decentralized administrative set up. Consistent with that water management is much decentralized and highly participatory in nature. In particular, the local level institutions representing heavily the local residents, especially the land-owners, are a key player in water management including policies, investment, maintenance and financing. In contrast, Bangladesh is heavily centralized. While a system of local government is slowly emerging, these are more administrative in nature rather than empowered and autonomous institutions for development. Consequently, water management is highly centralized and almost fully funded by the national budget.
- The Netherlands public administration is highly competent and innovative. Skills and institutions are plentiful. In Bangladesh administrative capacity is heavily constrained. The availability of skilled and professional staff in public institutions is limited. Public administration capacity constraint is a real challenge and as such ability to implement major institutional reform is limited. Accordingly, a gradual and pragmatic approach to institutional change is essential.
- Finally, the Dutch Delta institutions have emerged from a long history of experiments and learning by doing. These institutions have been shaped to a large part by history, culture, social relations and political environment. Many of these underlying factors are unique to the Netherlands and an attempt to transplant these institutions in Bangladesh or any other developing country without regards to history, culture and socio-political environment is bound to fail.

Given these differences, while a replication of the Dutch model in its original form is not a viable proposal, the main lessons of the Dutch experience can be distilled and applied to Bangladesh while mindful of the above substantial differences. The main lessons in terms of replicable principles are:

a) *Assigning topmost priority to safety and security from water disasters.* This was the main organizing principle of getting the citizens on board. The Dutch citizens decided that the type of disaster that happened in 1953 was not acceptable and preventive as well as adaptive measures will have to be taken to safeguard the life and property of citizens. This resolve has further grown over time as the Dutch per capita income and wealth grew and along with this the potential cost of large-scale flooding. Sensitivity to climate changes has similarly grown in view of the added risk they pose to flooding and loss of coastal land from sea level rise. The Dutch have institutionalized this in water planning by doing systematic cost benefit analysis of flooding and by imposing a large value (over a million Euro) per life lost to floods.

b) *The Dutch introduced a systematic cost-benefit approach to determining the volume of investment needed for water management.* The approach was first developed by Dutch mathematician Van Dantzig in 1956 when he was invited by the First Delta Commission to advise on setting up criteria for flood protection priority in terms of the amount of flood protection and their location. Van Dantzig came up with a simple rule: when allocating money to projects, account for both cost of damage and probability of damage. Regions with a high likelihood of flooding that would be costly to fix would receive the highest funding priority. Less costly regions would receive lower priority, even if the probability of flooding was high. The ideas closely related to the notion of cost/benefit analysis, and it gave planners a rational means by which to allocate funds. The approach was part of the *Delta Law* passed by Dutch Parliament in the late 1950s. What is striking about the parliament's action is that it does not provide uniform protection for all citizens. The Netherlands has fifty-three dike rings. Large regions protected by a single dike. One ring may be protected from a 2,000 year flood and another one from a 10,000 year flood. This approach was extended to the national level planning in 2012. The cost-benefit analysis at the national level aims to find out the optimum balance between the investment cost of flood reinforcements and the cost of economic damages from flood including loss of life. The driving forces are economic growth, which increases the loss from flood, and climate change, which increases the probability of flooding.

The main lesson for Bangladesh here is the need for systematic approach to investments for managing delta risks, based on a solid assessment of the net benefit of these investments in terms of contribution to the Delta objectives, including a probabilistic approach to risks of climate change. With limited resources and competing demands, this simple Dantzig rule yields a very powerful resource allocation mechanism. Highest priority should be given to those investments that yield the most net measurable benefit in terms of contribution to the Delta objectives.

c) *Innovation as the basis for delta management.* Added to the potential consequences of climate change, the 1990s floods made the Dutch aware that they could not go on raising their dikes indefinitely, and that excluding water would not bring about sustainable safety. This realization led them to adopt a new policy aimed at giving more space to water through solutions that seek not only to increase safety levels, but also to garner social, environmental and economic benefits. This led to the search for new solutions in rural as well as urban areas. In the Dutch city of Rotterdam, which aims to be "100% climate proof" by 2025 - but where traditional solutions such as creating new canals or strengthening levees do not suffice - the municipality is working on alternative solutions such as undergroundwater storage to catch storm water, subsidies for residents wishing to install green roofs, or water plazas built in such a way that they can serve as playgrounds in dry weather and as basins for storing water during heavy rain storms. In the Netherlands, the "dikes of the future" will indeed become multi-functional. These integrate entities as varied as industrial buildings and leisure facilities such as cinemas and parks.

A related initiative is the room for river project started in 2007. By this initiative the Dutch recognized that instead of fighting with nature it is best to accommodate it wherever possible. A river will have to flow before it drains to the sea. Room for the River restores the river's natural flood plain in places where it is least harmful in order to protect those areas that need to be defended. By adopting this programme the Netherlands lowered and broadened the flood plains and created river diversions and temporary water storage areas. They also restored marshy riverine landscapes to serve once again as natural water storage' sponges and provide biodiversity and aesthetic and recreational values.

There are two broad implications of this experience for Bangladesh. First, flood control and major irrigation investments are hugely capital intensive endeavors. The social and economic benefits can be maximized by making these investments multi-purpose. Thus, investments for coastal flood management might be combined with initiatives to develop coastal tourism facilities. Similarly, management of fresh water wetlands (haor and baor areas) can be combined into areas of eco-tourism. Another example is that lake cleaning and restoration in urban areas can be converted into recreational park areas. These multi-purpose investments can help cost recovery of capital investments to a large extent. Secondly, every attempt should be made to preserve the natural course of river through a room for river initiative that involves deepening the river and lowering and broadening the flood plains wherever practicable. The scope for this initiative will obviously depend on specific geographical and social context of Bangladesh, the limits of which are set by the heavy population pressure and shortage of land. The important point to understand is that in designing water management projects it must be understood that the flow of a river to the sea must not be hampered, as this will create flooding problem somewhere else. If situations where flow diversion is essential, then a proper alternative flow channel to the sea must be done.

d) *Need for an inclusive and participatory delta management.* A major feature of the Dutch Delta Management is the depth and quality of Delta Planning through an inclusive and consultative process. This systematic approach to the planning process has evolved over time starting with the First Delta Commission in 1956 and presently there is a system of Annual Delta Plans managed by the Delta Commissioner. In each phase the inclusive and consultative process was preserved. Best scientific minds are invited to participate and widespread participation of citizens is ensured. The lessons learnt from earlier planning processes are incorporated in improving the subsequent planning process. The delta planning is informed by a rich body of scientific research, water modeling, climate change analysis, impact assessment and quantitative detailed cost-benefit analysis of different approaches and initiatives. This is a remarkable participatory planning process.

While this process is hard to replicate in a developing economy like Bangladesh with weak knowledge infrastructure and capacities, the principles of participation, consultation, public-private partnership, evidence-based policy and planning, research and cost-benefit analysis can be introduced and developed over time in Bangladesh Delta Management.

e) *Need for an adaptive delta management:* A striking feature of the Dutch Delta Management is adaptive delta planning. The rationale for this is the major uncertainties in climate change and related natural forces. While there is considerable scientific progress in measuring temperature rise, the rising sea level and other adverse climate change factors, the specific magnitudes of occurrence in each countries and the likely adverse effects on climate variables like rainfall, flooding, hurricanes/cyclones and other natural disasters are not fully predictable and the impacts happen over a long period of time. Given these uncertainties, delta planning inevitably involves a long term vision with periodic updates of underlying climate parameters and investment responses. The Dutch Delta management is an excellent example how systematic adaptive approach to planning and investment responses have evolved over time starting with the First Delta Commission of 1953. To support ADM, the Dutch invest considerable amount of resources to gather data and conduct research on a range of delta related subjects including climate change variables. The knowledge is accumulated, stored and shared widely with policy makers, research and the public. Innovation is supported through research grants. The knowledge agenda is managed as a public private-partnership. The government invites the best scientific minds to work on the delta agenda. Innovative ideas and research suggestions are analyzed for effectiveness on the basis of cost-benefit analysis. This active knowledge management is a critical factor for the implementation of innovative approaches to water management in the Netherlands and a key success factor for ADM.

Bangladesh itself has a 50 year plus delta management experience, although not well organized or integrated. As noted in **Table 12.1** and **Table 12.3**, there are considerable donor-agency supported technical studies on different aspects of the delta management. Although they lack coherence and consistency with each other as they were each done in isolation and mostly independent of each other rather than as a part of a coordinated incremental approach, there is nevertheless a wealth of knowledge that lies under-utilized. As noted, some delta research is done by dedicated public institutions in the MoWR and in the MoA, but these are not done in any coordinated or organized fashion. Research is also done by the engineering universities, especially the BUET, and the agricultural universities. Further research on impact assessments is required. Most importantly, there is a lack of a strong data infrastructure. Additionally, there more efforts are required to gather available knowledge and share it with researchers or policy makers. Not surprisingly, water policy and related delta management is not supported by a well-functioning delta knowledge institution. This is an important area of institutional reform moving forward.

f) *Need for decentralized water management.* Perhaps the most striking lesson from the Dutch experience is the decentralized management of the water resources summarized in **Box 12.1** above. The important point is, starting with a historically water management system, the national government role gathered momentum over time as the country grew richer, the magnitude of risk intensified and the scale of intervention became large. But this role did not replace the role of the decentralized water management bodies. In fact, as was shown in **Box 12.2**, they still are the dominant force for managing the waterways, the dikes and the sewage treatment plants and account for 50% of the annual water investment. The legal framework for the water boards is provided by the Water Boards (regional water authorities) Act. Four types of stakeholders have to be represented in these councils: (1) the residents or inhabitants of the area; (2) the owners of real estate (farmers) consisting of open land which does not constitute a reserve or state land; (3) owners of natural reserves; (4) businesses/industries. Since residents pay the largest share, they have the majority in the council. Presently there are 25 regional water bodies.

The absence of stakeholder participation in water resources management is a major weakness in Bangladesh that needs immediate attention. Moving forward, what is needed is some bold and radical efforts to create truly participatory local water bodies in the same spirit as the Dutch water bodies. The success of Bangladesh Delta Management hinges critically on the establishment of these local water management bodies.

g) *Innovative water financing mechanism based on beneficiary pays principle:* Related to the decentralized water management is the innovative funding mechanism for water management in the Netherlands. National taxes cover the state tasks. In 1960, the Delta Commission considered that 1% of GNP could be spent on flood defenses. As major investments got completed through the Delta Works, the level of state resources allocated for water has fallen. For example, it amounted to € 1.2 billion in 2010. The Second Delta Commission went a step forward by advocating a Delta Fund at the national level. This Fund was created by the Netherlands Parliament as a part of the new Delta Act of 2011. The commitment is to provide an annual contribution of around € 1 billion to this Fund that is managed by the Delta Commissioner.

Maintenance of large scale flood defense projects funded at the central level is the responsibility of the provincial authorities from their own resources.

The water boards are self-financing, except in the case of major restructuring of large dikes that are financed at the national level. The main governing principles are:

- Direct benefit principle: People pay more if they have greater stake and a greater share of the benefit and they also have more say and voting rights.
- The polluter pays principle: This is also the Principle of Water Framework Directive.
  Solidarity principle: Water Boards are large enough for cities to subsidize sparsely populated rural areas.The cost recovery principle: All costs have to be recovered from the beneficiaries.
- The legality principle: All principles are legally embedded in the law.

The cost recovery from users is not a heavy load when compared with benefits and in relation to per capita income.

This two-step innovative financing principle (tax based plus beneficiary pays principle) has helped the evolution of the Dutch Delta as the safest delta with best maintained infrastructure. Quality of work of water bodies and proper maintenance of the water infrastructure is assured through approvals of design standards and inspections by the national or provincial authorities. By linking water financing directly to water and flood control benefits, the Netherland government is able to mobilize substantial resources for water management that would not have been possible from direct state tax resources alone.

The main lesson for Bangladesh is the need to invoke the direct benefit principle in some fashion in Bangladesh. Water investment, maintenance, institution building and research needs are enormous and there is no way that the ADP can meet all these requirements. The ability to establish local water bodies along the lines done in the Netherlands and assigning them direct stake in the planning, implementation, and maintenance of these investments can be a major breakthrough in developing sustainable financing options for water management under the Delta Plan.

Key elements of the governance and institutional reforms under the Bangladesh Delta Plan 2100: Drawing from the above noted replicable lessons of the Dutch Delta management, Bangladesh's past experience, and the present socio-economic-political realities, the proposed long-term approach to reforming the water and other related delta governance and institutions are as follows:

The framework for water resources management: Updating of the existing as well as formulation of new rules, regulations and procedures would be needed for providing a sound management and implementation coverage for the long term nature of BDP 2100. The main reforms need to be done immediately are (a) establishment of a 'Delta Wing' in GED; (b) formation of Delta Governance Council (DGC); (c) establishment of Bangladesh Delta Fund; and (d) establishment of Local Water Bodies. The idea of a "Delta Commission" as in the Netherlands was considered but the government feels that a more pragmatic approach is to entrust the GED of the Planning Commission to provide this coordinating function to start with.

(a) Delta Wing

An important way, the government has decided to signal its top priority to adaptive delta management including issues and challenges related to climate change, coastal zone and river management, water supply and sanitation, environment, biodiversity, agriculture, fisheries, blue economy, navigation and land management is to assign GED the responsibility of coordination, facilitation as well as M&E of BDP 2100 implementation. As such a well-structured set up is needed in GED, i.e. Delta Wing which will take the responsibility for rendering those tasks in an integrated and holistic manner.

Key functions of the Delta Wing in GED would be as follows:

- Plan and prepare the Delta Programmes and set priorities as per the Delta Plan. Programmes and projects need to be included in the Delta Programmes (BDP 2100 Investment Plan) for processing approval and implementation as well;
- In general, the project prioritization and approval pathway would remain the same as is currently practiced. The GED would undertake and approve related research studies, facilitate feasibility studies and capacity development projects/programmes to be financed from the earmarked Delta Fund discussed in the next section;
- Along with the implementing agencies, divisions and ministries, GED may also conceptualize, identify delta-related programmes and projects and consider for funding from earmarked Delta Fund through critical scrutiny with assistance from and in consultation with the Planning Commission and the relevant ministries and agencies;
- All the investment projects would be implemented by the relevant agencies, divisions, and ministries. The GED would coordinate, guide, facilitate, update, macro-level monitoring and evaluation of the implementation of BDP.
- GED would develop the terms of references of DGC and overall guidelines in respect of Delta fund operation and selection of projects under Delta Fund.

(b) Delta Governance Council (DGC)

The 'Delta Governance Council (DGC)' is proposed as a small but high-level inter-ministerial forum chaired by Hon'ble Prime Minister. DGC is proposed as a supervising and guiding entity and the Planning Minister, would be the Vice-Chair. The DGC would function as a formal linkage **for achieving political commitments** regarding BDP 2100, provide directions and makes decisions. It would provide strategic advice and policy guidelines.

The DGC would comprise of the Ministers of Finance, Water Resources, Environment, Forests and Climate Change, Disaster Mangaement and Relief, Agriculture, Land, Fisheries and Livestock, Food and Shipping. The Member, GED will serve as the secretary to the DGC. This high-level committee will provide overall coordination to the functioning of GED, will set policies and priorities and provide decisions. A second coordinating committee known as Project/ Programme Selection Committee (PPSC) will be chaired by the Member GED and comprise of representatives of Planning, Finance, Water Resources, Environment, Forests and Climate Change, Disaster Mangaement and Relief, Agriculture, Land, Fisheries and Livestock, Food and Shipping. Chief, GED will serve as Member Secretary. The PPSC will be primarily responsible for selection of specific projects and programmes for the Delta Plan.

(c) Bangladesh Delta Fund

As noted in **Chapter 11**, Bangladesh presently spends about 0.8% of GDP for water resources, mostly for new investments. O&M funding is negligible. This is very inadequate compared to the needs of the BDP 2100, as noted in **Chapter 11** on delta investment and maintenance requirements. The chapter also noted the limitations on budget funding imposed by fiscal resource constraints. **Chapter 11** suggested a minimum financing need of about 2.5% of GDP, of which 2.0% would be new investments and 0.5% of GDP as annual O&M. This proposed amount of annual Delta investments would amount to one third of the total ADP. Given competing needs, this jump from 0.8% of GDP to 2.5% of GDP can only be gradual. Importantly, this will also require alternative sources of financing. The Dutch experience showed that the national budget provided only about a quarter of total delta financing. Regional water management bodies and municipalities provided the remaining three-quarters. Bangladesh presently does not have autonomous municipalities and local water management bodies. Establishment of autonomous municipalities could be another major institutional reform which may take time. Similarly, the establishment of local water management bodies and their effective functioning will also take time. So, in reality the national budget will be the main source of delta financing in the next few years.

Given limited resources and the need for a coordinated and integrated approach to delta spending, it would seem appropriate to establish a Delta Fund. This can start with the consolidation of current ADP spending of 0.8% of GDP. But its allocation will gradually rise over the years up to 2.5% of GDP. The Delta Fund will be guided by the DGC to support Delta Program implmentation. GED will promote the generation of the Delta Fund and the allocation of the Delta Fund will follow the current development fund allocation practices. Delta Fund will include investments, O&M funding, research, capacity building and institutional development. Approved programmes will be guaranteed funding for the full life of the project and proper balance between new projects and completion of ongoing projects will be ensured. O&M fund will initially come from the Delta Fund but over time it will be phased away by transferring responsibilities to the municipalities and the local water management bodies. Similarly, over time the Delta Fund will manage only a small number of national high priority projects, innovation and research. The financing of smaller projects will transfer to municipalities and local water authorities with quality assurance on standards and inspection functions performed at the national level.

(d) Local Water Management Bodies

As discussed earlier, unlike the Dutch experience, water management is heavily centralized in Bangladesh and most water institutions are managed centrally at the national level. The main local institutions are the WASAs, the City Corporations; and the Pourashavas. These municipal institutions deal with water and sanitation issues, with services mostly concentrated in urban areas. They are managed by the Ministry of LGRD&C and mostly funded by the national budget with some limited cost recovery (charges for water and sanitation services). The missing institution is the representation of beneficiary stakeholders linked with coastal management, river management, fresh water wetlands (haors and baors) management, large irrigation schemes and flood control. Establishment of this missing link in water management is an essential reform for successful management of the BDP 2100.

These water management bodies fundamentally must represent the stakeholders. The water management bodies should be established based on a careful review of good practice international experiences including the Dutch experience, analysis of the past approaches to establishing water users association in Bangladesh and the reasons for their failure, and doing additional stakeholder consultations. The governance principles including membership, selection process, functions, financing and accountabilities must be provided in totality ensuring the participation of the representatives of regional and local water management bodies in managing water related issues. Regarding the number of such water management bodies, one possible approach is to consider the special water-related concerns, similar to the concept of hotspots. By this reasoning, a total of nine water management bodies that share broadly similar hydrological concerns, although with some overlap, are listed in **Table 12.4**.

Table 12.4: Suggested Regional Water Management Bodies

Sl. No	Water Management Body	Comprising Districts
1.	The Chattogram Coastal Belt Water Body (CCBWB)	Chattogram, Cox's Bazaar, Feni, Lakshmipur and Noakhali (5)
2.	The Barishal Coastal Belt Water Body (BCBWB)	Barguna, Barishal, Bhola, Jhalokati, Patuakhali and Pirojpur (6)
3.	The Khulna Coastal Belt Water Body (KCBWB)	Bagerhat, Jashore, Khulna, Narail and Satkhira (5)
4.	The Chattogram Hill Tracts Water Body (CHTWB)	Bandarban, Khagrachari and Rangamati (3)
5.	The Haor Area Water Body (HAWB)	Brahmanbaria, Kishoreganj, Habiganj, Maulvibazar, Netrakona, Sunamganj and Sylhet (7)
6.	The Barind Area Water Body (BAWB)	Chuadanga, Dinajpur, Jhenidah, Joypurhat, Kushtia, Magura, Meherpur, Naogaon, Natore, Nawabganj, Nilphamari, Panchagarh, Rangpur and Thakurgaon (14)
7.	The Central Area Flood Plain Water Body (CFPWB)	Dhaka, Gazipur, Kishoreganj, Manikganj, Mymensingh, Narayanganj, Narsingdi and Tangail (8)
8.	The Southern Area Flood Plain Water Body (SFPWB)	Chandpur, Cumilla, Faridpur, Gopalganj, Madaripur, Munshiganj and Shariatpur (7)
9.	The Northern Area Flood Plain Water Body (NFPWB)	Bogura, Gaibandha, Kurigram, Lalmonirhat, Pabna, Jamalpur, Rajbari, Rajshahi, Sirajganj and Sherpur (10)

Source: BDP 2100 Technical Team Analysis, GED, 2015

1) Strengthening core delta institutions: Success of any institutional arrangement depends critically upon the quality of these institutions. These in turn depend upon clarity of rules of engagements, clearly identified functions, measurable outputs and deliverables, clear accountability rules, quality of staffing and adequacy of budgetary resources. Bangladesh has considerable capacity constraints in its public administration. For the BDP 2100 to succeed and to effectively implement the Delta Act, it is imperative to strengthen the core delta institutions. This is a tough challenge and involves long term effort. Yet some core institutions require immediate attention. These include: the Delta Secretariat, MoWR, GED, BWDB, WARPO, DOE, DoF, the municipalities (WASAs, City Corporations and Pourashavas), the newly constituted regional and local water management bodies and all specialized institutions within different non-water Delta line ministries (specialized institutions working on delta-related issues in the Ministries of Agriculture, Disaster Management & Relief, Shipping, LGRD&C, Environment and Forests, Fisheries & Livestock and Land).

The GED will have the fundamental role of developing the medium term (5 year) Delta Programme that will be updated on an annual cycle. It will also be responsible for approving the annual Delta

Programmes that will include investments, O&M funding, research and capacity building. While these tasks need to be done consultatively with inputs from line ministries and water management bodies, the decision making functions will require substantial strengthening of capacities in areas of institutions, finance and economics. As in the case of the Dutch Delta Commission, it will also need to adopt sound economic principles based on cost-benefit analysis to approve individual programmes. The only thing that will not change is implementation of approved programmes. As presently, the approved programmes will continue to be implemented by concerned line ministry and municipalities.

As noted previously, MoWR is the primary water management institution in the country. Its work is supported by a number of specialized agencies & the two core institutions: BWDB and the WARPO. Both institutions need considerable strengthening in new technology, innovation, integrated planning, research, economic management and consultative processes. They will also need to help out with the establishment of the local water management bodies and learn to work with them collegially as a complementary institutions rather than as a competing institutions. The evolution of decentralized water management will face major challenges and will have obvious teething problems. WARPO and the BWDB can make this process smoother and less costly through proper support, encouragement and coordination.

The BWDB has a long history of involvement with water planning and implementation. BWDB has very capable water engineers, but is considered weak in areas of economic analysis, financing and institution and partnership building. These gaps will have to be addressed with proper staffing of experts in the missing areas. Additionally, BWDB must be encouraged to find innovative engineering solutions to water management problems. Considerable interaction with water engineers in the universities and international training from countries like the Netherlands that have excelled in designing innovative technical solutions to coastal belt management, river management, flood control and irrigation. Attention should be given to designing and adopting "no regrets" technical and socio-economic solutions to flood and irrigation management projects.

The functioning of water municipalities (WASAs, City Corporations and Pourashavas) were reviewed in detail in **Chapter 10**. The chapter suggested the need for substantial reforms. In particular, emphasis was placed on converting these institutions into autonomous bodies with considerable scope for cost recovery from users based on service provided. The demand for water and sanitation services in Bangladesh far exceeds the capacities of the municipalities, especially in small towns. While some of the gap can be met through private participation the capacity of the municipalities can be substantially strengthened by instituting sound cost recovery policies based on beneficiary and polluter pays principle. The transfusion of additional resources through proper cost recovery can provide the impetus for strengthening the capacity of the municipalities and providing additional services. This can also support innovative ways of encouraging good performance of municipalities by linking budget funding (block grants) with performance.

2) Strengthening cross-boundary dialogue and related institutions: As the lower riparian for all international rivers, Bangladesh faces some real risks from adverse developments upstream. The cross-boundary issues were discussed at length in **Chapter 4**. The chapter noted some successes but many issues and outstanding challenges remain. More recently, a major positive development that holds considerable promise of better cross-boundary water outcomes is the sharply improved political relations of Bangladesh with India. For making further progress frequent dialogues, discussions, visits and exchanges of information need to be effected.

Lessons of international experience suggest that a river basin approach has the best prospects of success. A further consideration would be to think of river agreements in terms of providing multi-purpose benefits. When water sharing is viewed as a zero sum game where more for one riparian means less for other, disputes become dominant and negotiations tend to fail. When water sharing involves multiple benefits (flood control, water storage, irrigation and hydro-power), the zero-sum game feature is converted to a win-win situation for both parties and the dialogue takes the shape of negotiating the best deal in terms of sharing of costs and benefits.

The ability to think innovatively requires both diplomacy and technical skills. The later is required to come up with well-thought multi-purpose river basin projects. Accordingly, the capacity of the Joint Rivers Commission (JRC) will have to be considerably strengthened. Partnership and coordination of JRC with BWDB and WARPO will need to be functionally strengthened. Possible multi-purpose technical options and cost-benefit analysis of these options will need to be developed as background research to dialogue with India.

Satisfactory progress with cross-boundary water management is a sine-qua-non for successful implementation of the BDP 2100. Positive results on this count will have far-reaching positive consequences including lower-cost water solutions for Bangladesh. The priority assigned to this task should be as high as priority given to large water infrastructure projects.

3) Creating a delta knowledge bank: As exemplified by the Dutch experience, creation of a delta knowledge bank is an essential pre-requisite for undertaking ADM. There are several ways of doing this. The knowledge agenda is discussed in detail in **Chapter 14**. The main issue to be noted here is the institutional responsibility for the delta knowledge management. With the establishment of Delta Wing in GED, this responsibility will be assigned to them, who will create a knowledge unit with following main responsibilities:

(a) collate all relevant delta related knowledge globally and nationally into a digitized knowledge library;
(b) establish a delta data bank;
(c) develop and implement a comprehensive delta knowledge and data updating effort.
(d) encourages researches by BUET, BAU and other technical universities/departments.

As a first step GED should undertake a quick stock taking of existing knowledge over a 6 months period. A summary of the knowledge bank stock should be shared with other delta-related public and private policy and research institutions to develop a knowledge and data upgrading agenda. The Delta Wing in GED should review this agenda to check for consistency and relevance with the needs of the delta management, especially in the context of doing a sound monitoring and evaluation of the Delta Plan, and develop a 3-5 year data and research work programme with annual targets. Resource requirements should be determined. Following approval by the DGC of the knowledge work programme and budget, implementation may proceed. Data work can be implemented in conjunction with the BBS and other delta ministries. Research can be out-sourced to universities and local research institutions. GED should be responsible for coordination and oversight. The knowledge management strategy for the BDP 2100 is discussed in detail in **Chapter 14**.

4) Developing a sound monitoring and evaluation (M&E) system: The practice of conducting M&E of government policies and programmes is a weak link in Bangladesh policy planning. Water related M&E is no exception. A solid M&E effort is essential for sound implementation of the BDP 2100 in the context of ADM. The M&E issues are discussed in detail in **Chapter 13**. The main point of note is the assignment of institutional responsibility for M&E. So far as investment projects are concerned, the M&E is the responsibility of the implementing agencies. Similarly, M&E of sectoral policies and programmes should rest with the concerned sectoral ministry and IMED. Regarding M&E of the entire Delta Plan & Delta IP, this will be a key responsibility of the Delta Wing. As in the case of implementation of the knowledge agenda, the Delta Wing can draw on the technical capabilities of its knowledge partners to help with the Delta Plan level M&E. Needless to say, the M&E for the Delta Plan will need to be done consultatively, drawing on the analysis of the M&E at the project and sectoral levels and involving all inter-ministerial agencies dealing with delta issues and the IMED.

Table 12.5: Summary of Delta Governance and Institutional Reforms

Needed Reforms	Required Actions	Responsible Agency	Outputs Generated
Assigning GED the responsibility of corordination, facilitation, M&E of BDP 2100 implementation and establishing a wing at GED for this tasks.	Establish a well-structured Wing under GED that will take responsibility for corordination, facilitation, M&E of BDP 2100 implementation	GED /Ministry of Planning	Smooth implementation of BDP 2100 by GED
Establish Bangladesh Delta Governance Council (DGC)	The 'Delta Governance Council (DGC)' is proposed as a small but high-level inter-ministerial forum chaired by Hon'ble Prime Minister. DGC is proposed as a supervising and guiding entity and the Planning Minister, would be the Vice-Chair. The DGC would function as a formal linkage **for achieving political commitments** regarding BDP 2100, provide directions and makes decisions. It would provide strategic advice and policy guidelines.	GED /Ministry of Planning	Gazette Notification
Establish Delta Plan Project and Programme Selection Committee	The Project and Programme Selection Committee (PPSC) will be an inter-ministerial committee at the secreatry level chaired with Member GED. Membership will include Secretaries of Finance, Planning, Water, Environment and Fisheries, Agriculture, Livestock, LGRD, and Fisheries, Land and Shipping.	GED / Ministry of Planning	Gazzette Notification
Establishment of Bangladesh Delta Fund	- Establish the Delta Fund to finance delta investment program. - The Bangladesh Delta Fund would be an earmarked fund for financing the implementation of the Bangladesh Delta Plan 2100. Sources of this fund may be GOB,	GED, Finance Division, Programming Division, ERD, DGC	Execution of the Delta Fund

Needed Reforms	Required Actions	Responsible Agency	Outputs Generated
	DPs, Environment and Climate Change related funds, PPP, etc. - The Government has a plan to allocate about 2% of GDP annually to the Delta Fund gradually by FY2031 as indicated in the 7th Five-Year Plan. - The Delta Fund would consist of capital expenditure for investment projects and recurrent budget funds for operation & maintenance to ensure sustainability of delta-related projects. - O & M budget for related infrastructure could be part of this Delta Fund. - Operational and administrative cost for the Delta Wing would be met from the GOB's annual budget		
Establish the Delta Knowledge Portal and Data Bank	- Create a delta knowledge bank within the Delta Wing: (a) collate all relevant delta-related knowledge globally and nationally into a digitized knowledge library; (b) establish a delta data bank; and (c) develop and implement work program to update knowledge and data. - Develop a 3-5 year data and research work programme with annual targets. - Implement work programme in partnership with BBS, BUET, IWM, CEGIS, other relevant public and private research institutions.	GED, Bangladesh Planning Commission	Delta Knowledge Portal and Data Bank
Establish an M&E System for the Delta Plan	- Adopt a quantitative development results framework for monitoring and evaluation of the Delta Plan. - Prepare annual reports on implementation of the Delta Plan. - M&E of Delta Plan - Submit M&E report to the DGC and NEC and disseminate through the Delta Wing website. - Delta Project level M&E will be done by concerned line Ministries. - Delta Sectoral level M&Es will be done by IMED and line Ministries.	-GED, Bangladesh Planning Commission -Line Ministries -IMED	M&E System for the Delta Plan

Chapter 13
Monitoring and Evaluation System for BDP 2100

Chapter 13: Monitoring and Evaluation System for BDP 2100

13.1 Importance of Monitoring and Evaluation (M&E)

Public programmes are intended to attain certain goals and objectives. However, in many cases apparently potential programmes might fail to reach those goals and that is why it is crucial to monitor them over time and to scrutinize their performance in a scientific manner. Monitoring is concerned with setting goals, indicators and targets and the information obtained by monitoring can be used to evaluate a programme. It can therefore be termed as a continuous process that uses systematic collection of data on specified indicators to provide policy makers and the stakeholders with an idea of the extent of progress and achievement of objectives. While comparing the outcomes of a specific programme with a set of targets, monitoring can help the policy makers to choose appropriate policies among a set of alternatives and can also help in improving the design and implementation of policies.

Evaluation, on the other hand, is the systematic and objective assessment of a project, programme, or policy with a view to determine the relevance and fulfilment of objectives, effectiveness, impact, and sustainability of that project, program, or policy. Such an assessment should be carried out in terms of its design, implementation, and results. An evaluation should provide information which is credible and useful, enabling the incorporation of lessons learned into the decision-making process. As a whole, M&E analyzes the way an intervention/policy option operates over time and evaluates the initial values of chosen indicators and desired outcomes.

Monitoring and evaluation promotes accountability and transparency in public spending, and ensures that resources are efficiently utilized for attaining the development goals. Governments use different tracking systems and the 'three legged stool' comprising of: (i) good human resource system, (ii) financial system and (iii) accountability system are crucial for efficient management of public resources. In case of a results based M&E system, public spending and achievements of objectives is emphasized and through that, inclusion of a 'fourth leg' into the system can be considered that reinforces good governance.

Monitoring provides the stakeholders and policymakers with the information about the current status of a policy/program/project relative to respective targets and outcomes, whereas evaluation gives evidence of whether targets and outcomes are being achieved or not. The primary purpose of M&E is therefore to help the government to measure the quantity, quality and targeting of outputs and to quantify how the outputs affect the lives of the common masses.

The Government of Bangladesh recognizes that an effective M&E system is crucial to monitor the implementation of the BDP 2100, including individual projects and associated programmes. Without an effective M&E structure, resources might be spent in an inefficient manner and could be disbursed in projects which are not consistent with the Delta priorities. However, in most cases the existing M&E structure of Bangladesh including for water and water-related investments mostly play an important role in tracking spending of projects/programmes. However, existing practices do not offer a scientific, systematic and results-based M&E framework which would ensure the best utilization of scarce resources.

13.1.1 M&E Practices in Bangladesh

Presently in Bangladesh, M&E is concerned primarily with tracking spending and the physical progress of the project/programmes. The government's dedicated M&E unit, the Implementation, Monitoring and Evaluation Division (IMED), is responsible for tracking the public sector development programmes. IMED primarily monitors and evaluates the development projects for efficient implementation. Monitoring primarily oversees the implementation process, identifies the challenges in terms of quality, time and costs and provides recommendations for improvement. The key stakeholders for the IMED are the ministries/divisions and other autonomous bodies.

IMED is involved at various stages of the project cycle- project preparation (pre-project), project completion and also post-project impact evaluation. In the pre-project phase, IMED's role is to suggest for improvement and modification whereas in the implementation phase, IMED monitors progress to ensure timely implementation and to maintain quality. It also gathers information from projects, agencies and ministries for effective monitoring consisting of: (i) periodic reports, (ii) procurement reports, (iii) field inspections, (iv) monthly coordination/review meetings, and (v) special meetings with the Project Directors. Information collected in this manner is analyzed on a monthly, quarterly and annual basis to review implementation performance of ministries/divisions.

In the post implementation phase, terminal evaluation reports are prepared by IMED on all projects, containing an analysis of the performance of project with suggestions for improvement. It also evaluates selected projects for assessing their impacts on certain indicators and the findings are used in future project design and implementation. The main consideration of IMED's M&E activities is identification of implementation problems and their timely resolution and all the reports prepared by IMED contain suggestions for improvement. These are discussed in review meetings held at the concerned line Ministry.

Every year, on an average, IMED monitors progresses about 1,200 projects under the Annual Development Programme and evaluates about 300 completed projects. It publishes: (i) Monthly performance evaluation of projects of the Ministries/Divisions, (ii) Quarterly performance evaluation reports of ADP included projects, (iii) Annual review report on ADP implementation, (iv) Annual project evaluation reports, (v) Impact assessment reports conducted by the external bodies.

As for impact evaluation, the Evaluation Wing of IMED carries out the evaluation in each project. Under this evaluation procedure, they carry out evaluation of already completed projects each financial year. The choice of those projects is made out of a list of proposed projects submitted by each of the ministries at the end of each fiscal year. After a thorough review process about ten to twelve projects are selected for evaluation. This evaluation is done either through: (i) out sourcing- under which the task of evaluation is conducted by a research firm and the selection of that firm is done through open advertisement and call for proposal; (ii) in house evaluation-under this system the evaluation Wing appoints consultants who carry out the evaluation. Under both of the procedures, a Technical Evaluation Team of IMED monitors the methodology, technical aspects, survey method or as a whole the procedure of the research. The final evaluation is placed in front of the Technical Evaluation Team as well as a Steering Committee. The result of the evaluation is finally disseminated for comments and suggestions. It is important to mention that, the methodology applied to individual project evaluation depends on the type of project as well as the choice of research firm/consultants regarding the project.

An important break with the past was secured by the government in the context of the 6th FYP and further consolidated in the 7th FYP. The 6th FYP for the first time introduced the concept of results-based monitoring and evaluation (RBM&E). It included a Development Results Framework (DRF) that defined certain quantitative results to be achieved at the end of the completion of the Sixth Plan. To measure progress it also provided baseline estimates of these core targets and objectives. The robustness of the RBM&E and the associated DRF was tested through an interim review and a full mid-year review was conducted to check for progress with the implementation of Sixth Plan. The analysis of the mid-year review was put on the website of the GED for public knowledge.

13.1.2 Results-Based M&E for the BDP 2100

The BDP 2100 advocates an integrated and adaptive management of the Bangladesh Delta. The BDP 2100 defines certain long term development objectives, goals and targets. These goals and targets are fairly long term. On the other hand policies, regulations, investments and institutions have to be developed now. Additionally, there are considerable uncertainties about the future path of the climate variables and the policy responses of upstream countries related to transboundary water management. The quality, relevance and adequacy of the current interventions and the need for changes in light of new evidence on climate variables and cross-boundary river interventions can only be assessed properly if there is a well-developed M&E system that monitors the implementation of the various BDP 2100 and develops interim progress reports on the long term results.

Presently water, land, environment, forestry, river transport, fisheries and crop agriculture are all managed as separate entities with little or no regards for their inter-linkages and how they interact to contribute to the BDP 2100 long term goals and targets. The BDP 2100 provides a strategy and suggests institutional arrangements for coordination of the various interventions as they relate to BDP 2100 goals and targets. These goals and targets constitute the DRF for BDP 2100. This DRF becomes the main focus of the BDP 2100 M&E.

Different BDP 2100 implemetaion related ministries provide a range of services to the public. Not all actions and programmes are directly linked to the BDP 2100 DRF. Yet, the actions and programmes of the MoWR are all of direct relevance to the DRF. This primacy of the MoWR to the DRF of BDP 2100 makes it the primary focus of the M&E effort.

13.2 Present M&E Practices for Integrated Water Management

The integrated planning and management of water resources in Bangladesh is guided by:

a) The National Water Policy (NWPo) and

b) The National Water Management Plan 2001/2004 (NWMP)

Both initiatives are spearheaded by the MoWR and incorporated and further referred to in the new Water Act, (2013); thus laying the basis for IWRM in the country.

Through the National Water Policy (NWPo), the GoB has taken steps to restructure and strengthen the existing institutions, in order to ensure that the agenda for reform and the action plan are implemented efficiently. The policy dictates that each institution must be held accountable for financial and operational performance. NWMP has been prepared to respond to these challenges with an attention on the sustainability of water systems and ecosystems in light of current water management practices and expected future changes. The Plan is structured with 84 different programmes planned over 25 years contributing individually and collectively to attain overall objectives and sub-sectoral goals.

NWMP has been prepared to provide a framework at national and regional level within which line agencies, local government and other stakeholders may plan and implement their own activities and projects in a coordinated manner, consistent with overall national and sectoral objectives. It is a rolling 25 year plan in three phases: the short phase (2000-05), the medium phase (2006-10) and the long term phase (2011-25). Implementation of the plan will be monitored regularly and it will be updated every 5 years.

The 84 different NWMP programmes are being implemented by line agencies and others as designated. Each organization is responsible for planning and implementing its own activities and projects within the NWMP framework. These projects are expected to adhere to the GoB's administrative procedures and conform to all relevant rules and guidelines issued by GoB. The responsibility of the overall coordination of NWMP implementation lies with the National Water Resource Council (NWRC), which issues directives through its Executive Committee.

These programmes are grouped into eight sub-sectoral clusters and are spatially distributed across eight planning regions of the country. Information on each, together with a wide range of planning data, is contained in the National Water Resources Database (NWRD), accessible through a Management Information System.

Table 13.1: The 84 Programmes of NWMP

Sub-sectoral clusters	Lead agencies
Institutional Development (ID)	10 programmes under ID sub-sectoral cluster are led by DBHWD, Bangladesh Meteorological Department (BMD), BWDB, Disaster Management Bureau (DMB), Department of Environment (DoE), Local Government Division (LGD), Local Government Institutes, Rice Research Institute (RRI), WARPO
Enabling Environment (EE)	13 programmes under EE sub-sectoral cluster are led by WARPO and BWDB
Main Rivers (MR)	12 programmes under MR sub-sectoral cluster are led by BWDB, BIWTA, Power Development Board
Towns and Rural Areas (TR)	8 programmes under TR sub-sectoral cluster are led by BWDB, Department of Public Health Engineering(DPHE) and Pourashavas
Major cities (MC)	17 programmes under MC sub-sectoral cluster are led by BWDB, Water and Sewerage Authority of Dhaka and Chattogram, DPHE, Khulna City Corporation and Rajshahi City Corporation
Disaster Management (DM)	6 programmes under DM sub-sectoral cluster are led by DMB, Bangladesh Railway, DAE, LGED and Roads and Highways Department (RHD)
Agriculture and Water Management (AW)	8 programmes under AW sub-sectoral cluster are led by Barind Multipurpose Development Authority (BMDA), BWDB, Department of Agricultural Extension (DAE), LGED
Environment and Aquatic Resources (EA)	10 programmes under EA sub-sectoral cluster are led by DBHWD, BWDB, DoE, DoF (Department of Fisheries), Department of Forest (DoFo), Ministry of Industries, WARPO

Source: NWMP 2001-2004

As noted in Chapter 12, the NWRC is the highest national body relating to water sector in Bangladesh. The NWRC is chaired by the Prime Minister. The Executive Committee of National Water Resources Council (ECNWRC) is chaired by the MoWR. The WARPO acts as the Executive Secretariat of ECNWRC. It also acts as the exclusive government institution for strategic and macro-planning arm for integrated water management under the MoWR. As such, the responsibility for M&E of integrated water management lies with WARPO.

Over 40 different agencies and organizations are involved in the water sector, of which 35 are organizations related to the national government. At least 13 different Ministries are involved directly or indirectly. However, the main GoB organizations involved in the water sector include the following seven ministries and their implementing agencies:

- Ministry of Water Resource (MoWR)
- Ministry of Local Government, Rural Development and Cooperative (LGRD&C)
- Ministry of Shipping (MoS)
- Ministry of Agriculture (MoA)
- Ministry of Fisheries and Livestock (MoFL)
- Ministry of Land (MoL)
- Ministry of Environment,Forests and Cliamte Change (MoEFCC)

Each of the 84 programmes under the NWMP has been assigned immediate objectives, each of which has a key objective of relevance to the NWMP as a whole and a development objective. WARPO is expected to elaborate and implement regular monitoring of implementation of the NWMP and the impacts achieved in relation to the set of indicators. However, available evidence suggests that there is no systematic effort to do a proper M&E of the integrated water management. Each line Ministry monitors the implementation of its own projects and IMED does the routine M&E noted above that focuses primarily on financial and physical targets.

More broadly, a systematic approach to do a results-based M&E of the integrated water sector is lacking. There is no agreed DRF for the water sector as a whole that defines agreed objectives and targets, base-year benchmark estimates and end goal targets. There is no periodic analytical report and updates that provides an overall assessment of the developments in the entire water sector, related targets and results. This is a serious gap that will need to be addressed under BDP 2100.

There is however an effort to monitor the pattern of a large number of water and climate change behavioural variables. The NWPo mandated WARPO to establish and maintain the NWRD to meet the demand for data and information of planners, experts, researchers and managers in the water and related sectors by assembling information from various authorized data collecting agencies. Generally, quality control is the responsibility of the agencies. Each agency has its own collection mechanisms with equipment and staff provided from its own budget, often supplemented through project funds. The data is then organized into a relational database format, to form the largest geo-spatial database in the country. It includes the following groups of data:

Table 13.2: Delta Related Data Monitoring

Base data	Covers administrative boundaries at various levels: national, divisional, district, Upazilla and Union. The base data also cover other features such as airway, catchment, and navigation, planning unit, power sector project, railway regions, river, road, water bodies and topography.
Surface water	Includes water level, discharge, salinity, sediment, river cross section and relevant Master Plan Organization data.
Groundwater	Covers water levels, water quality, abstraction, aquifer properties, lithology and information from MPO.
Meteorological	Covers rainfall, evaporation, humidity, temperature, wind speed & direction, sunshine-hour data, etc.
Soil and Agriculture	Includes geo-ecological zones, crop suitability, crop statistics, drought maps, fertilizer use, land type, agricultural land use and soil association.
Forest	Includes forest land data
Fisheries	Covers fish catch data.
Socio-economic	Encompasses census, char land, and economic data.
Environment	Covers data related to indicative parameters, industry, natural disaster and surface water quality.
Images	Various satellite images like LANDSAT, IRS and SPOT satellite images covering different regions or the whole country are stored in CD-ROM and usually used for WARPO's internal analysis purposes.

Source: BDP 2100 Technical Team Analysis, GED, 2015

ICRD is a subset of NWRD and was developed during the preparation of ICZMP. It contains information related to coastal zone of Bangladesh categorized as Natural Resources and Environment, Human beings and Social Conditions, Assets, Infrastructure and Services, Economics and Finance, Administration and Institutions and Funds and Interventions.

BWDB is the primary source of hydro-meteorological data. The Hydrology Division within BWDB collects, stores and disseminates data on water level, discharge, groundwater, sediment, rainfall and evaporation. River cross section data are also collected by the division. They store data in digital format in relational database system.

DBHWD has developed a web-enabled and GIS-based Integrated Haors & Wetlands Resources Database (IHWRD) using the latest tools and techniques. The IHWRD contains 100 data layers of different sectors like Hydrology, Morphology, Water Resource, Climate Change, Agriculture, Fisheries, Ecology, Forestry, Livestock, Health, Education, Industry, Energy, Economy and more. The aim of the development of this comprehensive and integrated database is to assist and guide the planners in the preparation of the Master Plan and coordination of haor management activities by the concerned line agencies.

IWM provides the services in the field of Water Modelling, Computational Hydraulics & Allied Sciences for Integrated Water Resources Management. IWM has developed high level analytical capabilities in the state-of-the-art mathematical water modelling to support its water resources management. IWM operates under the aegis of the MoWR.

The Climate Change Cell of DoE has developed a web-enabled Climate Change Database to provide the stakeholders with latest and updated data and information related to climate change, its impacts, adaptation and risk management in Bangladesh that is expected to have a positive influence in global response to climate change.

LGED maintains and updates a web-based road database which consists of Upazilla Road, Union Road, Village Road A and Village Road B. This database can be accessed from their website. Information on different roads can be extracted for a particular Upazilla and be printed.

BBS primarily conducts three decennial censuses: the Population and Housing Census, the Agriculture Census, and the Economic Census. BBS also maintains the unique Geo-coding system for different administrative unit such as division, district, Upazilla and union.

BMD, working under the Ministry of Defence, is responsible for maintaining the network of surface and upper air observatories, radar and satellite stations, agro-meteorological observatories, geomagnetic and seismological observatories and meteorological telecommunication system of Bangladesh. BMD collects 3 hourly data on all meteorological parameters such as rainfall, sunshine, temperature, wind speed, humidity, evaporation, cloud and radiation for surface and upper air throughout the country.

BARC under the MoA has developed Agro-Ecological Zone database that contains information on land resources, including physiography, soils, climate, hydrology, cropping systems and crop suitability. It has been used to generate readily accessible information on the physical land resources of the country for use by researchers, extension workers and decision-makers in land and agricultural resources management as well as agricultural development planning.

Also under the MoA, SRDI investigates soil-related problems for agricultural research and development. The functions of SRDI include reconnaissance soil survey of the whole country on the basis of aerial photo interpretation and field and laboratory investigation of soils; detailed and semi-detailed soil surveys of development project areas and research firms for various beneficiary agencies; soil surveys for locating areas of problem soils; soil moisture characterization of the soil tracts of the country; and preparation of various maps and reports based on the surveys.

SOB is the national survey and mapping organization of Bangladesh with a well-equipped digital mapping center. RHD under the Ministry of Road Transport and Bridges also maintains and updates spatial database which consists of National Highway, Regional Highway, Zilla Road, Bridges and Culverts. RHD has developed web-based Road Maintenance Management System. It allows users to search for roads and view general information on the roads. Information on roads is generally collected once a year.

Some of major data collecting agencies and their corresponding data are listed below:

Table 13.3: Sources of Data on Water Resources

Type of data collected		Major agencies
• Surface Water Level • Discharge • Sediment • Rainfall • Evaporation	• Surface water quality • Groundwater level & quality • River Morphology • Lithology • Aquifer testing	BWDB
• Irrigation equipment, • Irrigation water quality, • Groundwater levels	• Irrigation costs • Crop production cost • Water Quality	Bangladesh Agriculture Development Corporation (BADC)
• Groundwater table	• Water quality	DPHE
• Temperature	• Sunshine	BMD

Type of data collected		Major agencies
• Relative humidity • Rainfall	• Soil moisture • Pan evaporation	
• Census data	• Agricultural products	BBS
• Water level (Tidal & Non tidal) • Discharge (Tidal & non-tidal) • Velocity profile • River cross section • Bathymetric data • Bed sample	• Groundwater Level • Evaporation • Rainfall • Water Quality • Land Topography • Suspended sediment	BWDB and WARPO
• Water level • Discharge • Groundwater level • Groundwater quality • River cross section • Rainfall	• Temperature • Humidity • Wind speed • Sunshine hour • Evaporation	BWDB and WARPO
• Fish production	• Fish biodiversity	DoF

Source: BDP 2100 Technical Team Analysis, GED, 2015

Most of the data layers in NWRD consist of spatial data, temporal data and attribute data. Data are provided in both hard and soft copy. The database is designed using Oracle in the back-end to store the data, and Arc View GIS software for spatial query and display. Metadata for each data type are also available in the NWRD.

Hydro-meteorological data are especially vital for water resources development planning and design. Availability of these data from the various agencies is summarized below:

Table 13.4: Hydro-Metrological Data Collection Sources

Data type	Data collecting agency	Available data range
Water level (non-tidal)	BWDB	1965- 2009
Water level (tidal)	BWDB	1960- 2009
	BIWTA	1977- 2002
Discharge (Non-tidal)	BWDB	1934- 2007
Discharge (Tidal)	BWDB	1964- 2007
Rainfall	BWDB	1961- 2008
	BMD	1960- 2008
Groundwater level	BWDB	1967- 2003
	DPHE	1986- 1997
	BADC	1984- 1991

Source: BDP 2100 Technical Team Analysis, GED, 2015

13.3 Data Usage and Dissemination Practices

A number of data users depend on the NWRD and the most common categories of data users are:

- GoB organizations
- Semi-government organizations
- Autonomous bodies

- Projects and programs of governmental, semi-governmental and autonomous organizations
- Local and international non-government organizations
- Private companies
- International organizations
- Local and foreign educational institutions
- Local and overseas researchers
- Individual users and
- Others

One of the important and mandated routine tasks of WARPO is data dissemination. Since 1999, WARPO is disseminating data to national and international organizations, universities, research organizations, projects etc. Data is being used for water resources planning, management, research, study, etc. From October 2013 to January 2014, WARPO has disseminated data to 10 agencies including the RRI, BUET, Dhaka University, BAU, BRAC University, etc. from NWRD and ICRD.

13.4 Challenges and Drawbacks of Current M&E Practices

A number of challenges and drawbacks emerge from the current M&E practices carried out by different ministries and their respective agencies. These challenges include absence of a systematic M&E framework for integrated water management, issues around data quality, accessibility, updating, archiving and overall coordination amongst data collecting agencies.

The biggest gap is the absence of a systematic approach to integrated water sector M&E based on an agreed DRF, baseline estimates and end-year targets. Even at the project level, the M&E focus is on physical completion of project and use of financial resources rather than an informed assessment of results achieved the gaps in results and the reasons thereof, and implications for future projects. The absence of a systematic M&E effort is a serious planning drawback, especially in view of the many uncertainties of climate behaviour and related implications for water variables.

The existing equipment, human and financial resources of the various data collecting agencies are often inadequate to collect process and publish necessary data in a timely manner. Most projects in the water sector have their own form of data collection and information processing, and presenting their outputs in the form of reports and project databases. The lack of formal mandate to share reports or store data in a central archive often results in loss of valuable research data and findings and are not available to other users.

There are overlaps in data collection activities. BWDB and BMD collect meteorological data; while BWDB, BIWTA, IWM and CEGIS collect water level and morphological data. BWDB, DPHE and BARC all have responsibilities for groundwater data. These overlaps result in duplication of work, gaps between data collected and user needs, inconsistent data formats, and additional expenditure, which could be avoided with better planning and coordination.

WARPO has signed MoUs with BWDB, LGED, and JRC, Physical Infrastructure Division of the Planning Commission, Char Development and Settlement Project of BWDB, and CEGIS. These MOUs mostly concern data sharing arrangements. However, due to lack of stronger institutional presence, insufficient coordination with these agencies and limited revenue budget, the collection of data is hindered.

There is no standard in place for checking and maintaining the quality of water resources data at a national level. The problem of data quality control is widespread and profound, permeating even the most basic data and affecting the entire data collection process. In order to improve the data quality, the NWRD team prepared draft guidelines on NWRD Spatial Data Quality and Time Series Data Quality Control during the NWMP project. However, these documents have not been finalized yet.

The current situation is that large quantities of data are spread over many different organizations. A common theme throughout these organizations is the absence of sound backup and archiving policies for the electronic data that they retain and the corresponding failure to adapt their backup and archiving systems to new infrastructure that is introduced as the computer technologies evolve. In part this problem also results from insufficient financing.

Apart from BWDB and LGED, most agencies involved in implementing the NWMP do not readily share their data or M&E results with WARPO. However, reliable information on the implementation status of the NWMP is an important aspect of updating the Plan and it is evident that the monitoring of the implementation status of NWMP has not been satisfactory.

13.5 Lessons Learnt from International Experiences

Institutional M&E experiences in integrated water management exists from many developing and developed countries. The M&E experiences at the delta level exist in countries such as Netherlands and USA. They have evolved over a long period of time, adapting to the needs of the situation. Though all positive institutional experiences may not be replicable in the context of Bangladesh as they have shaped in a particular delta, the organizing principles, the safeguards, and the adaptive features of these experiences can provide useful insights for Bangladesh in developing its own M&E system for the Bangladesh Delta management.

The following lessons emerge for improving water resources M&E and data management in Bangladesh:

- Need for a systematic approach that links the delta objectives and targets to the M&E exercise.
- Need to develop measurable quantitative indicators to monitor progress with delta management. These indicators change with time as new information is available, especially in view of the uncertainties of climate change.
- Invest in data, analysis and research. The Netherlands and Germany are two excellent examples of this.
- Assign institutional responsibility for M&E.
- Conduct M&E exercise at regular intervals and make this widely available for policy analysis and research.

13.6 The Delta M&E Framework

13.6.1 The BDP 2100 M&E System and its Aims

In order to ensure ADM, uncertainties and risks have to be managed appropriately. Also, policy pathways have to be converted into actions and adaptive measures need to be implemented timely. This will require a change in usual processes in governance and institutional environment.

Therefore, acceptance and ownership of the Delta M&E Framework and its vision and strategies are crucial at all levels, including individual projects, ministries and the overall national level. For ensuring successful multi-sectoral coordination, integration among agencies and their practices of M&E, and good governance, the Delta M&E Framework is a pre-requisite. Governance for ADM should provide a decision-making structure that fosters communication between implementing agencies and decision makers, and has clear lines of authority facilitating timely decisions are made and implemented. Governance for implementing adaptive management must provide for the institutional capacity to interact, learn, and adapt.

The Delta M&E Framework will help guide and ensure effective implementation and M&E in relation to progress and identification of tipping points and possible change in pathway(s). Moreover, attention has to be paid to comply with the critical control points. In accordance with the Framework, the assessment and analysis of data are anticipated to lead to periodic adjustments in management of the BDP 2100 interventions and updates in operations and monitoring plans. The BDP 2100 M&E system is aimed at generating information that can be used in the achievement of these objectives. The M&E system is envisioned to be a living process and would need to remain flexible to respond effectively to unanticipated events.

13.6.2 BDP 2100 Development Results Framework (DRF)

Measuring environmental, social, and economic conditions and influences on these conditions constitutes an important part of knowledge-building and adaptive management. The BDP 2100 Delta Framework brings together indicators that will inform stakeholders about water system conditions and their relationships to ecosystems, social systems, and economic systems. The evaluation of the selected indicators is anticipated to reveal how different actions or inaction can degrade or improve conditions that lead to water sustainability. The Framework is built around both statements of intent (e.g. objectives) and themes (e.g. water quality).

Reporting on indicators ought to be based on the principle of measuring how far a current condition is from a desired condition. The Framework is intended to support reporting of indicators to a wide array of water and environmental stakeholders, the public, and decision-makers to build knowledge and to enhance adaptive decision-making and policy change.

The basis of the Framework is an overall vision for water-related sustainability indicators for Bangladesh, including an understanding of sustainability, indicators, and related terms. The Framework is designed to be scale-independent, so it can be applied from local to national scales. Ultimately, the Framework informs policy makers how well the country is sustaining the natural, social, and economic systems that the population depends upon, at least in terms of water, and based on what is known about stresses to these systems and how degraded conditions can be improved.

The starting point for developing the DRF for BDP 2100 is the Delta Vision and the associated objectives, goals and targets discussed in **Chapter 5**. As noted there, the BDP 2100 sets two types of goals: higher level national goals set by National Plans and 6 specific goals of the BDP 2100 that contribute to these higher level goals.

The higher-level national level goals are an outcome of the implementation of a wide-ranging economy-wide policies, programmes and institutions. The BDP 2100 is one major element of these policies, programmes and institutions involving the work programme of water and other water-related delta ministries. There are many other programmes involving macroeconomic management, infrastructure, human development, social development, etc. that contribute to these higher-level goals. The Government's medium term development plans provide the full national development strategy for achieving these and other national goals. As noted, a system of RBM&E was introduced in the 6th FYP and the effort has been broadened in the 7th FYP. The DRF associated with the 7th FYP provides the basis for assessing the implementation of the two higher level national goals.

Regarding the BDP 2100 Specific Goals, the ability to monitor and evaluate performance against these goals require identifying measurable targets for each of these goals, mobilizing and defining benchmark or baseline values for those targets and setting end-year values. Since the goals are long term moving upto year 2100 and there are considerable uncertainties underlying the exogenous climate related factors that affect these targets, the future targets can only be considered in an adaptive fashion as a moving target. Therefore, a time path approach is necessary, by which intermediate targets are set for every 5-10 years and these targets are revised in light of development experience.

Table 13.5 illustrates a possible approach to the BDP 2100 DRF. This is done on the basis of existing knowledge. As is obvious, there is considerable knowledge gap. A top priority for the BDP 2100 is to establish a proper DRF that adequately captures progress in its implementation. The DRF should be seen as an adaptive framework that can be modified and refined as more experience is gained and better information is available. In particular, indicators for both 2030 and 2050 are all indicative and will have to be updated frequently as implementation with the Delta Plan proceeds.

Table 13.5: The BDP 2100 Development Results Framework

No	Indicators	Sub-Indicators	Quantity	Parameters		
				2016	2030	2050
Goal 1: Ensure safety from floods and climate change related disasters						
1A	Risk free zones from natural disasters	Average flood affected area[37]	% of total area of Bangladesh	25	25	25
		Catastrophic flood affected area[38]	"	60	55	50
		Drought (extreme) free area[39]	"	53	75	90
		Storm surge affected area[40]	% of total Coastal Zone[41]	29	10	5
		Dry season salinity[42] intrusion free area	"	47	50	50
		Water logging free area	"	97	100	100
1B	Population vulnerable to natural disasters	Flood vulnerable people	Nos. in million	88	60	20
		Cyclone vulnerable people	"	8	7	5
		Erosion vulnerable people	"	1	0.7	0.2
		Water logging vulnerable people	"	0.9	0.2	0.1
Goal 2: Ensure water security and efficiency of water usages						
2A	Dry season flow availability (Jan-May)	-	% of total flow	14	30	30
2B	Dry season irrigation coverage	-	million ha	5.5	7	7
2C	Irrigation water efficiency[43]	-	% of supplied water	30	40	50
2D	Urban domestic water efficiency[44]	-	% of supplied water	60	90	100

[37] **Average flood:** The flood events that usually inundate the low lying floodplain regions of the country and causes minimal damage to lives and property. In other words, it is the flood that we cannot live without.

[38] **Catastrophic flood:** This includes the one in 50 to one in 100 year flood events that usually occur due to some unprecedented event such as unusually high amounts of catchment precipitations coupled with superimposition of peak flows from more than one major river system and generally leaves huge devastation at its wake and is associated with damage to life and property to a catastrophic degree.

[39] **Extreme Drought:** This entails a cumulative effect of meteorological, hydrological as well as agricultural droughts, effects of which are more prominent in the northwestern regions of Bangladesh.

[40] **Storm surge affected area:** This includes the polder area of the Coastal Zone.

[41] **Coastal Zone:** The Coastal Zone of Bangladesh has been delineated as per the "Integrated Coastal Zone Management Project" (ICZMP) in 2005 with 19 coastal districts; combined area of which comprises approximately 30% of the total area of Bangladesh.

[42] **Dry Season Salinity:** This is the surface water salinity for the dry period (Jan-May).

[43] **Irrigation Water Efficiency:** This includes both surface and groundwater efficiency.

[44] **Urban Domestic Water Efficiency:** This includes groundwater supply.

No	Indicators	Sub-Indicators	Quantity	Parameters		
				2016	2030	2050
2E	Rural population with safe drinking water access	-	% of rural population	87	100	100
2F	Rural population with safe sanitation	-	% of rural population	58	100	100
2G	Surface water polluted by industrial wastes	-	% of total river areas	11	9	5
2H	Surface water sources polluted by other wastes[45]	-	% of total river areas	10	7	5
Goal 3: Ensure sustainable and integrated river systems and estuaries management						
3A	Erosion along major rivers	Area eroded along Jamuna	ha/ year	1,500	1,000	400
		Area eroded along Ganges	"	600	450	250
		Area eroded along Padma	"	1,300	650	400
		Area eroded along Lower Meghna	"	2,900	2,000	1,200
3B	Area of reclaimed lands	-	ha (total)	52,313	170,000 (approx.)	300,000 (approx.)
Goal 4: Conserve and preserve wetlands and ecosystems and promote their wise use						
4A	Permanent wetland with connectivity		Percent connectivity	Establish connectivity asap	Full main-tenance	Full main-tenance
4B	Seasonal wetland with connectivity	-	Percent connectivity	Establish connectivity asap	Full main-tenance	Full main-tenance
4C	Habitat protection	Area of perennial aquatic habitat	Ha	13,200	15,000	Tbd
		Area of seasonal aquatic habitat	"	30,880	50,000	Tbd
		Area of marine habitat	"	32,300	50,000	Tbd
4D	Harnessing of ecosystem services and goods	-	Expert judgment	Poor	Fair	Good
Goal 5: Develop effective institutions and equitable governance for in-country and transboundary water resources management						
5A	Rural people with adequate capacity for WRM	-	% of rural population	20	35	50
5C	Equitable share of water among users	-	Qualitative judgment	Poor	Fair	Good
5D	Adequate monitoring mechanism	-	Qualitative judgment	Poor	Fair	Good
5E	O&M budgeting	-	% of Delta Plan budget	5%	25%	25%
Goal 6: Achieve optimal and integrated use of land and water resources						

[45] **Surface water sources polluted by other wastes:** This primarily includes domestic waste and solid waste dumping.

No	Indicators	Sub-Indicators	Quantity	Parameters		
				2016	2030	2050
6A	Spatial zoning of integrated land and water uses	-	Qualitative judgment	Limited	Fair	Good
6B	Spatial standardization of drainage density	-	Qualitative judgment	None	Fair	Good
6C	Flood control, drainage and irrigation capacity	Area under irrigation schemes	Ha	672	800	Tbd
		Area under drainage schemes	"	878	1200	Tbd
		Area under drainage and irrigation schemes	"	434	800	Tbd
		Area under FCD schemes	"	1,863	3000	Tbd
		Area under FCDI schemes	"	2,209	3000	Tbd
		Area under coastal FCD schemes	"	1,000	2000	Tbd
		Area under coastal FCDI schemes	"	28	40	Tbd
6D	Sectoral use of water	Surface water used for irrigation	km^3	6.62	12	Tbd
		Groundwater used for irrigation	"	24.88	24	Tbd
		Domestic water use	"	3.6	Tbd	Tbd
		Industrial water use	"	0.8	Tbd	Tbd
6E	Navigation capacity	Wet season navigation course	Km	5,968	5,968	Tbd
		Dry season navigation course	"	3,865	4500	Tbd

Tbd= to be determined

Source: Basic base year data updated to 2016 using CEGIS 2015, CSIRO 2014, IWM 2015, BADC 2015

13.6.3 Institutional Arrangements for M&E

Proper institutional arrangements for M&E are important to establish clarity of accountability for this important task. So far as investment projects are concerned, the M&E is the responsibility of the implementing agencies. Similarly, M&E of sectoral policies and programmes should rest with the concerned sectoral ministry. The IMED will also continue to do its M&E, although it will be appropriate that IMED plays more attention to RBM&E of projects working in collaboration with concerned line ministries.

Regarding M&E of the entire BDP 2100, as noted in **Chapter 12**, this will be a key responsibility of the GED. Needless to say, the M&E for the BDP 2100 will need to be done consultatively, drawing on the analyses of the M&E at the project and sectoral levels, consultation with IMED and technical arms of all concerned Delta line ministries, especially the MoWR.

The quality and usefulness of the BDP 2100 M&E will depend upon the quality of staffing and the adequacy of data. Data issues are discussed below and in **Chapter 14**. The quality of staffing is of paramount importance. Necessary budgetary allocations will have to be provided. Partnership of the GED with other institutions like CEGIS, IWM, BUET, BBS and private research institutions will be necessary.

Regarding the frequency of M&E, two types of reports may be necessary. First, an interim progress report of the BDP 2100 implementation on an annual cycle may be useful to inform the formulation of next year's annual BDP 2100 programme. A second, longer term (3-5 year cycle) full M&E report of the BDP 2100 implementation to inform the necessary changes to the next medium term Delta Plan strategy and the associated DRF. This will be a critical input to adaptive delta management.

13.7 Data Collection and Analysis

The knowledge strategy for BDP 2100 involving data and analysis, proper storage and sharing is discussed in detail in **Chapter 14**. In this Section some issues pertaining to the timely generation of relevant data for doing an adequate M&E are discussed.

As noted above, there is already a practice of monitoring and collecting a large number of data relevant to BDP 2100 including on water, land, climate change, environment and land use. The GED needs to take stock of the adequacy of the existing data for doing the M&E of the BDP 2100 in accordance with the DRF noted in **Table 13.5**. To assist this evaluation, the possible sources of data for measuring each of the monitorable performance indicators of the DRF are summarized in **Table 13.6**.

Some of the data can be routinely generated on an annual cycle. Yet, some require special purpose sample surveys. Partnership and strong collaboration between the GED, other line ministries and their agencies and the national data institution BBS is essential. The survey work can either be done through BBS or if needed through BIDS, BUET, CEGIS, IWM or private sector research and knowledge institutions.

Data mobilization requires resources. Adequacy of funding M&E, data requirements and knowledge is a critical element of implementing the BDP 2100. In the Netherlands Delta Management, emphasis placed on data generation, data management and knowledge is a distinguishing feature that has contributed enormously to its success as global best practice.

Table 13.6: Data Requirements for BDP 2100 DRF

No.	Indicator	Parameters	Data analysis tools/Method	Frequency of data collection	Data sources / Responsible agencies
Goal 1: Ensure safety from flood and climate change related disasters					
1A	Risk free zone from natural hazards	Water level, Discharge, Rainfall	Frequency analysis, Hydrodynamic Modelling	Sub-daily to Daily	BWDB, Flood Forecasting and Warning Centre (FFWC), CEGIS, IWM
		Water level, Discharge, Rainfall	Frequency analysis, Hydrodynamic Modelling	Sub-daily to Daily	BWDB, FFWC, CEGIS, IWM
		Wind speed, Pressure at different levels, Sea surface temperature (SST), Mean sea level pressure (MSL), Meteorological parameters	Storm Surge Model, RCM	Sub-daily to Daily	Space Research and Remote Sensing Organization (SPAARSO), CEGIS, IWM
		Rainfall, Temperature, Soil	DRASS, SPI analysis,	Sub-daily to Daily	BWDB, CEGIS, IWM

No.	Indicator	Parameters	Data analysis tools/Method	Frequency of data collection	Data sources / Responsible agencies
		moisture, Evaporation	Hydrodynamic model		
		Salt concentration	Salinity Model, Hydrodynamic Model	Sub-daily to Daily	BWDB, CEGIS, IWM
		Rainfall, Drainage data, Water level data	GIS analysis/ Hydrodynamic model	Sub-daily to Daily	BWDB, CEGIS, IWM
1B	Population not vulnerable to natural disasters	Population data	Surveys, Data analysis of floods, Flood inundation modelling	Annual to Event basis	BBS, FFWC, CEGIS, IWM
		Population data	Surveys, Data analysis of cyclones, Storm surge modelling	Annual to Event basis	BBS, SPAARSO, CEGIS, IWM
		Population data	Surveys, Erosion prediction model	Annual	BBS, BWDB, CEGIS
		Population data	Surveys, Data analysis of water logging events	Annual to Event basis	BBS, BWDB, CEGIS, IWM
Goal 2: Ensure water security and efficiency of water usages					
No.	**Indicator**	**Parameters**	**Data collection tools/Method**	**Frequency of data collection**	**Data sources/ Responsible agencies**
2A	Dry season flow availability	Rainfall, Temperature, Discharge	Hydrologic/ Hydrodynamic model	Sub-daily to Daily	JRC, CEGIS, IWM, BUET
2B	Dry season irrigation coverage	Rainfall, Temperature, Water availability, Number and status of deep tube wells, shallow tube wells, low lift pump	Surveys, Data and GIS analysis	Seasonal	BADC, DAE, CEGIS, IWM
2C	Irrigation water efficiency	Effective irrigation water use, total irrigation	Surveys, Hands on calculation	Seasonal	BADC, DAE, Bangladesh Institute of Development Studies (BIDS)
2D	Urban domestic water efficiency	Effective urban domestic water use, Total urban domestic water supplied	Surveys, Hands on calculation	Monthly to Annual	WASAs, City Corporations and Municipalities with metered water supplies
2E	Internal Renewable Water Resources	Average annual flow of rivers, Groundwater data, Recharge rate of groundwater, Rainfall	Data analysis and modelling	Monthly, Seasonal and Annual	CEGIS, IWM
2F	Rural population with	Number of tube wells and demographic data	Surveys, Data and GIS analysis	Annual	DPHE, WASH related NGOs, BBS

No.	Indicator	Parameters	Data analysis tools/Method	Frequency of data collection	Data sources / Responsible agencies
	improved drinking water access				
2G	Rural population with improved sanitation	Number of sanitary latrines and demographic data	Surveys, Data and GIS analysis	Annual	DPHE, WASH related NGOs, BBS
Goal 3: Ensure integrated river systems and estuaries management					
No.	**Indicator**	**Parameters**	**Data collection tools/Method**	**Frequency of data collection**	**Data sources/ Responsible agencies**
3A	Erosion along major rivers	Area eroded	GIS and RS analysis	Annual	BWDB, CEGIS
3B	Area of reclaimed lands	Additional area reclaimed	GIS and RS analysis	Annual	BWDB, CEGIS
3C	Developed areas from reclaimed lands	Land use areas	Surveys and Satellite image	Annual	BWDB, CEGIS
Goal 4: Conserve and preserve wetlands and ecosystems and promote their wise use					
No.	**Indicator**	**Parameters**	**Data collection tools/Method**	**Frequency of data collection**	**Data sources / Responsible agencies**
4A	Identified wetlands	Wetland area and number of wetlands	GIS and RS analysis	Annual	DBHWD, CEGIS
4B	Water related ecosystem sustainability	Prevalence of indicator species	Surveys	Annual	DoE, CEGIS, DoF, Local and International Research Institutes
4C	Habitat protection	Protected area and number of sites	Surveys, GIS and RS analysis	Annual	BFD, DoF, CEGIS
Goal 5: Develop effective institutions and equitable governance for in-country and transboundary water resources management					
No.	**Indicator**	**Parameters**	**Data collection tools/Method**	**Frequency of data collection**	**Data sources and /Responsible agencies**
5A	Rural people with adequate capacity for WRM	Population data, Information on participatory WRM	Surveys, Data analysis	Annual	BWDB, CEGIS
5C	Equitable share of water among users	Level of satisfaction among selected water user groups	Surveys, Data analyses	Annual	BWDB, CEGIS

No.	Indicator	Parameters	Data analysis tools/Method	Frequency of data collection	Data sources / Responsible agencies
5D	Adequate monitoring mechanism	Number of projects monitored	Surveys, evaluation of monitoring reports	Annual	IMED, Line Ministries, GED
5E	O&M budgeting	Budget allocation (ADP)	Data analysis	Annual	GED
Goal 6: Achieve optimal and integrated use of land and water resources					
No.	**Indicator**	**Parameters**	**Data collection tools/Method**	**Frequency of data collection**	**Data sources/ Responsible agencies**
6C	Flood control, drainage and irrigation capacity	Information on FCDI schemes	Surveys, GIS analysis	Annual	BWDB, CEGIS
6D	Sectoral use of water	Information on surface water used for irrigation	Surveys, Data analysis	Annual	BADC, BIDS, BWDB
		Information on groundwater used for irrigation	Surveys, Data analysis	Annual	BADC, BIDS, BWDB, BMDA, RDA
		Information on domestic water use	Surveys, Data analysis	Annual	WASAs, City Corporations, Pourashavas, DPHE
		No. of industries and their water use	Surveys, Data analysis	Annual	BEZA, BEPZA, BSCIC, WASAs BADC, BIDS, DoE,
6E	Connectivity of rivers and canals	Number of rivers with perennial and seasonal connectivity to upstream reaches	Surveys, Satellite image analysis using remote sensing and GIS analysis	Annual	DBHWD, CEGIS, BIWTA, BWDB
6F	Navigation capacity	River network, Navigation route network, Water Level, Cross section	Surveys, GIS analysis	Annual	BIWTA, CEGIS

Source: BDP 2100 Technical Team Analysis, GED, 2015

13.8 Reporting Results

The M&E effort can only be beneficial if it is widely disseminated and is used for policy making. The institutional arrangements for BDP 2100 implementation discussed in **Chapter 12** lays out clearly the accountabilities and coordination mechanisms for the BDP 2100. The M&E reports should be prepared by GED in consultation with other Delta agencies and local water management bodies. It will be useful to have wider consultations with other stakeholders including business sector, the research institutions and the NGOs. This final draft should go to the DGC and NEC chaired by the Prime Minister for approval. Once done, GED should use this to inform the next update of the BDP

2100. The final document should be put on the website of GED/ Bangladesh Planning Commission for wider dissemination and use by the general public and media.

13.9 BDP 2100 Accountability

As BDP 2100 will adopt results based monitoring, its accountability will also be results based. While the DRF of the BDP 2100 described above will form the backbone of this accountability, several specific actions are suggested.

- GED is required to submit to the DGC and the NEC an annual Report called the 'State of the Bangladesh Delta'.
- GED will maintain a website to report progress and problems in both Bangla and English languages.
- The website will contain a feedback mechanism to receive comments/suggestions from community or any government and non-government agencies.
- GED is answerable to questions raised by Honourable Members of Parliament (MPs) in Jatiya Sangshad. Its activities are also discussed in the meetings of relevant Parliamentary Standing Committees.
- Implementation of both BDP 2100 and individual projects are audited by the Comptroller and Auditor General (CAG) of Bangladesh.
- GED will maintain 'information centres' at national and divisional levels.

Chapter 14

Delta Knowledge Hub and Data Management

Chapter 14: Delta Knowledge Hub and Data Management

14.1 Role of Knowledge in Delta Management

The adaptive nature of delta management puts knowledge at a premium. Faced with considerable uncertainties about key variables that affect future climate change behavior and their implications for changing delta strategies and policies, availability of data and analysis of past and projected behavior of climate change, the expected pattern of weather related natural events, knowledge of global climate change and analysis, and regional experiences will all play important roles in guiding future strategies and policies. Without an adequate knowledge base consisting of relevant national, regional and global climate change and response behavior it will be very difficult to formulate proper strategies and policy options.

The best practice in international delta management clearly establish the important role of knowledge, research and innovation. These three are inter-linked and require strong investment in all three areas in order to implement a sound ADM. The Dutch experience in particular shows the need for public- private partnerships. Universities and research institutions as well as many private sector organisations, have a wealth of technical expertise and knowledge capabilities that can be tapped for strengthening and enriching the Delta Knowledge agenda. Another important lesson fom the Dutch experience is the need for inter-ministerial and institutional coordination within the public knowledge institutions.

Government of Bangladesh has been strongly pursuing ICT Policy and Strategies to achieve 'Digital Bangladesh' by 2021. BDP 2100 would contribute in realizing the vision for which it would be continuously science,knowledge and ICT driven. The knowledge management approach is anchored in the Delta Vision and Goals (**Chapter 5**). Therefore, the targets of the BDP 2100 knowledge management approach are crosscutting with respect to achieving the 6 Delta Goals, as follows:

1. Initiate and Coordinate Delta related knowledge generation towards implementation of the BDP 2100 (coordination of knowledge elicitation, programming and implementation);
2. Inspire knowledge related partners by offering a platform for focused discussion on the science, knowledge and data needed to ensure long term water and food security, economic growth and environmental sustainability.

In relation with this, the objectives of this chapter are to:

- highlight the context and current aspects and practices of knowledge management relevant to ADM,
- identify the main issues and elements for knowledge development strategy and knowledge agenda,
- highlight the strategy for developing the required knowledge management framework, and identify the main policy and institutional needs for implementing this Delta Knowledge Agenda which is meant to direct research investments and generate research programs.

14.2 Context and Current Situation of Delta Knowledge and Data Management

14.2.1 Context of Delta Knowledge Management

The comprehensive knowledge domains of delta issues as well as the adaptive nature of delta management emphasize the importance of knowledge, its management and the requirement of a structured approach. Knowledge management is the process of capturing, generating, storing, disseminating and using or applying information and knowledge. Knowledge generation is about continuous identification of needs, creation of knowledge, transfer, combination, and conversion of the different types of knowledge, as involved actors practice, interact, and learn. Data are generally defined as raw facts and figures, information is viewed as a structured set of data, and knowledge is conceived of as meaningful information.

BDP 2100 is a 'long term, inter-sectoral, water-centric, techno-economic plan', which will require an ongoing development of its scientific and practical knowledge basis. Formulation, implementation and maintenance of the BDP 2100 in a manner that is science based and data informed will require vast amounts of accessible knowledge to diverse stakeholders. Knowledge on the Bangladesh Delta is - like the rivers that it consists of - always changing. Delta knowledge will therefore require constant updating and development.

Information and knowledge management is also one of the core elements of the governance mechanisms of the BDP 2100. Informed decision making is required to be based on well-structured knowledge management.

Situation Analysis

Establishing, operating and managing a knowledge portal for the BDP 2100 as a knowledge hub containing authentic and reliable data, information collected and generated by stakeholders working under the BDP 2100 or contributing to BDP 2100 implementation will be a challenging task. There is a need to differentiate between four areas of the knowledge agenda: (a) knowledge creation; (b) knowledge storage; (c) data updates (as different from knowledge creation based on research); and (d) knowledge sharing, dissemination and use.

The key pillar is knowledge creation, which is formation of new ideas through interactions between explicit and tacit knowledge in individual human minds. As defined by Ikujiro Nonaka, it consists of socialization (tacit to tacit), externalization (tacit to explicit), combination (explicit to explicit), and internalization (explicit to tacit).[46] Knowledge creation is about continuous transfer, combination and conversion of the different types of knowledge as users practice, interact and learn. Data are defined as raw facts, information is viewed as an organized set of data, and knowledge is conceived of as meaningful information (Bhatt, 2001). Knowledge is rooted in information and information in turn originated from the data (Davenport & Prusak, 2000). While information is descriptive, knowledge is eminently predictive (Argyris and Schön, 1996; Alipour et al, 2011). The process of

[46]Nonaka & Toyama's Knowledge Creation in: Gray & Densten, 2005, p. 597

capturing, generating, storing, disseminating and effectively using information and knowledge is called knowledge management.

In Bangladesh, a huge amount of information - data / datasets, databases - are being continuously generated under different projects and studies undertaken by various government bodies that have implications for the delta knowledge management (**Table 14.1**).

Table 14.1: Delta-Related Government Information Databases in Bangladesh

No.	Name
1	National Water Resources Database (NWRD) of WARPO
2	Integrated Coastal Resources Database (ICRD) of WARPO
3	Integrated Haors& Wetlands Resources Database (IHWRD)
4	Bangladesh Water Development Board (BWDB)
5	Bangladesh Meteorological Department (BMD)
6	Bangladesh Bureau of Statistics (BBS)
7	Directorate of Land Record and Survey (DLRS)
8	Survey of Bangladesh (SOB)
9	Local Government Engineering Department (LGED)
10	Roads and Highways Department (RHD)
11	Department of Environment (DoE)
12	Soil Resource Development Institute (SRDI)
13	Bangladesh Agricultural Research Council (BARC)
14	Fisheries Resource Survey System (FRSS) (DoF)

Source: BDP 2100 Baseline Study: Information and Knowledge Management, 2015

The NWRD has been developed by WARPO to help in preparation of NWMP. All national level information required for water resources planning are available in this database. Recently, WARPO has updated the database with current information under the WMIP project. WARPO has also developed ICRD to provide information required for Integrated Coastal Zone Management Planning (ICZMP). This database contains all local level information related to the coastal area. It is also updated by WARPO under WMIP project. The Directorate of Bangladesh Haor & Wetlands Development (DBHWD) has developed Integrated Haors & Wetlands Resources Database (IHWRD) during the preparation of Haor Master Plan, 2012. This database is enriched with the information from different sectors required to help and guide the planners in the development of the Master Plan and harmonization of haor management activities by the different line agencies. CEGIS has developed a computer based Drought Assessment framework (DRAS) with active cooperation of BARC, which uses GIS and other analytical tools.[47]

[47] For an overview of the type of database government agencies in Bangladesh are currently managing see: Baseline Study. 2015. Information and Knowledge Management. Bangladesh Delta Plan 2100 Formulation Project. General Economics Division, Planning Commission, Government of Bangladesh, pp. 3-10.

However, distinguishing data and information gathering from knowledge creation, there are several institutions in Bangladesh involved in the four areas mentioned above as documented in **Table 14.2**.

Table 14.2: Institutions Involved in Knowledge Creation, Updating and Dissemination

Name of the Institutions			
a) Knowledge creation	**b) Data storage**	**c) Knowledge updates**	**d) Dissemination**
For example: BARC BAU BCAS BUET CEGIS DoE, MoEF DoF IWM Ministry of Agriculture SRDI RDA BARD BFRI[1] BFRI[2] BARI SSRC	For example: BBS BMD BWDB DLRS DoF ICRD IHWRD LGED NWRD RHD WARPO BMDA SPARSO	For example: BBS BMD BWDB DLRS DoF ICRD IHWRD LGED NWRD RHD WARPO	For example: Delta Knowledge Hub and linked institutions BARC BBS BMD BUET BWDB CEGIS DoE, MoEF DoF DLRS ICRD IHWRD IWM LGED MoA NWRD RHD SRDI DAE

Source: BDP 2100 Analysis

The leading knowledge producers/ creators on water and climate change include among others BUET, CEGIS, DoE, and IWM while the MoA with its affiliate institutes and research bodies is responsible for technical research on all aspects of agriculture productivity under different soil, climate and water conditions. Yet, there is little or no coordination of the various research bodies in relation to delta management. As a consequence, knowledge and information regarding impact of sea level rise on farm productivity, income and employment at the Upazilla and district level is not easily accessible in digital form on the web. Furthermore, a systematic, well-coordinated national climate change research agenda to which all knowledge producers are contributing is lacking; there seems to be a significant knowledge gap and use of outdated data in almost all areas of the delta planning and management. Hence, the weak knowledge base needs to be filled up over time through systematic research, planning and decision-making linked to the needs of the BDP 2100.

There is a need to foster a *Delta Knowledge Community* to share their knowledge and views from academia, policy-making, civil society and the private sector. To this effect, a *Knowledge Agenda Round Table* was held on 1 March 2016 to explore a draft Knowledge Agenda wherein around 100 experts from various water-related fields participated. Knowledge gaps and challenges including burning issues and most important and urgent research questions have been identified in the context of the BDP 2100 during the Round Table Knowledge conference.

14.2.2 *Strategic Considerations and Challenges*

The BDP 2100 knowledge management needs to address questions of knowledge creation, assimilation and dissemination relevant to implementation and updating of the BDP 2100. To that, issues, challenges and related elements need to be considered for development of a delta knowledge strategy.

Data and knowledge updating is a real challenge as a systematic approach and role clarification of various institutions is lacking. The Bangladesh Bureau of Statistics (BBS) does not currently reflect categories of information (e.g. SLR and impacts on agriculture) that would be useful in BDP 2100. Economic impacts of climate change at the district level are also absent as assessment of loss and economic damage to crops, infrastructure, and livelihoods is not being systematically collected or updated in national, district, and Upazilla statistics; only ballpark figures and amounts are cited if these appear in internationally funded reports of natural disasters (cyclones)[48]. There is an absence of data relating to consolidated financial accounts on how much public spending has gone into water management capital expenditure and how much has been spent on O&M. This makes it extremely difficult to implement a good M&E framework without systematic data collection efforts at regular intervals. The role of BBS and the concerned line ministries in data generation to conduct M&E is absolutely critical.

While the BDP 2100 Knowledge Hub will primarily deal with knowledge dissemination, there needs to be clarity on institutional responsibilities, financing and coordination between the various actors involved with the knowledge agenda. These are some of the important challenges in the development of information and knowledge management system for BDP 2100. Also, unavailability of required information or availability of information from source organizations in unusable format and reluctance of sharing data with others are significant challenges to updating information.

Most of the databases available in Bangladesh are in the form of lists and PDFs and not interactively searchable and accessible to the general public; some contain GIS maps that can zoom in and out. Again, a few organizations maintain relational database systems to manage their data and information. Other organizations store their data in excel, access, text, dbf and other digital or in hard copy format. So, it will be a time consuming task to convert these data into a relational database format. Moreover, in case of spatial data, different organizations use different projection system such as LCC, UTM, or BTM. During transformation of the projection system, shifting occurs in spatial data and it loses positional accuracy. Another significant issue is the sustainability of the developed system.

Another important issue is whether data currently being collected and stored is accessible by users (scientists, specialists, researchers, project implementers, project monitors and evaluators, general public); if not, how will a BDP 2100 implementation function with maximum stakeholder participation and minimum hindrance if a knowledge hub to be established for BDP 2100 does not allow for wider participation and sharing of pertinent knowledge. Currently, government relies on IWM, CEGIS and BUET, to mention a few institutions, for providing most of the water-related

[48] This data could be linked with BBS, which is planning to reflect such events in future updates.

research findings and results; is this adequate? Are institutional arrangements currently in place for mobilizing knowledge and making it available for monitoring and evaluation (M&E) and policy making adequate? Would it be useful if this knowledge platform could be broadened to cover public and private sector, government and non-government institutions dealing with similar issues and content?

The National ICT Policy of Bangladesh calls for sharing of knowledge generated by different studies, research, and projects undertaken by various industries, organizations, universities and institutions. The best way to share such knowledge is through a knowledge portal allowing wider access. This knowledgebase information needs to be stored and managed properly for future use.

Due to lack of required IT professionals as well as IT infrastructure, it would be very difficult for GED to maintain the portal after the end of the project. Regular updating of data is also a big challenge. Currently, there is weak coordination among data collectors and knowledge managers in various institutions. For the implementation of BDP 2100 investment over the short, medium and long term, it will be of crucial importance to establish, operate, manage and update knowledge in the most efficient and transparent manner.

This brief review of the current state of play of the Delta knowledge management suggests the need for a strong coordinated effort to develop a coherent strategy for knowledge management. This strategy can benefit from a review of the international experiences of knowledge management in other deltas. The lessons should focus on the principles and adapt them to the reality of Bangladesh. This is a long term effort and will require resources, institutions and policies.

14.3 Lessons from International Experiences

There is a need to learn from successful portals and knowledge hubs operating internationally. The World Bank maintains a Climate Change Knowledge Portal categorized by country; it contains basic climate change information on Bangladesh, which could be used as a model to build up a BDP 2100 Knowledge Portal. Some of the top 10 most popular portals provided in **Table 14.3** are thematically oriented (Popular search engines, commercial, educational, social network, entertainment and informational).

Table 14.3: Top Ten Most Popular Portals on the Web

No.	Name
1	Google (most popular search engine)
2	Yahoo (second most popular and busy web portal)
3	YouTube (video sharing portal)
4	Facebook (most popular social network)
5	Windows Live
6	MSN being replaced by Microsoft's Live service)
7	Blogger (most popular blogging platform)
8	Wikipedia – (community driven source of basic information)
9	Baidu – (leading Chinese search engine)
10	My Space (popular social network)

Source: The Top ten Most Popular Portals on the Web at:http://webtrends.about.com/od/webportals/a/topten_portals.htm

While portals listed in Table 14.3 may seem to be less relevant to BDP 2100, among the most relevant websites to be mentioned in the context of delta planning are:

1) **Netherlands:** Delta Portal (https://www.deltaportaal.nl) of the Dutch Commissioner in-charge of the Delta Programme in the Netherlands;
2) **Netherlands:** Climate Change Post and Climate Research Website;
3) **P.R. China:** Pearl River Delta,
4) **Vietnam**: Mekong Delta Portal,
5) **Vietnam:** Environmental Migration Portal reporting on planned relocations in the Mekong Delta,
6) **USA:**EPA environmental portal,
7) **USA:** American Carbon Registry,
8) **USA:** Earth Trends – the environmental information portal of the World Resources Institute (WRI),
9) **Germany:** Hamburg. Multifunctional Flood Defences;
10) **Germany**: German Environmental information Portal – PortalU of the Federal State of Saarland.
11) **UK:** Flood and Coastal Erosion. Risk management authorities.

Significant **lessons** can be learnt from international experiences: some countries are already dealing with climate change adaptation planning and linking knowledge creation with infrastructure adaptation and investments in deltas and coasts.

In the **Netherlands,** the water sector, knowledge institutes and the business community have joined forces to expand market involvement and encourage innovation. At the international level, collaborative efforts are underway to make optimum use of the Delta Programme[49] as a domestic market, to market knowledge and expertise, and to coordinate the management of border-crossing rivers. The parties within the Delta Programme are working on integrated solutions in a wide range of ways. Integrated solutions benefit from integrated research – research that connects sectors and in which various disciplines work together. Together with the top sectors of Agriculture & Food, Horticulture & Cultivation Materials and Water, and the knowledge institutes DLO, Deltares, MARIN and TNO, the Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs are investigating how cross-sectoral collaboration can be reinforced further. The National Water and Climate Knowledge and Innovation Programme (NKWK) brings parties together in order to improve the interaction between knowledge and practice, and between the scheduling of knowledge issues and research. The NKWK is taking up together with other parties, matters such as the long term and large-scale coastal behavior, smart water management, climate-proof cities, flood defences, and the replacement of hydraulic structures and the development of the National Water Model. To this end, joint multi-year research plans are being prepared, that constitute part of the input for the Delta Technology Knowledge and Innovation Agenda 2016-2019.

[49] At: https://deltaprogramma2016.deltacommissaris.nl/viewer/paragraph/1/delta-programme-/chapter/hoofdstuk-/paragraph/knowledge-market-and-innovation#

City of Hamburg, Germany[50]**:** Following the publication of "Climate change, impacts and vulnerability in Europe 2012" by the European Environment Agency a European Adaptation Strategy was developed by the European Commission in 2013. However, the riparian countries of the North Sea have continuously reinforced flood defence structures since 1953 and 1962 and the Northern German Coastal Cities, led by Hamburg developed action strategies such as KLIMZUG-NORD. In 2007 Hamburg also established a climate research campus called Klima Campus that brings together top international scientists in a unique network formed by numerous university institutes and famous non-university partners, such as the Max-Planck Institute for Meteorology, the Helmholts Centre and the German Climate Computing Centre (DKRZ). This is an excellent international example of "knowledge creators" that are housed in a 20,000 m^2 new building hosted by Hamburg where the programme has already received funding of up to EUR 29.5 million of which Hamburg contributed EUR 7.4 million. Hamburg's adaptation initiatives and "Climate Protection Master Plan" have triggered planning and building of new residential areas and the city districts close to the port in such a way to keep these dry in a hundred years to come; planning is on-going as to how the emergency response will cope in 2050; completion of flood defences by 2016 which will be effective in 2030 with new flood defence programme adopted and requisite funding included in the budget planning; the "Warft concept", i.e. building on artificial mounds, a long term town planning strategy to expand Hamburg's city centre without being forced to encircle the area with a dyke; the Rain-Infrastructure-Adaptation project with Rainwater Structural Plan 2030 underpinning water management measures integrated into town, landscape, and traffic planning.

The European Union commissioned[51]the Climate Change Challenge for European regions report as well as a number of climate change country reports produced by the Policy Research Corporation (e.g. Denmark, Germany, Sweden). The **United Kingdom** House of Commons produces reports such as the Flood defence spending in England[52], which provides a good account of flood damage costs of 1.1 billion pound sterling per year and damage costs could exceed 27 billion pounds sterling across the UK by 2080.

14.4 Strategic Considerations for the Bangladesh Delta Knowledge Hub

14.4.1 Strategic Components of Delta Knowledge Management

As a starting point for a knowledge and data management approach, the BDP 2100 suggests a model for a well-accepted knowledge and competence management cycle in which main issues are addressed. This model shows the main aspects and operations for societal and governmental

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[50]Goennert, G. Coastal Protection in Hamburg.Free and Hanseatic City of Hamburg. Agency of Roads, Bridges, and Waters; Speech delivered by the Mayor of Hamburg to the Climate Change Adaptation Conference, 18 March 2013; Goltermann, D. Ujeyl, G. Pasche E. 2008. Making Coastal Cities Flood Resilient in the Era of Climate Change. 4th International Symposium on Flood Defence: Managing Flood Risk, Reliability and Vulnerability. Toronto, Ontario, Canada, May 6-8.

[51] At: http://ec.europa.eu/regional_policy/sources/docoffic/working/regions2020/pdf/regions2020_climat.pdf EU; Germany_climate_change_en.pdf;

[52]House of Commons Library. 2014. Standard Note SN/SC/5755. Oliver Bennett, Sarah Hartwell-Naguib. 19 November. Section Science and Environment

knowledge and competence management. Societal and governmental knowledge and competence management involves a process of investigation of knowledge needs and making knowledge easily available to utilize it in an optimal way. The model consists of four main components (**Figure 14.1**).

14.4.2 *Investigation of Knowledge Needs*

In a science, knowledge and data-based approach such as ADM within an increasingly knowledge based society, the requirements for knowledge, validated data and related working skills change continuously. New ways to investigate requirements and experiences and from that basis focus and direct resources, and establish the main goals of data collection, research and education in order to balance better the demand and supply for skills and knowledge development. This calls for improvement of existing and identification of new ways of communication and knowledge intensive cooperation between relevant Delta related authorities, knowledge institutions and private sector organizations. Below presented model provides the main elements which have been elaborated during the BDP 2100 formulation process.

14.4.3 *Creating Knowledge*

Fruitful conditions for knowledge creation are face-to-face communication, informal environments, concentration and variety of knowledge, and a cross-disciplinary research and educational approaches. A major part of new scientific knowledge and innovations are created in global and national centers of excellence. The key knowledge accumulation experience is learning by doing in everyday tasks, in human networks. Globalization and virtual communities change the way for creating new knowledge. A big part of created knowledge is tacit, and therefore not easily transferable to colleagues, new employees and students without face-to-face communication or more systematic knowledge sharing.

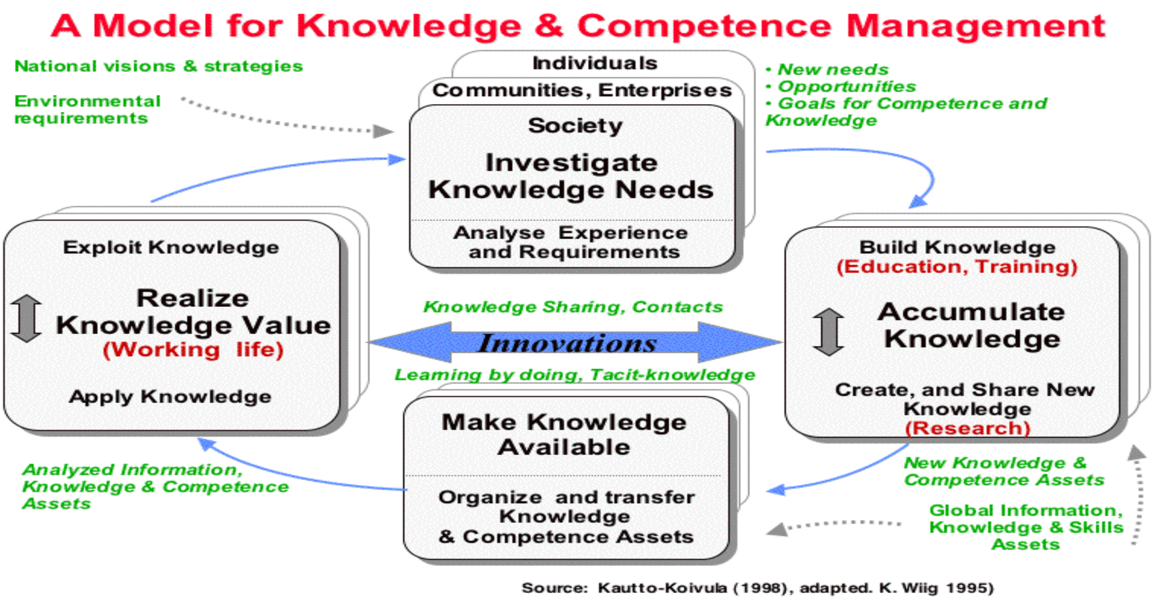

Figure 14.1: BDP 2100 related elements of Knowledge and Competence Management

The digitization and modernization in many sectors also demand research and educational reform. The operation mode, content, methods, role of learning or teaching environments of the whole education chain have to be developed to respond more flexibly and proactively to the needs of the knowledge communities and economy. This means a new way of networking among educational institutions as well as with stakeholders.

14.4.4 Making Existing Knowledge and Information Available

The internet and intranets today serve a common environment for information and knowledge access, sources and services. In spite of powerful search engines, a lot of challenges exist, e.g., information overload and the difficulty of quickly finding needed, meaningful information and knowledge. There is a need to find methods to better navigate in information networks. This could be done by analyzing, organizing and mapping existing information and knowledge assets and by producing meta-level information, information about information.

14.4.5 Realization of Knowledge Application and Innovation

A national innovation system is a knowledge community and a channel connecting those who create, apply and exploit new knowledge. In a knowledge society, innovations systems are based heavily on national, regional and global networking and value-chain modeling. Challenges are how small and medium size government or private organizations and institutional research centers can be supported in developing their operation mode and skills to adopt the new working methods of the knowledge networks. This requires the globalization of national and regional research centers, support for establishing new value chains and motivation for organizational and individual innovations. In addition to technical innovations, social innovations will become important in the future.

Knowledge and competences do not transform automatically into economic growth, new jobs, and welfare. They must also be strategically directed and managed. The best results can be achieved if public sector organizations, education and research institutions, private sector and other relevant parties develop a common vision and strategy regarding required core competencies and knowledge in society with respect to a specific knowledge domain. This would require a continuous (annual) strategy process. Strategic governance should give through its vision and strategy processes the main goals for operations as well as the creation of proper conditions.

14.4.6 Developing Knowledge Strategy for BDP 2100

The Knowledge Management Strategy aims to support the achievement of the Delta Goals, which means that the goal related knowledge domains, burning issues and research questions have to be addressed and prioritized as well as to be elaborated in Strategies and Project Concept Notes. This together provides the Knowledge Agenda. The Delta knowledge strategy (**Figure 14.2**) consists of several sub-strategies:

1. Investigate knowledge needs;
2. Accumulate knowledge, conduct necessary studies, answer knowledge questions;
3. Make knowledge and data available, establish a central Information Portal or knowledge hub and other means;
4. Realize the knowledge value, make planning and implementation science and knowledge driven and monitoring and evaluation result based and arrange knowledge and data link with updating of BDP 2100.
5. Develop and facilitate a Delta Knowledge Community with knowledge and data related partners e.g. further develop platform of Knowledge Roundtable participants;

- develop a central knowledge node and portal to BDP 2100 and a strategic partnership with primary knowledge institutions
- create a BDP relevant community of national and international knowledge and data generators and users;

6. Arrange institutional setup and funding for Delta knowledge and data management related strategies and actions.

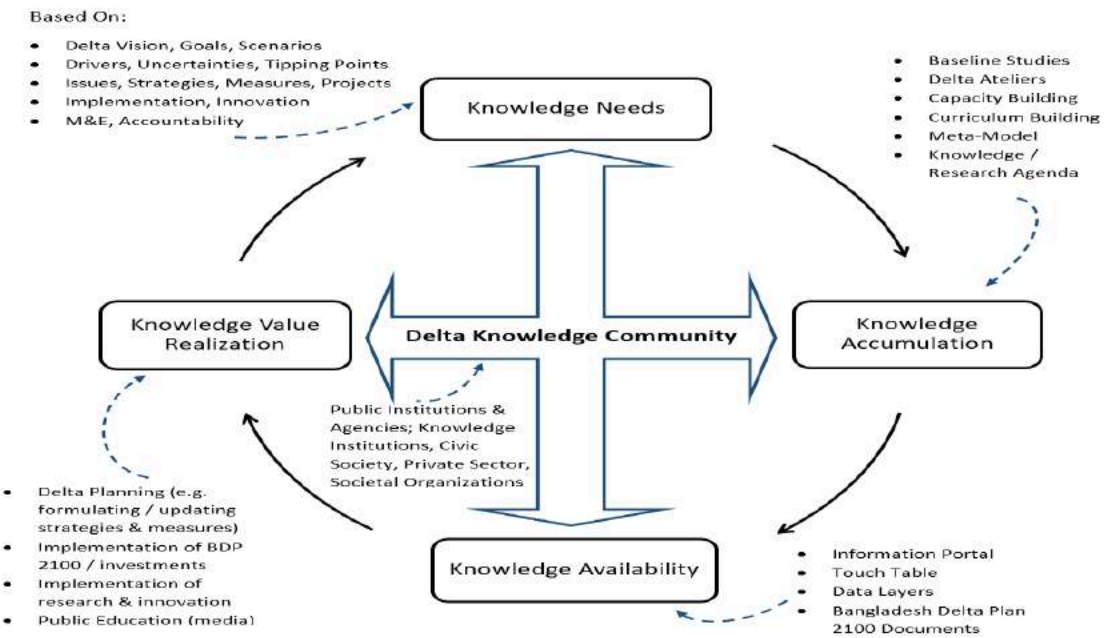

Figure 14.2: BDP 2100 Knowledge and Data Management Strategy

Source: BDP 2100 Technical Team Analysis, GED, 2015

Sub-strategy 1: Investigate Knowledge Needs and Develop a Knowledge Agenda

For Delta Knowledge Management, the basic question is- what is the benefit and quality of existing knowledge and what are needs or requirements for new knowledge, validated data and related scientific methods or skills in a continuous changing delta situation? On this basis, a prioritized list with knowledge questions has to be formed representing knowledge demand.

In Bangladesh, Delta related research is conducted by different ministries through their specialized agencies but there is limited institutional coordination. Thus, for example, CEGIS and IWM conduct water management research for the MoWR. The MoA through its various affiliates does technical research on a range of agriculture production and productivity related issues including soil productivity, salinity, seeds, water use, fertilizer use, etc. Similarly, the MoEF supports research on forest management, ecological balance, environmental sustainability, etc. Issues of river navigability are researched by the Ministry of Shipping. Research under each ministry is typically done as stand-alone research with little or no coordination and collaboration. Importantly, this research agenda is uncoordinated and done in response to a donor project or donor-assisted technical program. There is no guarantee that this research responds to a particular knowledge gap of the BDP 2100 strategy or even mutually consistent. As a consequence, piles of stand-alone technical reports have emerged over time, especially in the MoWR, with little implementation or relevance for a coordinated delta management. This is a significant challenge moving forward and has to be a core focus of the new knowledge strategy.

Knowledge needs have been formulated as basis of the Delta Plan's Knowledge Agenda. This Knowledge Agenda takes the knowledge gaps and research questions of the Delta Plan's Formulation Project's Baseline Studies, as gathered in a Knowledge Gaps and Research Questions document, as its starting point. The Knowledge Agenda identifies the key subjects as burning issues with their top-3 most important research questions (**Table 14.4**).

Table 14.4: BDP 2100 Knowledge Agenda

Knowledge Area No.	Issue	Most Important Research Questions
1. Climate Change	What are the local and regional consequences of climate change on the scale of 50-100 years over the Ganges, Brahmaputra and Meghna catchment areas?	1. How can tailor-made climate projections for different sectors and users for adaptation purposes be deveoped? 2. How can climate scenarios be drawn up with a high spatial and temporal resolution? 3. How does changing climate condition affect monsoon and tropical cyclone formation? 4. How quality of natural resources (soil, water and air) will change? 5. How international relations will change?
2. Adaptive Delta Management	How to integrate the principles of flexibility and iterative learning in delta management and how to exploit synergies between water resources related and other investment agendas of sustained food security and economic growth?	1. How can adaptive / flexible planning and delta management concepts (like adaptation pathways and scenario planning) be integrated, operationalized and institutionalized in water and related sectoral planning and management practices? 2. What changes (if any) are needed in the relevant national policies to improve ADM? 3. What should be the strategies to create a functional, applied adaptation research-practice-policy interface? 4.
3. Rivers and Eco-Systems	If the discharge of one of the major rivers of the country were to diminish dramatically, what would the consequences be?	1. How can one mitigate and adapt to a low-discharge situation? 2. What will be the hydro-morphological response in a low-discharge situation? 3. What are the environmental, social and economic consequences in a low-discharge situation? 4. How to keep aquatic ecosystems functioning? 5. How to restore degraded ecosystems?
4. Coastal Zone	How can future strategies be developed and integrated to provide a	1. Sediment management in the coastal zone:

Knowledge Area No.	Issue	Most Important Research Questions
	simultaneous answer to the myriad challenges facing the coastal zone (e.g. salinization, fresh water, food security, siltation, flooding, cyclones, land erosion and accretion, economic development, etc.)?	a. What are the drivers of sedimentation and morphological processes? How can they be influenced e.g. to stimulate land reclamation? b. What is the potential for land reclamation? c. What is the effectiveness of Tidal River Management for water and sediment management in the medium and long term, considering technical and societal issues? 2. How to monitor the coastal issues in connection with ADM and identification of possible tipping points and how to characterize the physical and social science processes which govern coastal vulnerability? 3. What are the available fresh water sources and what drives water demand at present and in the future, in the Coastal Zone? 4. How can coastal ecosystems be made more resilient? 5. Study dynamics of resources quality and growth dynamics of Sundarbans.
5. Flood Risk Management	What level of safety against floods for people, assets, agriculture and environment does Bangladesh want to provide in 2050 and 2100?	1. Which decision criteria are fundamental for flood risk management and how to justify these? 2. What is the expected future flood risk without any policy? 3. How effective are (non-)structural measures to decrease flood risk?
6. Water for Sustained Food Security	If food security is to be ensured, where will food production areas be in medium and long term and how will water for food production be available?	1. How can agricultural and food security research be strengthened in order to make farming and other sources of food production as well as availability, access and utilization of food be more climate-resilient? 2. What will be the projected food demand in the medium and long term and how can this be met? 3. How can agricultural and other food related practices be made more efficient in terms of land, water and other inputs in an integrated way (incl. crops, fisheries, forestry and livestock)?

Knowledge Area No.	Issue	Most Important Research Questions
7. Urban Water Management	What is the trend of urban growth and how will cities deal with water and related problems (water supply and sanitation, drainage, water pollution, groundwater) under different urbanization scenarios in the medium and long term?	1. How to achieve inter-agency linkages for sustainable water management? 2. How to manage water supply and demand in an integrated manner? 3. How to prepare and ensure water sensitive urban planning?
8. Governance and Institutional Development	Preparing optimal institutional arrangements for continuous improvement of implementation and updating of BDP 2100.	1. How to reduce the gaps between planning and implementation? 2. How can local government better work together with national water-related implementing agencies on the short term? 3. How to prepare and realize decentralization of ADM and create Water Management Organizations with financial mechanisms for cost recovery?
9. Financial Arrangements and Funding	How to guarantee sufficient BDP 2100 related capital and recurrent resources to ensure a sustainable Bangladesh in 2100?	1. What combination of innovative fiscal and financial instruments (micro- to macro-scale) can be used ADM with a Delta Fund? 2. What are viable options for decentralized financing mechanisms in the water sector? 3. What is an effective Public-Private Partnership approach for Bangladesh?

Source: BDP 2100 Technical Team Analysis, GED, 2015

Sub-strategy 2: Knowledge and Data Accumulation

This sub-strategy refers to accumulation of knowledge, conducting necessary studies, answering knowledge questions. Validation and formalization of knowledge and data is important: e.g. which climate change models and data are qualified and approved by GoB, etc.

An initial step in knowledge accumulation has been made with the completion of the BDP's Baseline Studies (see list after References section). These Baseline Studies are rich sources of knowledge and data accumulation. These thematic knowledge and data has to be further developed and frequently updated, especially on real water system and field level data.

In this respect, knowledge was gathered in the field through four rounds of Delta Ateliers. This knowledge can be further developed with the stakeholders. Training programs arranged by the Delta Secretariat or capacity building program of implementing agencies can be used to promote data collection and knowledge generation, as well as parallel curriculum development projects.

A promising possibility is to create or make relationships with centers of delta knowledge excellence. Good examples of this are the Dutch public-private delta knowledge networks which are involved in climate and delta challenges worldwide. Other examples are Cities of Rotterdam (Rotterdam Climate Initiative) and Hamburg (climate research campus called Klima Campus). Both bring together top international scientists and practitioners in a unique network formed by numerous university institutes and famous non-university partners. In Bangladesh centers like BUET, CEGIS and IWM can be further strengthened. However, there are major gaps in knowledge areas as indicated in the Knowledge Agenda. These need to be strengthened in the first place.

Ensure quality of research by focusing on staffing of the knowledge and data unit as well as on research assignments. This is a generic principle that comes through the experience of all high quality knowledge management programmes. The Government has already taken several measures to build autonomous research institutions as well as develop partnerships with universities and local research institutions. The application of this broad principle will be strengthened in the case of Delta Knowledge and Data Management

Sub-strategy 3: Knowledge Availability

The BDP 2100 will make knowledge available through a web-based information portal, gathering geographical data layers, studies, policy documents, meeting reports. Geographical data will be made available through a viewer. Importantly, geographic data layers will be accessible through Touch Tables, allowing diverse stakeholders to access and discuss data at the same time.

During formulation of the BDP 2100, a lot of information and scientific data have been gathered and generated, starting with the Baseline Studies. The information is needed for the development of the Climate Atlas and updating of the various measures, scenarios, Delta Vision, Delta framework and implementation. The information that is produced will be stored in a knowledge repository, with all the relevant reports, documents, presentations and minutes of meeting.

The Baseline Study on Information and Knowledge Management has been prepared for the development and implementation of the Information and Information and Knowledge Portal. The Baseline Study report describes the Information and Knowledge Management practice of different government organizations and other stakeholders. A number of organizations such as BWDB, WARPO, BBS, DBHWD, BMD, DLRS, SoB, LGED, etc. are now using state of the art technology to efficiently manage information. Existing situation of databases, data management and Information Portals of different organizations such as NWRD (**Box 14.1**), ICRD, IHWRD and other databases are described briefly.

These information and knowledge management systems help to organize and store information and assist in national level as well as local level planning and decision making. Latest hardware, software and other ICT facilities that are used by different government and private organizations for knowledge management, exchange and sharing are mentioned in this baseline study.

Box 14.1: National Water Resources Database

National Water Resources Database (NWRD) was established by WARPO to provide data and information required for the development of National Water Management Plan (NWMP). It is the largest geo-spatial database in the water sector of the country. It contains more than 500 data layers consisting of spatial, temporal and attributes information. The data available in NWRD have been collected and collated from different data providing agencies. Data are organized in NWRD into several data groups like Base data, Surface water, Groundwater, Soil and Agriculture, Fisheries, Forest, Socio-economic, Meteorological, Documents and Reports, Environment and Images. Each Data Group is sub-categorized into number of Data Types. Each Data Type contains several Data Layers. A web enabled user-friendly interface has been developed for NWRD to view, query and analyse data from the database. The interface contains five components. Metadata Viewer helps to view metadata. Data Source Viewer is designed to view spatial, tabular and temporal data. Time Series Viewer assists users to view temporal data as a chart or a graph. Statistical Tool helps to perform simple statistical analysis such sum, min, max, average, count and standard deviation on temporal data. Analysis can be done on either calendar year or hydrological year. A user-friendly generic Export Tool has been developed for easy exporting of data from database. Export Tool allows users to take copies of the data from the database into different format such as excel, access, text, etc. NWRD has been updated and upgraded under Component 3B of Water Management Improvement Project (WMIP). All data layers have been updated using latest information available with the source organizations. Some new data layers have been incorporated. WARPO has also taken an initiative to host the database on the internet to ensure proper utilization of the database by wider range of users, planners and decision makers.

The Information and Knowledge Portal

The developed BDP 2100 Information and Knowledge Portal or knowledge hub needs to:

a. Operate as an instrument to develop, assimilate and disseminate knowledge and data to meet the requirements of the adaptive delta plan formulated under BDP 2100;
b. Coordinate existing and future data and research relevant and pertinent to implementing the BDP 2100 investment programme from public and private sources, government and non-government;
c. Establish, safeguard and uphold the structured development of the baseline data layer and quality of the system by using an ISO-standard such as the OAIS-model (Open Archival Information System);
d. Establish Memoranda of Understanding (MoUs) with government and non-government institutions, programs and projects, national, regional and international institutions that are willing and able to share data that contributes to evidence-based knowledge and understanding towards implementing the objectives of the BDP 2100;
e. Provide a BDP 2100 knowledge portal with a user-friendly web-interface, accessible through desktops, laptops, tablets and smart phones (IOS and Android);
f. Provide access to legislators, policy and decision-makers seeking updates and information for reviewing progress, M&E of BDP 2100 implementation and assist in making informed decisions about challenges, risks, setbacks and achievements based on reliable and updated data;
g. Provide authenticated access to professional users involved in participatory and interactive planning and implementation of the BDP 2100;
h. Provide free access to educators, students, researchers, civil societies, community groups and leaders seeking information and knowledge to support and/or improve BDP 2100 implementation; and
i. Provide access to journalists and media seeking accurate and reliable information on climate change impacts, disaster risk management and improved climate proofing and climate resilience.

BDP 2100 Information and Knowledge Portal will have to become a knowledge hub containing authentic and reliable data and information collected and generated by stakeholders working under the BDP 2100 or contributing to BDP 2100 implementation. The Information and Knowledge Portal for BDP 2100 will be web based with a user-friendly interface, easily accessible through internet and mobile application (app) on smart phones, and usable by a wide range of planners, decision makers, plan implementers, specialists, academics, researchers, the media and the general public. It will allow users to access the generated and collected information from a single point on the web or through the downloaded app. The knowledge hub can provide support for participatory and interactive planning process, ensuring quick and efficient sharing of information and knowledge, and fostering adaptive management of the Bangladesh Delta. The information in the portal will be periodically updated so that the planners can use most recent information in their decision making process. Weather and cyclone early warning messages disseminated by the Bangladesh Meteorological Department (BMD) will be linked to the Information and Knowledge Portal.

As web based facility and ICT facilities are expanding and internet connections rapidly improving in Bangladesh, a BDP 2100 Information and Knowledge Portal will be widely used. Government organizations like WARPO and BWDB and public and private educational institutions are already using on-line libraries to provide access and share valuable books, journals, reports and other documents digitally available with them for a wide range of users.

In the 7th FYP, GoB has taken initiatives to share available knowledge among different communities. In line with this initiative, the National Institute for Local Government (NILG), under LGD, and the Access to Information (a2i) has taken up a program to make public and private information available to the marginalized communities in rural areas. In order to share and exchange information, the National Portal comprises 25,000 web sites and the ICT infrastructure is also being strengthened at the Upazilla and union levels. In line with the national policy on Right to Information (RTI), this information will be made transparently and available online in an Information and Knowledge Portal. The Knowledge Hub will assist in ensuring adaptive management of the BDP 2100, transparency, and lead to a well-informed public. The data will be made accessible by theme and by hotspot with links to institutions collecting and holding the data.

Transparency, open access and building up an evidence-based knowledge hub under the BDP 2100 requires an institutional set-up that is capable of designing, adjusting, operating, trouble shooting, responding to feedback for improvements and financially sustaining operations in the long run.

An efficient action plan including needs assessment and design of the initial system architecture of the portal is described in detail in the BDP 2100 Baseline Study Report on Information and Knowledge Management. The portal has been designed and developed using the standard four-tier architecture of software development. The main challenges in the development of information and knowledge management system for BDP 2100 are: unavailability of required information or availability of information from source organizations in various formats, reluctance of sharing of data with others, periodic updating and sustainability of the developed system. The solution for sustainability is to seek assistance for system maintenance from any partner organizations having required facilities readily available. Every year GoB fund can be allocated for periodic updating of the portal. Finally, a detailed work plan for implementing the system has also been incorporated in the Baseline Report. Delta Plan Tools developed to support strategy making and to take care of data digitization, archiving and data utilization are described in the Baseline Report.

Sub-strategy 4: Knowledge Value Realization

This sub-strategy aims to Generate Value of Delta Knowledge by putting it to use in practice. This is done, for example, in actual planning, such as the input to the 7th FYP, preparation of the Climate Atlas, the BDP 2100 updating and BDP 2100 Investment Plan, or when related policies are informed by available knowledge and scientific findings (e.g. information on the SDG's). In future, the implementation of innovations will realize value from delta knowledge. In addition, dissemination of delta knowledge among the public (e.g. through the media) will bring benefits in the form of better-informed decisions by individuals.

Sub-strategy 5: Delta Knowledge Community

Develop a strategic partnership between government, business and the private knowledge institutions as has been done in the Netherlands and promote centers of delta knowledge excellence. In Bangladesh, there are already a few dedicated semi-autonomous institutions funded by the government that conduct water, climate and environment related research. These are CEGIS and IWM of MoWR, and IWFM of BUET. All of them are excellent research institutions. The partnership can be expanded to include all other government and public institutions that create knowledge (as listed in **Table 14.2**), bring in other private knowledge institutions that have expertise in institutional management as well as economic management, modeling and financial analysis, and representatives from business community that deal with different aspects of the delta (water, land use, ports and river transport, fisheries, watershed, agriculture, pollution and environment).

The BDP 2100 aims to bring delta knowledge and ADM to life in a *Delta Knowledge Community*, comprising academics, policy makers, international donors, NGOs and field workers in a *community of participants*. This Delta Knowledge Community will be able to engage in continuous self-reflection and continuously make knowledge available to its stakeholders, enabling them to engage in ADM.

The main goal of the establishment of a delta community and an institutional set-up to that is:

- To create ownership in knowledge generation and the created knowledge in particular of organizations with specific responsibility towards delta management;
- To be sustainable in the long run;
- To involve the scientific community, practitioners, international partners and the next generation of delta managers.

The set-up could be that of a network organization with a central hub e.g. of Delta Wing and separate (or regional) nodes. This can then be maintained and further expanded upon, beyond the completion of the BDP 2100 Formulation Project, in the Delta Knowledge Community. An important coordinating role in the Delta Knowledge Community will be played by the GED. Further important stakeholders in the Delta Knowledge Community will be policy makers, knowledge institutes, development partners, NGOs, the public and the private sector. Suggested options for the knowledge nodes are a number of fixed parties (such as national institutes for research and implementation, GED and WARPO as repositories, development partners and temporary parties (e.g. consultancies, fora on specific themes, etc.).

The role of the central Information and Knowledge Portal will be identification of knowledge needs of the participants of the Delta Community, coordination of programming, organizing the repository, monitoring of knowledge generation and application. Role of the nodes differ depending on the features of the node (university, research institute, public or private knowledge institution, etc.). It ranges from voicing research questions, implementation and being a repository of knowledge (roles to be specified for each node). BWDB, WARPO, DoE, DAE, BUET, CEGIS and

IWM form leading knowledge creators and users on water and climate change while the MoA with its affiliate institutes and research bodies generates knowledge on all aspects of agriculture productivity under different soil, climate and water conditions (**Table 14.5**). Yet there is limited coordination of the various knowledge institutions in relation to the four knowledge elements of delta management. A systematic, well-coordinated Knowledge Agenda to which all knowledge producers are contributing has to be created as there are many knowledge gaps and outdated data in almost all areas of delta planning and management. The total Delta knowledge base needs to be filled up and renewed over time through systematic research, planning and decision-making linked to the needs of the Delta Plan.

Table 14.5: Agencies involved in Delta related Knowledge Management

Knowledge Needs & Creation (amongst others)		Knowledge storage, availability and up-dating (amongst others)	Delta Knowledge Community, possible linkage with Delta Information Portal	
WARPO	BUET	WARPO – NWRD, ICRD	WARPO	DLRS
BWDB	CEGIS	BWDB	BWDB	IWM
BARC	DoE	DBHWD - IHWRD	BARC	LGED
BBS	IWM	BBS	BBS	DAE
BAU	DAE	BMD	BMD	RHD
BCAS	SRDI	DLRS	Universities	SRDI
		LGED	CEGIS	BMDA
		RHD	DoE	RDA
			BARD	SPARSO
			SSRC	

Source: BDP 2100 Technical Team Analysis, GED, 2015

The following data provider institutions and data source, to name a few, are important to be represented in the BDP 2100 Knowledge Portal[53]:

- National Water Resources Database (NWRD)
- Integrated Coastal Resources Database (ICRD)
- Integrated Haors and Wetlands Resources Database (IHWRD)
- Bangladesh Water Development Board database
- Bangladesh Meteorological Department (BMD) database
- Bangladesh Bureau of Statistics (BBS) database
- Bangladesh Space Research and Remote Sensing Organization (SPARRSO)
- Directorate of Land Record and Survey (DLRS)
- Survey of Bangladesh (SOB)
- Local Government Engineering Department (LGED)
- Roads and Highways Department (RHD)
- Department of Environment (DoE)

[53]Data on issues related to fisheries, navigation, water supply including water quality and sanitation, industrial water use, sources of pollution, etc. may also be targeted.

- Soil Resource Development Institute (SRDI)
- Bangladesh Agriculture Research Council (BARC)
- National Institute for Local Government (NILG under LGD).

Sub-strategy 6: institutional setup and funding for Delta knowledge and data management

This sub-strategy is described in detail in the section 14.5.

14.5 Institutional Set-up for Operating the Knowledge Hub[54]

Transparency, open access and building up an evidence-based knowledge hub under the BDP 2100 requires an institutional set-up that is capable of designing, adjusting, operating, trouble shooting, responding to feedback for improvements and financially sustaining operations in the long run.

There are two possible options. One option is to follow the Dutch approach. The Netherlands Delta Commission has a public-private outlay with knowledge being managed by a consortium of science, administration, and business (a tripartite venture) facilitated by the existence of the Delta Commission. In this approach, a public-private trust as a separate entity is needed. This Trust will operate as an open access forum, operating with a board of trustees made of public and private sector members, an investment/capital budget to set up the data back-end-and-front-end data integration and access by multiple stakeholders and an operational budget to operate, maintain, and make improvements to the knowledge hub.

A possibly more pragmatic approach that does not require the establishment of an entirely new institution is to assign this responsibility to GED in partnership with WARPO. Under the Water Act 2013, WARPO already has been entrusted with the mandate to take responsibility for all water related technical aspects of planning

The effectiveness and capabilities of GED and WARPO will have to be substantially strengthened to play this knowledge coordination role. As noted in **Chapter 12**, the knowledge strategy will need to be developed and approved by GED along with a three year rolling work programme. GED will need to create a special unit for day-to-day management of the knowledge agenda and to undertake the M&E of the overall BDP 2100 (**Chapter 13**). This unit will be staffed by technically competent experts. An illustration of how this knowledge unit might function is shown in **Figure 14.3**.

[54] Availability of satellite images will be an important issue in Delta Planning. Good quality satellite images and past data are often expensive. The knowledge HUB may be a repository of such images and can be distributed among intended users on payment, if necessary.

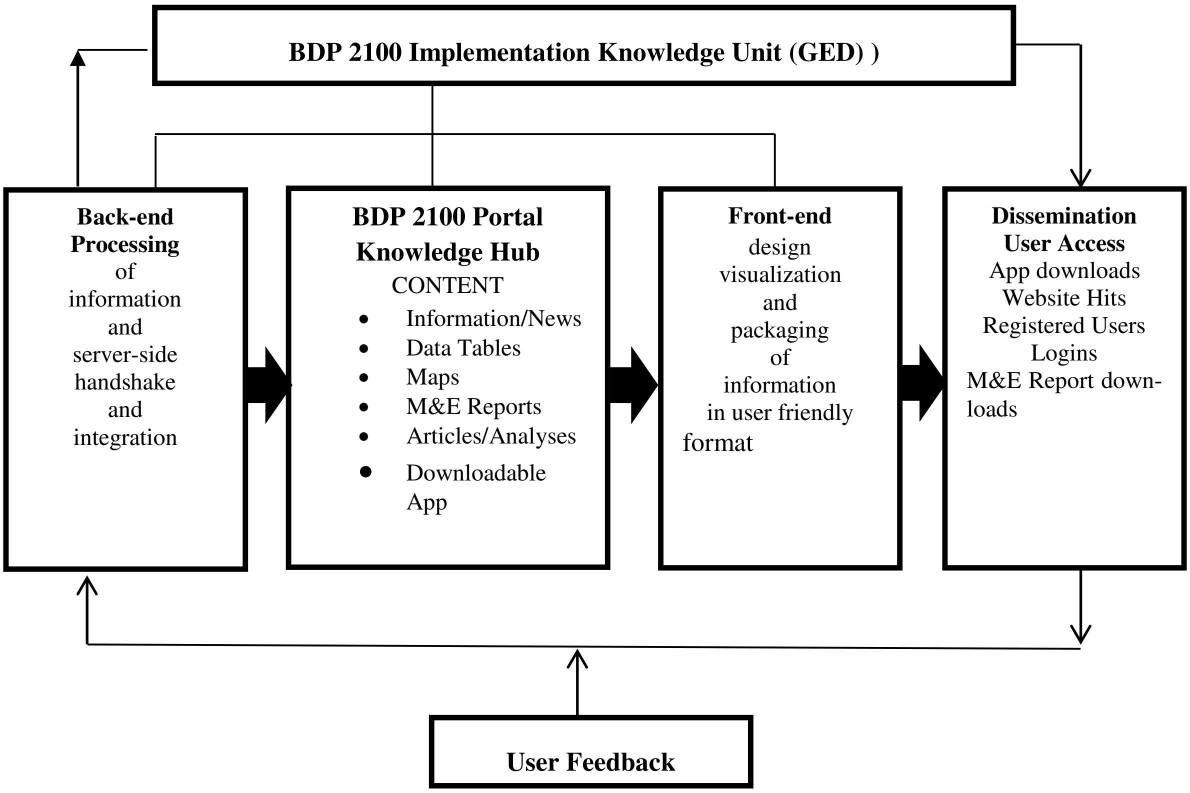

Figure 14.3: Illustrative BDP 2100 Portal Flow of Information

Source: BDP 2100 Technical Team Analysis, GED, 2015

A number of tasks will be required for the development of the knowledge portal; these are as follows:

- System requirements analysis.
- Design and development of the database.
- Design and development of the knowledge portal.
- Processing of collected and generated data and converting into database format.
- Uploading data into the database.
- Installation and configuration of knowledge portal at the server end.
- Software Testing; and
- Users training and capacity building.

The back-end and front-end integration of data in the main knowledge hub server is extremely important. This needs to be set up by database managers and IT experts with knowledge of handling and integrating large and multifarious types of data into a portal that can offer web-based access to users. An inter-active mapping tool with feedback and editing screen (for data correction) accessible by local officials through the knowledge portal can enable active participation of local experts and resource persons in improving accuracy and quality of the database. The day-to-day operations will be run by a Knowledge Hub management team under GED and overseen by the Delta Coordination Committee (**Figure 14.4**).

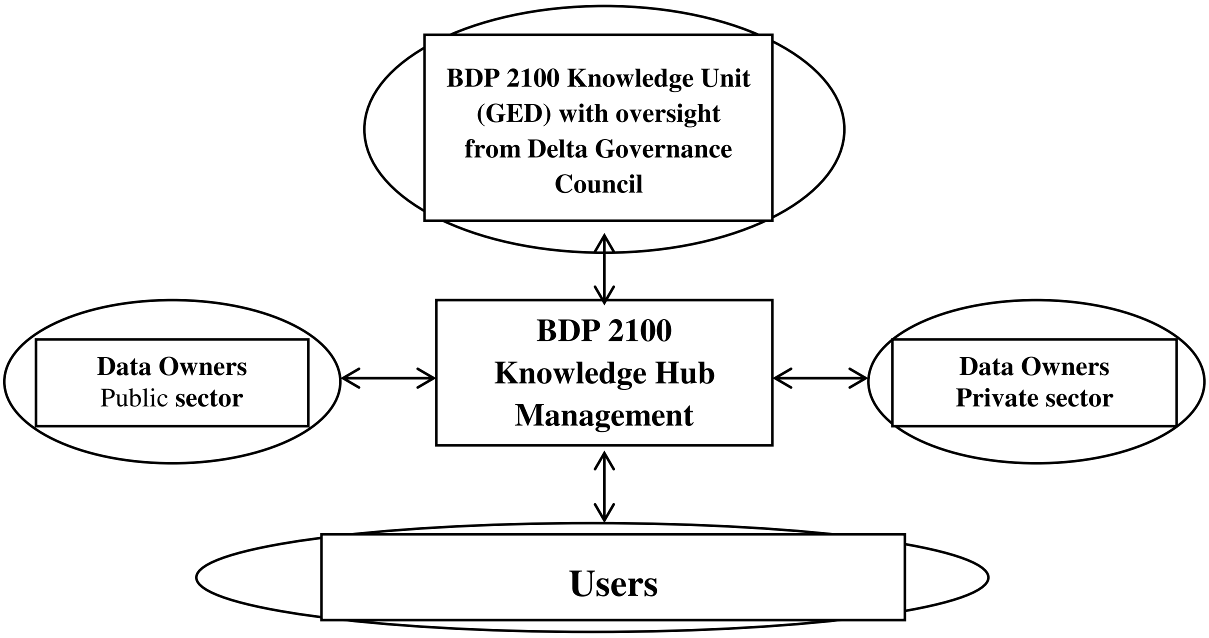

Figure 14.4: Institutional Mechanism to Operate the BDP 2100 Knowledge Hub

Source: BDP 2100 Technical Team Analysis, GED, 2015

There are numerous institutions generating data and information in various formats and degree of usability. However, the main interfacing and integration into the web portal – Knowledge Hub – requires a centralized clearing house (a router function) for data receiving, formatting, verification, cleaning and then uploading onto the knowledge hub server. A centralized coordinating institution needs to be identified that can sustain data management and maintenance by providing for IT specialists as well as hardware and software updates, ensuring a 24/7 access to BDP 2100 Knowledge Hub.

The core issue is one of sustaining services of the knowledge hub and regular updating of the data and flow of newly generated information, progress, status and achievements. This is a big challenge.

The Bangladesh Computer Council (BCC) under the Ministry of Posts, Telecommunications and Information Technology, provides support to ICT related activities to different government organizations. It has established a National Data Center for hosting all the government websites, knowledge portals, e-mail services and web applications. This could be a likely candidate for hosting the knowledge hub. However, CEGIS has been in the forefront of providing spatial information and assisting in identifying hotspots; it has established MOUs with several government departments and receiving data. Both the BCC and CEGIS are directly under the supervision of government. However, it might be possible to consider a public-private partnership to host the BDP 2100 knowledge hub; a public-private trust mechanism, similar to the trust mechanism overseeing CEGIS, but governed by a public-private partnership modality could be set up to underline the importance of collaboration among public and private sectors, including civil societies to maintain a sustainable BDP 2100 knowledge hub that is well funded in the long term operating on a not-for-profit basis.

The public-private-trust mechanism could be supported initially for ten years with funds from BDP 2100 investment programme. A percentage of funds from Delta Programme Projects during BDP 2100 implementation could be dedicated to operating the single-window Delta knowledge hub.

For sustainable financing the following could be considered: Some data could be downloaded at cost; similarly usage of specialized information on a downloadable smart phone app could be at a subscription fee channeled through telco service providers (Taka 1 per download). Similarly, a nominal fuel sale levy at gas stations (1 Taka per sale receipt) could be tapped for funding the knowledge hub; a fossil fuel emissions are a contributory cause to increasing climate change impacts this kind of a levy is well justified.

As data categories are built up, distinction can be made between data that is freely available and data that can be purchased by public and private sector agencies (e.g. data required for infrastructure development, risk assessment of flooding and other extreme events, land reclamation, engineering data, etc). Revenue can be shared between the data owners (those providing the data) and the knowledge hub managers (the public-private trust). The use of apps could also be made at a nominal monthly subscription that will allow revenue to be generated for operations of the knowledge hub. By the end of 10 years, a review could be undertaken to take a decision on whether to continue the model and on what terms this should be done. It is imperative that the public sector retains a stake in the knowledge hub as part of its public fiduciary responsibility to provide accurate information for and on development, risk avoidance and risk mitigation promoting a safe and secure living environment for all.

14.6 Data Access Policy

Currently baseline studies and data have been generated in the preparatory phase of the BDP 2100. The studies conducted and data collected can be uploaded for open and free access categorized by thematic groups. The restricted data and information is envisaged to overcome data sharing fears and objections (categorizing some under restrictive access but allowing authenticated users access to the data); each institution generating and holding data can choose to provide data as per categories. However, open access to information about the BDP 2100 implementation would be a beneficial, long term vision to strive for.

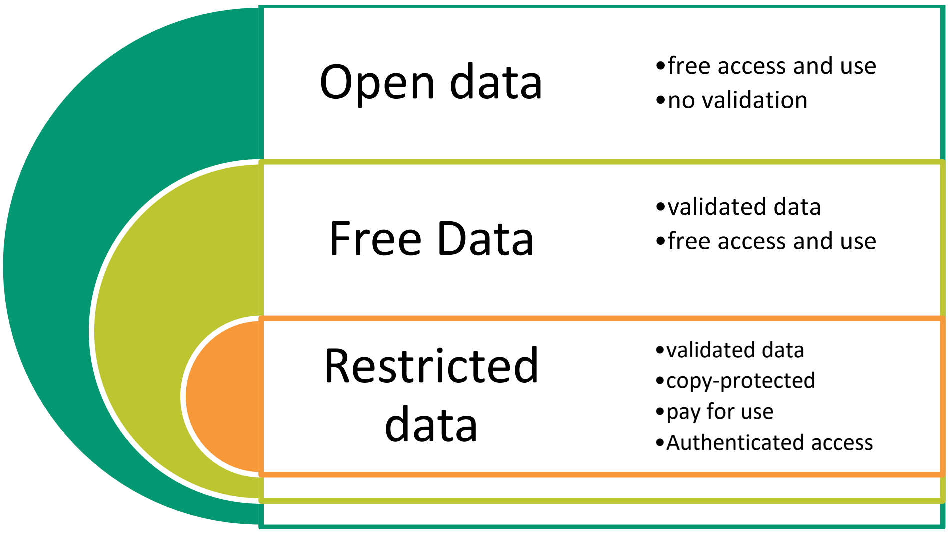

Figure 14.5: Data Access Categories

Source: BDP 2100 Baseline Study:- Information and Knowledge Management, 2015

The data access policy on the BDP 2100 web portal can be categorized into three types: i) open data, including news items, calendars, events that are freely available in the public domain and which are not validated by the BDP 2100 implementation group; ii) free but validated data is open to all to access without authentication; this category includes statistics, spatial information, interactive maps etc., which have been validated by the BDP 2100 implementers and which are made available for consumption by the general public; iii) restricted data is information, which is validated by the BDP 2100 implementers, could be copyright protected, or made available at a fee or charge, and to which access is granted through an authenticated login. In this context, authentication could differentiate between intranet (implementer) users and registered users from the general canals with authenticated login rights.

14.7 Data Standards and Knowledge Hub Hosting

For the structured development of the baseline data layer and to safeguard the quality of the system, an ISO-standard could be used: the OAIS-model (Open Archival Information System). This model describes the way information is preserved and made available to designated user groups. The model takes the maintenance of the information into account, including the impacts of changing technologies, support for new media and data formats and a changing user community. The model sets the standard for the activities that are involved in preserving a digital archive and its development towards a reliable (trusted) repository that can be used as a base for policy formulation. The functionalities of the model not only cover the delivery of the data and information (terms of delivery, metadata structure, standard layout for spatial data (maps, drawings), selection and value assessment of delivered data), but also the access and dissemination of the data, hereby using a layered structure. This structure encompasses several principles:

- No data will be stored without basic metadata description.
- The quality, integrity and validity of the data are safeguarded.
- It enables an access policy to ensure correct (re)use of the data; and
- It makes possible to address different levels of data users.

Data or information that are not sensitive or restricted will be incorporated into free access area of the Knowledge Portal. No sensitive data will be made available in the open knowledge repository. The quality of the data will be ensured before uploading. A relational database will be used to develop the physical database. To avoid data redundancy and inconsistency, the database will be normalized and a number of tables will be used to store information. Parent-child relationship will be implemented between tables to maintain data relationships and the referential integrity will be implemented for maintaining the data integrity. The referential integrity will ensure that, no data could be entered in the child tables without entering corresponding data in the parent table. Each table will maintain a primary key, which will uniquely identify each record in the table to reduce the chances of data duplication. Spatial data that already have been generated are stored in geo-server for using in touch table application. These data will be directly used from the geo-server. If any technical problem arises, then spatial data will be stored on a hard disk in a hierarchical file/folder system. The location of these data layers will be kept in the database. In order to sort and query data easily and efficiently, all data will be categorized into different data groups. Each data group will be further classified into different data type. Each data type will contain several data layers. Relevant studies, articles and other background material used during the analyses and formulation of the plan will also be placed in the knowledge repository. The quality of the deliverables that are produced by the project will depend completely on the availability of validated, reliable data and information.

Data and information on the Bangladesh Delta is available at different scales and from multiple sectors. The knowledge portal will accumulate all the generated knowledge, integrating the multi-sectoral issues covering spatial scales and spatial dimensions. Data will be processed to produce information aggregated and summarized according to clusters and themes. Integrated and cross-sectoral analysis of the available data and information will help generate knowledge including new scenarios for future perspective. Users using the intranet (implementer) platform within the BDP 2100 portal with authenticated login rights can conduct participatory planning, reviews and share and exchange information during Plan implementation. Furthermore, responsible project officers from implementing agencies can upload their M&E reports at regular intervals, which can be read by legislators, policy and decision makers and senior management of implementing agencies.

14.8 Monitoring and Evaluation (M&E)

The knowledge portal will be particularly useful for tracking projects undertaken under BDP 2100 implementation, such as objectives, indicators to be achieved, budgets allocated, disbursed amounts, physical and financial progress – in short – an M&E of the overall Plan and Vision 2100. This will contribute to transparency, a better learning environment, and peer pressure among stakeholder implementers to improve performance. Standard formats could be used for reporting by all project implementers under BDP 2100 implementation to report on and enable the knowledge portal to upload and disseminate these reports. Detailed data requirements for M&E are discussed in **Chapter 13**.

This kind of monitoring format and reporting could be particularly well visualized through mobile smart phone apps. The updates could be flagged as they are uploaded in the portal and automatically downloaded by app subscribers. This will be a useful and transparent way of information dissemination to all stakeholders (in English and Bangla languages).

14.9 Knowledge Hub Usage and Usefulness

Knowledge is useful only if this is easily available to all users in usable format and at low cost. The rapid expansion of mobile phone and the growing use of smart phones have made knowledge dissemination a fairly low cost and easy task. The main challenge is to make the knowledge accessible to all users.

A major objective of the delta knowledge management is to make knowledge useful and relevant for policy making. As noted in section, a core element of the delta knowledge strategy is to identify the knowledge gaps that need to be addressed for informing the BDP 2100 strategy. As this new knowledge is available, it must feed directly into BDP 2100 policy making. This coordination between knowledge generation, dissemination and use is essential to secure the full benefits of the investment in the delta knowledge agenda.

One of the mentioned key challenges is to give easy access to available maps and spatial information in such a way that it can be used by planners and decision makers in problem analysis, strategy-making and monitoring steps. Delta Plan tools need to be have been developed for this purpose and all the delta tools are connected to one central Information and Information and Knowledge Portal. **Figure 14.6** presents the information structure.

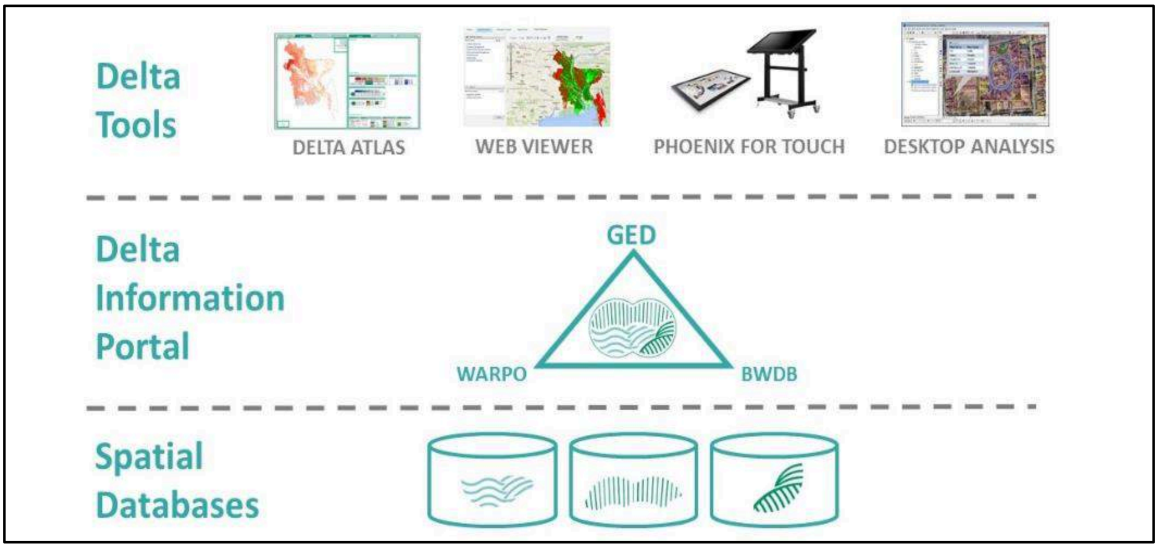

Figure 14.6: Information Structure

Source: BDP 2100 Technical Team Analysis, GED, 2015

The Delta Plan tools are to be developed to access and to interact with the data in the Information Portal. Each tool has a specific target group and use. The Phoenix software is used on touch tables. The purpose of this tool is to use the data in interactive planning and design sessions. More advanced users may wish to use the data on the Information Portal for more technical analytical purposes. The Meta Models are being developed and a GIS desktop application (e.g. ArcGIS) can be used to perform spatial analysis and calculations. The Data Viewer makes all information publicly available, and the Delta Atlas summarizes all layers in an interactive pdf. This gives users the opportunity to develop a map they like by combining different map layers, for instance to be used in reports or presentations. In this way, the Delta Tools are separate modules that can be used independently of each other, for a variety of uses.

During the BDP 2100 formulation project, each step has been supported by tools. To identify hotspots and to summarize the spatial data from the Baseline Studies, a Delta Atlas was developed. All data was harmonized and stored on a central server. The server data can be viewed on any computer using the Knowledge and Information Portal. With the PHOENIX Touch Table application all data can be viewed and users can draw onto the maps and drawings can be stored as GIS shapefiles. This supports interactive design and planning workshops. Desktop GIS and the Meta Model can be used to perform calculations from the desktop. Strategies can be evaluated and assessed (in qualitative way) using the Assessment Framework Rapid Assessment tool.

The tools (Delta Atlas, Touch Table and Information Portal) have different uses and purposes. The **Table 14.6** presents the main target groups and potential uses.

Table 14.6: Main target groups and potential uses

Tool	Target group	Functionality	Potential use
Touch Table	Stakeholders involved in the BDP 2100 planning and design process	Zoom, draw, placing measures, overlay maps	Interactive workshops, planning and design support
Interactive Delta Atlas	All interested people and stkaeholders in the BDP 2100	Available off-line, annex to the BDP plan, can be sent as a PDF once fully developed	Getting insight in the main issues, summary maps of the hotspot level issues. Overview of the BDP 2100 knowledge base
Information Portal	Professional stakeholders (with GIS expertise)	Access to the BDP Geoportal data layers visualized in a web viewer, Input for the touch table, Delta Atlas and web viewer	Access to the spatial BDP 2100 knowledge base, and availability post-BDP (legacy)

Source: BDP 2100 Technical Team Analysis, GED, 2015

14.9.1 The Touch Table Platform

All spatial information that was gathered for BDP 2100 has been stored on a local server. The data can be accessed through the information portal but also through the Touch Table. The Touch Table interface enables all parties involved to continue with this approach. With the Touch Table platform, the power of spatial information is used for better decision-making as it provides an environment for interactive collaboration. The application combines the ease of working on paper with the flexibility provided by a digital work environment and the capabilities of geo-information. During the Delta Ateliers the use of the touch table platform has led to more involvement of stakeholders. The touch table interface allows users to interactively work with the Delta Atlas. All maps are available and tools such as drawing mode, zooming, measuring distances and diameters and adding measures to the map are available. The main purpose is to support interactive planning and design processes.

14.9.2 The Interactive Delta Atlas

The interactive Delta Atlas visualizes the most relevant maps. The atlas has the advantage of being available off-line (it is an interactive pdf). This means the atlas can be sent out to a wider audience, for instance as an annex. The atlas has an interactive legend. Users can view various maps by change the background layers, select maps, and scroll through the legend. The purpose is to study the Bangladesh delta, to analyze and view the various aspects that are relevant for long term delta planning. Zooming and drawing is however not possible in this tool. The touch table application gives users the possibility to draw, overlay and zoom. Also the web-viewer will allow users to browse and zoom through layers.

14.9.3 The Meta-model in the Planning Context of BDP 2100

The 'meta-modelling initiative' was a pilot activity of the BDP 2100 formulation project. The main purpose of the pilot was to demonstrate the potential of meta-modelling to support decision making process on Delta planning in Bangladesh. Decision-making for the BDP 2100 includes all key socio-economic sectors. Integrated impact analysis is therefore the key. The pilot initiative also aimed at supporting decision-making under conditions of uncertainty and developing an adaptive plan.

The measures included in the BDP 2100 are a mix of detailed feasibility studies, concept notes and programmes. A number of these measures have been assessed by using (detailed) models. Typically, the studies, notes and programmes are difficult to compare for a number of reasons: different consultants, tools, data and assumptions or different evaluation criteria. Moreover, most proposals are generally focused on one particular sector or policy goal and do not take into account the interactions with other interventions and sectors. The meta model supports the: i) assessment of impacts of combinations of measures on a consistent set of policy indicators; ii) assessment of the synergy, competition or overlaps across measures; and iii) prioritization of measures from a list of multiple possible measures. In the figure below, the use of the meta model in the Policy Planning process is illustrated. Typically, this would take place for every new Five Year Plan, BDP 2100 update and for the annual review process.

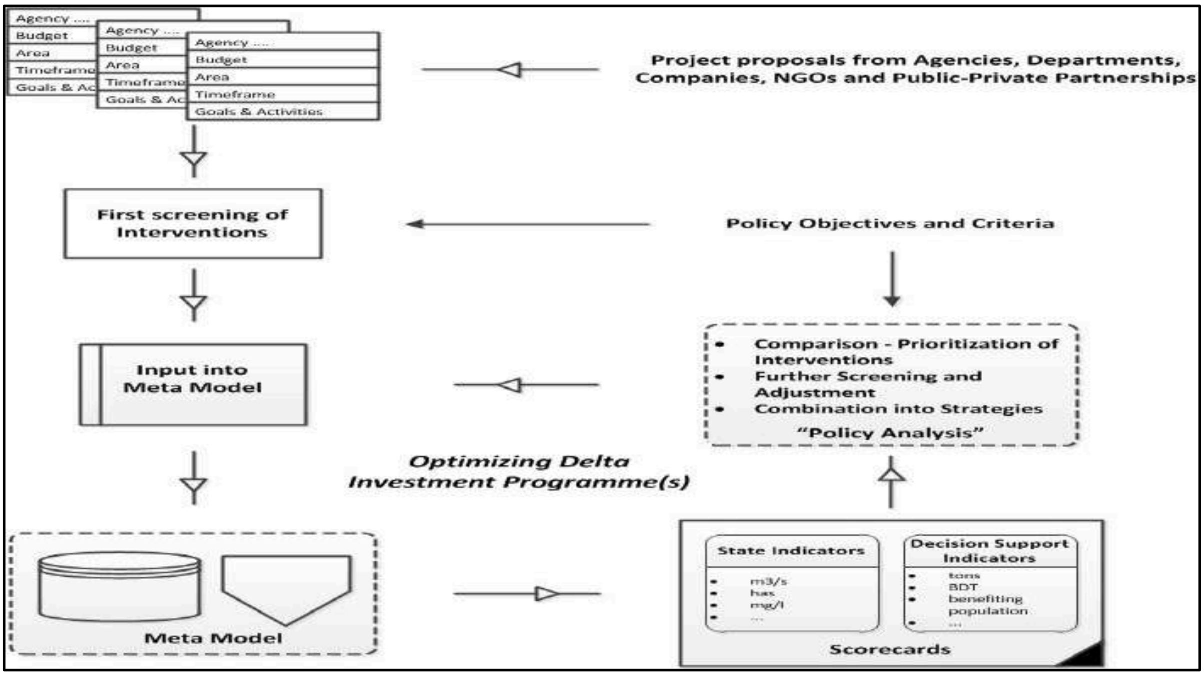

Figure 14.7: Structure of the Meta Model

Source: BDP 2100 Technical Team Analysis, GED, 2015

As illustrated above, the input to the meta model is the result of an internal screening process within the different departments and agencies that submit proposals to the Planning Commission through ministries/divisions as part of the Annual and Five Year Planning process. The output of the meta model will be structured in an Intervention Fact Sheet, summarising the most important State and Decision Support Indicators. These fact sheets are then used as inputs into the Policy Analysis step. The policy analysts of GED, Planning Commission will lead this process, supported by the meta model experts and selected experts from the different departments, agencies and sectors.

ESPA Deltas project also has developed an integrated analysis tool for delta planning called "Delta Development Integrated Emulator Model" (ΔDIEM). ΔDIEM is currently ready to be applied to the coastal zone hotspot. The implications of many of the proposed interventions can be simulated providing a rich set of indicators including information on livelihoods and poverty which is not readily available from more traditional assessment methods. In the medium term the ΔDIEM approach could be extended both in terms of approach and geographic coverage to provide a national coverage for the entire Delta Plan. As such, ΔDIEM can contribute to the suite of models that support the BDP 2100 as a whole. These meta models and ΔDIEM would be further developed and used in BDP 2100 investment planning process in future analysis and updating during the implementation of the BDP 2100.

14.9.4 *The Information Portal and Web Viewer Tool*

The Information and Knowledge Portal has been developed based on information collected and generated under the BDP 2100 by different partners, scientists and specialists working under the formulation project. The aim of this development was to provide support to the planners and decision makers for participatory and interactive planning and decision making process to ensure adaptive management of Bangladesh Delta.

The portal has been designed and developed using the standard four-tier architecture of software development. It consists of the following layers:

- Presentation (user-interface)
- Web-server
- Application server
- Data-server.

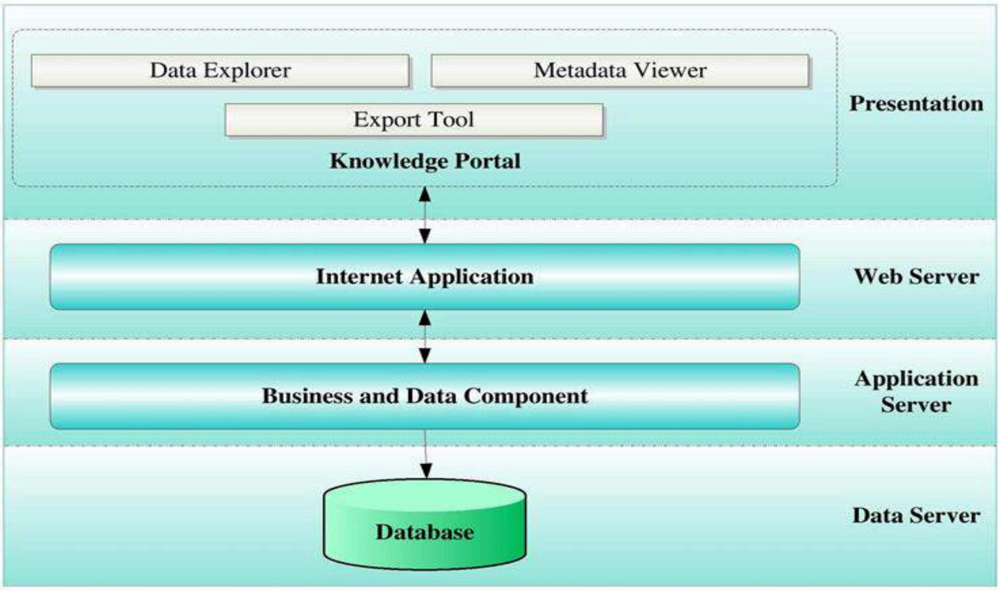

Figure 14.8: System architecture of Information and Knowledge Portal

The presentation layer represents user-interfaces that a user uses to interact with the application. This layer has been developed using ASP .Net. HTML5 and CSS3 with jQuery are also used to develop the user interface. The design and look of the interfaces has been made simple and user-friendly in consultation with BDP 2100.

The main service component for a web-based application is the web server. It is a program that manages and delivers web pages and allows users to communicate with the server for data service through the Internet or the Intranet. The web server is configured using Internet Information Services.

The application layer is the main development area, which consists of business and data components. The business component is used to impose different business rules and logics. The data component is responsible for retrieving data from the server. The application layer has been developed using Asp .Net.

The data server has contained data, views, triggers and stored-procedure. It executes SQL statements, views, triggers and stored-procedure for data manipulation and presentation. A relational database PostGreSQL is used to store and organize data.

14.9.5 Data Components of Information and Knowledge Portal

The Information and Knowledge Portal has been installed and configured in a secured server. The web address of the Information Portal is ***http://202.53.173.179/delta/.***

The Portal has a user-friendly and interactive interface. It allows users to access all generated and collected information from a single place through the web. This portal has three components: Data Explorer, Metadata Viewer and Export Tool. The Data Explorer helps to display spatial, temporal and attribute data. In order to sort and query data easily, all data available in the portal are categorized into different data groups based on thematic area of the project. The Metadata Viewer has been developed to display Metadata for each data layer. Metadata is the information about data that enables intelligent and efficient access and management of data. It is the background information, which describes the content, quality, condition, and other appropriate characteristics of data. Web based customized metadata viewer has been developed on the basis of ISO standard and model developed for NWRD. The Expert Tool allows authorized users to download information from the portal. Spatial data, and attribute information can be downloaded for further analyses.

14.9.6 Maintaining and Updating the Delta Plan Tools

The Delta Information Portal is the central depository for all geospatial data used and generated in BDP 2100. Its long term maintenance and regular updating is of crucial importance. The GoB institutes (in particular GED, WARPO and BWDB) will bring this information portal under their responsibility. GED, WARPO and BWDB will make the database open access so that all relevant parties involved in the implementation of the BDP 2100 can make use of the wealth of information generated.

GED will work towards setting up a support team that is capable of the operations and maintenance of this information structure. This means operating and updating the information portal, but also making the connections between the portal and the delta tools. For example, if a new data layer is added to the portal this layer has to be added to the Phoenix touch table application. This requires continuous effort and is the role of the support team. New research results need to be integrated in the information portal. Innovations in the tools need to be implemented where user needs and requirements are prioritized. This requires a close link with the actors involved in the planning and implementation of the BDP 2100 strategies. The team needs to ensure that the information portal remains up to date, contains news, for instance by highlighting successes in the implementation. The information portal and the delta tools connected to it should become a dynamic up to date system that also highlights the progress and successes achieved. It should become a basis for a lively community of practice, sharing scientific information, practical experiences and lessons learnt.

14.9.7 Financing Knowledge Management

The knowledge strategy has also included a financing strategy. It aims to esablish *structural means* to develop specific knowledge questions and to coordinate the knowledge agenda. Knowledge fundamental for system understanding (e.g. 'what' questions, early in planning process) should be financed by universities or national research funds, while knowledge needed for implementation (e.g. 'how' questions, later in planning process) will be financed by the Delta Fund.

References

References

2030 Water Resource Group. An Analysis of industrial water use in Bangladesh with a focus on the leather and textile industries, Draft report. 2015.

Abdedin, S., Tackling the problem of childhood obesity, The Independent pubslihed online on 5 December, http://www.theindependentbd.com/printversion/details/25495. 2015.

ADB. Southeast Asia and the Economics of Global Climate Stabilization. In 2015 Paris Climate Conference, COP 21, 2015.

ADB. The Economics of Climate Change in Southeast Asia: A Regional Review. Manila: Asian Development Bank. 2009.

ADB. Stregnthening the Resilience of the Water Sector in Khulna to Climate Change, Asian Development Bank. 2010.

Agrawala, S., T. Ota, A.U. Ahmed, J. Smith and M. van Aalst. Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sunderbans. Paris: Organisation for Economic Co-operation and Development (OECD). 2003.

Ahmed A U, "Bangladesh Climate Change Impacts and Vulnerability A Synthesis", Climate Change Cell, Department of Environment, Comprehensive Disaster Management Programme, Government of the People's Republic of Bangladesh, 2006

Ahmed, A. A. & Shah, S. M. A., Application of adaptive neuro -fuzzy inference system (ANFIS) to estimate the BOD of Surma River. Journal of King Saud University - Engineering Sciences, (2015).

Ahmed, A. M., & Roy, K. Utilization and Conservation of Water Resources in Bangladesh. 2004. http://www.nourin.tsukuba.ac.jp/~tasae/2006/Bangladesh.pdf

Ahmed, A. U., Neelormi, S., Adri, N., Alam, M. S., & Nuruzzaman, K. Climate Change, Gender and Vulnerable Groups in Bangladesh. Climate Change Cell, Department of Environment, Ministry of Environment and Forests. 2009.

Ahmed, F. Alternative water supply options for arsenic affected areas of Bangladesh. 2002.

Ahmed, M. and Suphachalasai, S. *Assessing the Costs of Climate Change and Adaptation in South Asia*. Manila: ADB and UK Aid. 2014.

Ahmed, M. J., Haque, M. R. & Haque, T. Physicochemical Assessment of Surface and Groundwater Resources of Greater Cumilla Region of Bangladesh. International Journal of Chemical and Environmental Engineering, (2010): p. 8.

Ahmed, M. J., Haque, M. R., & Haque, T. Physicochemical Assessment of Surface and Groundwater Resources of Greater Cumilla Region of Bangladesh. International Journal of Chemical and Environmental Engineering, 8 (2010).

Ahmed, S. (n.d.). Water Supply Situation Analysis. http://users.physics.harvard.edu/~wilson/arsenic/conferences/Feroze_Ahmed/Sec_2.htm (Accessed 2016)

Ahmed, Tanvir, K. M. & Begum, D. A. Air Pollution Aspects of Dhaka City. 2010.

Ahmeduzzaman, M., Kar, S., & Asad, A. A Study on Ground Water Fluctuation at Barind Area, Rajshahi. International Journal of Engineering Research and Applications, 2(6) (2012): 1465-1470.

Ahmeed, Tanvir, K. M. & Begum, D. A. Air Pollution Aspects of Dhaka City. 2010.

Alam, M. M. An Evaluation of Water Resources Planning Organization, an Apex Planning Organization in Water Sector Bangladesh. Asian Journal of Applied Science and Engineering, Volume 3, No 2 (2014).

Alam, M. M. and Quevauviller, P. An Evaluation of Integrated Water Resources Management (IWRM) activities in Bangladesh. Asia Pacific Journal of Energy and Environment, Volume 1, No 1 (2014).

Alam, M. M., Rahman, M. A. and Alam, M. S. An Investigation of National Water Resources Database, Bangladesh. Asian Journal of Applied Science and Engineering, Volume 3, No 2 (2014)

Alam, M. M., and Quevauviller, P. An Evaluation of Integrated Water Resources Management (IWRM) activities in Bangladesh. Asia Pacific Journal of Energy and Environment, Volume 1, No 1 (2014): 21-38.

Alam, M.K. A guide to eighteen species of bamboos from Bangladesh. Bulletin: Forest Research Institute, Chattogram, Bangladesh (Plant Taxonomy Series), no.2 (1982): 29pp.

Alam, M. and Rabbani M.G. *Vulnerabilites and Responses to Climate Change for Dhaka*, Environment & Urbanization Vol 19(1): 81–97. DOI: 10.1177/0956247807076911. International Institute for Environment and Development (IIED). 2007.

Ali, L. An Integrated Approach for the Improvement of Flood Control and Drainage Schemes. In Agency and Change, R. Caldwell (ed.), 88-209. New York: Routledge. 2006.

Alipour, F., Idris, K., and Karimi, R. Knowledge Creation and Transfer: Role of Learning Organization. International Journal of Business Administration. Vol. 2, No. 3: 61-67, 2011.

Amarsinghe, U.A., Sharma, B.R., Muthuwatta, L. and Khan, Z.H. Water for Food in Bangladesh: Outlook to 2030, Research Report 158, International Water Management Institute. 2014.

Argyris, C. Y. S. and Schön, D. Organizational learning II: Theory, method and practice. Reading, PA: Addison-Wesley. 1996.

Aziz, K. M. A.; Cairncross, Alexander M; Hasan, Z.; Hoque, Bilqis Amin; Huttly, S. R. A.; Minnatullah, Khawaja M.; Patwary, M. K.; Rahaman, Md. Ataur; (World bank Report: Water supply, sanitation and hygiene education : report of a health impact study in Mirzapur, Bangladesh)

BADC. Minor Irrigation Survey (2012-13). Bangladesh Agricultural Development Corporation, Ministry of Agriculture, Government of People's Republic of Bangladesh, Bangladesh. 2013.

BanAuDeltAS. Bangladesh Delta Plan 2100 Formulation Project: Baseline Report on River System Management. General Economics Division, Planning Commission, Government of Bangladesh. 2015.

BanDuDeltAS. BDP2100 Strategy Formulation-Flood Risk Management - DRAFT. 2016.

Bangladesh Agricultural Research Council's (BARC). 2015 http://www.fao.org/docrep/004/y1717e/y1717e05.htm/ (Accessed: 22 December 2015)

Bangladesh Computer Council (BCC). 2015 http://www.bcc.gov.bd/site/page/01cbf22a-b9f5-4a67-829e-55c27ab216f6/Overview/ (Accessed: 2 August 2015)

Bangladesh Water and Flood Management Strategy (BWFMS), 1995 (FPCO-1995)

Banglapeida, Forest and Forestry, http://en.banglapedia.org/index.php?title=Forest_and_Forestry 2015.

Barua, S. Towards Interactive Urban Flood Management: A Case of Dhaka, Bangladesh. Netherlands: Erasmus University Rotterdam. 2008.

Basak, J. K., Titumir, R. A. M. & Dey, N. C. Climate Change in Bangladesh: A Historical Analysis of Temperature and Rainfall Data. Journal of Environment, (2013): p. 6.

Bangladesh Bureau of Statistics (BBS). *Population and Housing Census 2011 - National Volume -3: Urban Area Report*, Bangladesh Bureau of Statistics, Dhaka, 2012.

BCCSAP. Bangladesh Climate Change Strategy and Action Plan 2008. Dhaka: Ministry of Environment and Forests, Government of the People's Republic of Bangladesh, 2009

Bangladesh Delta Plan 2100, *Water Resources Baseline Study*, 2015.

Bangladesh Delta Plan 2100, *Baseline Study on Information and Knowledge Management*, 2015.

BBS. *Statistical Year Book of Bangladesh 1999*. Bangladesh Bureau of Statistics, Dhaka, 1999.

BBS. *Statistical Year Book of Bangladesh 2011*. Bangladesh Bureau of Statistics, Dhaka, 2011.

BBS. *Statistical Year Book of Bangladesh 2011*. Bangladesh Bureau of Statistics, Dhaka, 2015.

BBS. Technical Documentation for Development of Web-based GIS Application Software and Linkage with BBS Website. Dhaka: Digital Information System Project. Bangladesh Bureau of Statistics. 2013.

BBS. National Report Volume 3 – Urban Area Report, Bangladesh Population and Housing Census 2011, Bangladesh Bureau of Statistics, Dhaka, 2014.

Bhatt, G. D. Knowledge management in organizations: examining the interaction between technologies, techniques, and people. Journal of Knowledge Management, 5(1): 68-75. 2001

Bhattacharya, B., & Suman, A. Flash flood characterisation of the Haor area of Bangladesh, 2012.

BHWDB. Master Plan of Haor Area, Volume I: Summary Report. Ministry of Water Resources, Government of the People's Republic of Bangladesh, Bangladesh. 2012.

Biswas, R. K., Roy, D. K., & Islam, T. M. Assessment of drinking water related to arsenic and salinity hazard in Patuakhali district, Bangladesh. International Journal of Advanced Geosciences, (2014).

BIWTA. Bangladesh Inland Water Transport Authority, Bangladesh. http://www.biwta.gov.bd/website/?page_id=2,

BNBC. Bangladesh National Building Code. 1993: 2006

Brammer, H. *Land Use and Land Use Planning in Bangladesh*, University Press Limited, 2002.

Brammer, H. Bangladesh's dynamic coastal regions and sea-level rise. Climate Risk Management 1, (2014), pp. 51-62.

Brammer, H. Climate Change, Sea Level Rise and Development in Bangladesh. Dhaka: UPL. 2014

Brammer, H. *Can Bangladesh be Protected from Floods?* University Press Limited, 2004.

BWDB. Bangladesher Nod-Nodi. Dhaka: Bangladesh Water Development Board. 2011.

Byomkesh, T., Nakagoshi, N., & Rashid, S. M. State and management of wetlands in Bangladesh. Landscape and Ecological Engineering, (2008).

CEGIS. Bank erosion prediction of different mighty rivers of Bangladesh (Dhaka: 2014).

CEGIS. Development of a GIS based Industrial Database for the Department of Environment. CEGIS. 2015.

CEGIS. Final Report on Impacts of Climate Change on the morphological processes of the main rivers and Meghna Estuary of Bangladesh. Dhaka: Mimeo. 2010.

CEGIS. Master Plan of Haor Area Vol. I (Summary report) and Vol. II. Dhaka: Ministry of Water Resources, Bangladesh Haor and Wetland Development Board. 2012.

CEGIS. Technical Notes on Assessment of BDP2100 Indicators using GIS Data Layers. Dhaka: Climate Change and Disaster Management Division, Center for Environmental and Geographic Information Services (CEGIS). 2016.

Choudhury, A. H. Consequences of Global Warming and SLR in Bangladesh. Marine Geodesy, 20: 13-31.1997

Consultative Committee for Space Data Systems. Reference Model for an Open Archival Information System (OAIS). Washington, DC: CCSDS Secretariat, p. 1-1. 2012

CSIRO, BWDB, IWM, WARPO, BIDS, & CEGIS. Bangladesh Integrated Water Resources Assessment: Final Report. 2014.

Das, D.K. Forest Types of Bangladesh. Bulletin 6, Plant Taxonomy Series. Forest Research Institute, (1990): 9.

Dasgupta, S. Left unattended, 5.3 million of Bangladesh's poor will be vulnerable to the effects of climate change in 2050. World Bank blog. 2010. http://blogs.worldbank.org/developmenttalk/left-unattended-53-million-bangladesh-s-poor-will-be-vulnerable-effects-climate-change-2050

Dasgupta S., Zaman A.M., Roy S.; Huq M.; Jahan S. and Nishat A. , *"Urban Flooding of Greater Dhaka in a Changing Climate: Building Local Resilience to Disaster Risk"*, Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/22768. 2015

Davenport, T. H. and Prusak, L. Working knowledge: How organizations manage what they know. Harvard Business Press. 2000.

Decaluwé, B., A. Lemelin, H. Maisonnave, and V. Robichaud. The PEP Standard Computable General Equilibrium Model Single-Country, Recursive Dynamic Version: PEP-1-t . Partnership for Economic Policy (PEP) Research Network.; at: www.pep-net.org/programs/mpia/pep-standard-cge-models/pep-1-t-single-country-recursive-dynamic-version. 2010

Dey, D. N., Bala, S. K., & Islam, A. S. Sustainability of Groundwater Use for Irrigation in NorthWest Bangladesh. National Food Policy Capacity Strengthening Programme. 2013.

Dhaka Tribune. Bogura Economic Zones Groundwork Begins. Dhaka Tribune. 2016. http://www.dhakatribune.com/business/2016/jan/28/bogura-economic-zones-groundwork-begins

DoE *National Action Programme (NAP) for Comabting Desertification*, Dept. of Environment, Ministry of Environment and Forest, Government of the People's Republic of Bangladesh. 2005.

DoF *Fish Fortnight Publication*. Department of Fisheries, Ministry of Fisheries and Livestock. 2009

Durkin M, Khan N, Davidson LL, Zaman SS, Stein ZA. The effects of a natural disaster on child behaviour: evidence for post-traumatic stress. American J Public Health. 83: 1549-1553, 1993

DWASA. Dhaka Water Supply and Sanitation Authority. 2016. http://www.dwasa.org.bd

DWASA. Master Plan for Water Supply and Sanitation for Dhaka City. Dhaka: Dhaka Water Supply and Sanitation Authority. 2015.

Economist. Ebb and Flow. Economist. 16-05-2013.

EGIS. Riverine Chars in Bangladesh: Environmental Dynamics and Management Issues. Dhaka: The University Press Limited. 2000.

Elahi, K. A. Riverbank Erosion, Flood and Population Displacement in Bangladesh. Dhaka: Jahangirnagar University. 1999.

Fahmida, K., Lemon, M. H. R., Islam, M. S. & Kader, M. A. Assessment of Supplied Water Quality of Khulna WASA of Bangladesh. Rajshahi. 2013.

Faneca Sanchez, M., Bashar, K., Janssen, G.M.C.M., Vogels, M., Snel, J., Zhou, Y., Stuurman, R. and Oude Essink, 2015: SWIBANGLA – Managing saltwater intrusion impacts in coastal groundwater systems in Bangladesh, Final Report

FAO, IFAD, and WFP. The State of Food Insecurity in the World 2014: Strengthening the Enabling Environment for Food Security and Nutrition. Rome: FAO, IFAD, and WFP. 2014.

FAO. Building Resilience for Adaptation to Climate Change in the Agricultural Sector: Proceedings of a Joint FAO/OECD Workshop. Rome: FAO. 2012.

FAO. Climate-Smart Agriculture Sourcebook. Rome: FAO. 2013

FAO. Climate-Smart Agriculture: Policies, Practices, and Financing for Food Security, Adaptation, and Mitigation. Rome: FAO. 2010.

FAO. Draft, Mapping Exercise on Water Logging of South West in Bangladesh. United Nations. 2015.

FAO. Irrigation in Southern and Eastern Asia in Figures- AQUASTAT Survey 2011. Food and Agriculture Organization of the United Nations. 2012.

FAO. Stability of Food Security in a Green Economy Environment, FAO Greening the Economy Working, Paper 3. Rome: FAO. 2012

FAO. The Monitoring and Assessment of Greenhouse Gas Emissions and Mitigation Potentials in Agriculture. Mitigation of Climate Change in Agriculture (MICCA) Programme. 2010.

FAO. Water Use Data for Bangladesh. Food and Agriculture Organization of the United Nations. 2016. http://www.fao.org/nr/water/aquastat/water_use/index.stm

Ferdous, Z. et al. Evaluation of Surface Waters Quality Obtained from Different Sources of Mymensingh District of Bangladesh. A Scientific Journal of Krishi Foundation. 2015.

Flanagan, D.C. et al. Transactions of the American Society of Agricultural and Biological Engineering, 2012

FPMU. Monitoring Report 2013. Food Planning and Monitoring Unit, Ministry of Food, Government of the People's Republic of Bangladesh. 2013

FPMU. Monitoring Report 2015. Food Planning and Monitoring Unit, Ministry of Food, Government of the People's Republic of Bangladesh. 2015

Ganesh-Kumar A., S.K. Prashad & H. Pullabhotisa. Supply and Demand for Cereals in Bangladesh 2010-2030. IFPRI Discussion Paper. June 2012.

General Economics Division. Bangladesh Delta Plan 2100 Main Report, Inception Report. Dhaka: Planning Commission, Government of Bangladesh. 2015.

Girard, J.P. and Girard, J.L. Defining knowledge management: Toward an applied compendium. Online Journal of Applied Knowledge Management. 3(1) (2015): 1-20.

Global Water Partnership. Monitoring and evaluation indicators for IWRM strategies and plans. 2005. http://www.gwp.org/Global/ToolBox/Publications/Technical%20Briefs/03%20Monitoring%20and%20evaluation%20indicators%20for%20IWRM%20strategies%20and%20plans%20(2006)%20English.pdf

Government of Bangladesh. Bangladesh Climate Change Strategy and Action Plan. Dhaka: Ministry of Environment and Forests. 2009.

Government of Bangladesh. Master Plan for Agricultural Development in the Southern Region of Bangladesh. Dhaka: Ministry of Agriculture and FAO. 2013.

Government of Bangladesh. Master Plan for Development of Haor Areas Vol. I, II, and III. Dhaka: Ministry of Water Resources, Bangladesh Haor and Wetland Development Board. 2012.

Gray, J. H. and Densten, I. L. Towards an integrative model of organizational culture and knowledge management. International Journal of Organisational Behaviour, 9(2) (2005): 594–603

Haasnoot M., Kwakkel J.H., Walker W.E. and ter Maat J. '*Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world*' Global Environmental Change, Volume 23, Issue 2, April, Pages 485-498. (2013)

Habibullah, M., Ahmed, A.U., and Karim, Z. In Assessment of Foodgrain Production Loss Due to Climate Induced Enhanced Soil Salinity, S. Huq et al. (eds.), Vulnerability and Adaptation to Climate Change for Bangladesh, Dordrecht: Kluwer Academic Publishers, pp. 55-70, 1998.

Halder P.K., Paul N., Hoque M.E. and Ali .H., Municipal Solid Waste and its Management in Rajshahi City, Bangladesh: A Source of Energy. International Journal of Renewable Energy Research, p. 8, 2014.

Hallegatte, S. M. Bangalore, L. Bonzanigo, M. Fay, T. Kane, U. Narloch, J. Rozenberg, D. Treguer and A. Vogt-Schilb. Climate Change, Agriculture, and Food Security. In Shock Waves: Managing the Impacts of Climate Change on Poverty, 49-77. Washington DC: World Bank 2015.

Haque, A. M., Jahan, M. S. & Azad, M. A. K. Shrimp Culture Impact on the Surface and Ground Water of Bangladesh. Iranian Journal of Earth Sciences (2010).

Haque, S. Salinity Problem and Crop Production in Coastal Regions of Bangladesh. Department of Soil Science, Bangladesh Agricultural University, Mymensingh, Bangladesh. 2006.

Haque, S.A. Salinity Problems and Crop Production in Coastal Regions of Bangladesh. Pak. J. Bot., 38(5) (2006): 1359-1365.

Hardy, T. Green house impacts: SLR. In Workshop on Climatic Impacts on the Coastal Zone, North Queensland, Australia: James Cook Univ. of North Queensland, February 12-18. 1992.

Hasegawa, K. *Features of Super Cyclone SIDR to Hit Bangladesh in Nov. 07 and Measures for Disaster*—from Results of JSCE Investigation, Foundation of River & Watershed Environment Management, Hokkaido Office, Sapporo, Japan. 2008.

Havlík, P., H. Valin, M. Gusti, E. Schmid, D. Leclère, N. Forsell, M. Herrero, N. Khabarov, A. Mosnier, M. Cantele, and M. Obersteiner. Climate Change Impacts and Mitigation in the Developing World: An Integrated Assessment of Agriculture and Forestry Sectors. Washington DC: World Bank. 2011.

HDRC. Baseline Survey, for Urban Component of GOB-UNICEF Water and Sanitation Project, 2009.

Hessel C. Winsemius, Jeroen C. J. H. Aerts, Ludovicus P. H. van Beek, Marc F. P. Bierkens, Arno Bouwman, Brenden Jongman, Jaap C. J. Kwadijk, Willem Ligtvoet, Paul L. Lucas, Detlef P. van Vuuren & Philip J. Ward. Global drivers of future river flood risk

Hinkel, J., D. Lincke, A. T. Vafeidis, M. Perrette, R. J. Nicholls, R. S. J. Tol, B. Marzeion, X. Fettweis, C. Ionescu, and A. Levermann. Coastal flood damage and adaptation costs under 21st century sea-level rise. In Proceedings of the National Academy of Sciences 111:3292-3297, 2014.

Hope, Chris. The PAGE09 Integrated Assessment Model: A technical Description. Judge Business School Working Papers, Cambridge UK (2011).

Hossain, M. A., Nahiduzzaman, M., Sayeed, M. A., Azim, M. E., Wahab, M., & Olin, P. G. The Chalan beel in Bangladesh: Habitat and biodiversity degradation and implications for future management. Lakes & Reservoirs: Research & Management, (2009): 3-19.

Hossain, M.K. and Haque, A.T.M.R. Eucalyptus Dilemma in Bangladesh. IFES, University of Chattogram. 2013.

Household Income and Expenditure Survey (HIES) 2000 and 2010.

Huda, M. E. & Rahman, M. A. Study of the Seasonal Variations in Physiochemical and Biological Aspects of the Padma River at Paturia Ghat, Manikganj. Jahangirnagar University Environmental Bulletin, (2012).

ICG Bangladesh. International Haors vulnerability assessment. 2011. http://www.lcgbangladesh.org/ (Accessed 2016).

Information Systems for Water Resources Monitoring and Assessment. In Tenth South African National Hydrology Symposium: 26 – 28 September, 2001.

Institute of Water Modelling (IWM) and Centre for Climate Change and Environmental Research (CEGIS). Investigating the Impact of Relative Sea Level Rise on Coastal Communities and their Livelihoods in Bangladesh. Dhaka: Institute of Water Modelling and Centre for Climate Change and Environmental Research. 2007.

International Finance Corporation (IFC), 2015 (Annual Report)

IPCC. Climate Change 2001 – Third Assessment Report. 2001.

IPCC. Climate Change 2013: The Physical Science Basis. In Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, 2013.

IPCC. Climate Change: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. In Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, U.K. and New York: Cambridge University Press, 2014.

Islam, M. S., & Gnauck, A. Threats to the Sundarbans Mangrove Wetland Ecosystems from Transboundary Water Allocation in the Ganges Basin: A Preliminary Problem Analysis. International Journal of Ecological Economics & Statistics (IJEES), (2009).

Islam, M.S. Present Status of Wetland Biodiversity - A Study in Sujanagar Upazilla, Pabna, Bangladesh. IOSR Journal of Pharmacy and Biological Sciences (IOSRJPBS), Volume 3, Issue 1 (2012): 06-13.

Islam, S.N. Threatened Wetlands and Ecologically Sensitive Ecosystems Management in Bangladesh, Front. Earth Sci. China, 4(4) (2010): 438–448.

Islam, T. M., Hossain, M. M., & Hossain, A. A. Integrated Water Resources Management: A Case Study for Barind Area, Bangladesh. Journal of Mechanical and Civil Engineering, 11(5) (2014): 01-08.

IUCN. Bio-ecological Zone of Bangladesh. Nishat, A., Huq, S. M. Imamul, Barua, Shuvashish P., Reza, Ali A. H.M., Khan, Moniruzzaman A. S. (eds.). IUCN Bangladesh Country Office, Dhaka. 2002.

IUCN. Red Book of Threatened Fishes of Bangladesh. IUCN - The World Conservation Union, 116. 2000.

IUCN. Red List version 2015. Dhaka, Bangladesh: International Union for Conservation of Nature and Natural Resources, 2015.

IWM, Industrial Environmental Compliance and Pollution Control in Greater Dhaka – Final Report Study Phase I. 2007.

IWM. CEIP: Coastal Embankment Improvement Project, Technical Report. 2014

IWM. Impact Assessment of Climate Change and Sea Level Rise on Monsoon Flooding. Climate Change Cell, DoE, MoEF. 2008.

Karmakar, S., Haque, S. S., Hossain, M. M., & Shafiq, M. Water quality of Kaptai reservoir in Chattogram Hill Tracts of Bangladesh. Journal of Forestry Research, (2011): 87-92.

Khan, A., Mojumdar, S.K., Kovats, S., and Vineis, P. Saline contamination of drinking water in Bangladesh. Lancet, 371:385. 2008.

Khan, N. Z., Muslima, H., Shilpi, A.B., Majumder, S.K. and Khan, A.E., Neurodevelopmental Outcomes in Children Born to Climate Refugee Mothers in Bangladesh: Experiences from Cyclone Aila. Mymensingh Medical Journal: MMJ. 2016 Oct; 25(4):746.

Kunii O., Nakamura S., Abdur R. and Wakaia S. *The impact on health and risk factors of the diarrhoea epidemics in the 1998 Bangladesh floods*. Public Health. Mar;116(2):68-74. 2007.

LGD. *National Cost Sharing Strategy for Water Supply and Sanitation in Bangladesh*, Local Government Division Ministry of Local Government, Rural Development & Cooperatives, Government of the People's Republic of Bangladesh. 2011.

Loucks, C., Shannon Barber-Meyer, Md. Abdullah Abraham Hossain, Adam Barlow, Ruhul Mohaiman Chowdhury. Sea level rise and tigers: predicted impacts to Bangladesh's Sundarbans mangroves. Climatic Change, 98 (2010): 291–298.

Mainuddin, M. & Kirby, M. National Food Security in Bangladesh in 2050. Food Security (2015) 7: 633-646. June 2015.

Mathew, V. Virtual knowledge sharing and collaborative learning in organization, In Proceedings of First Virtual Conference on Business Management, 22-23 September 2009.

Matin, A. Bangladesh Poribesh Andolon (BAPA) Monitoring Cell, 2005.

Mcclelland, J., Top 5 tech innovations in agriculture, https://www.raconteur.net/sustainability/top-5-tech-innovations-in-agriculture 2015.

MCSP. *Multi-purpose Cyclone Shelter Project*, Summary Report, Bangladesh University of Engineering and Technology and Bangladesh Institute of Development Studies, Dhaka. 1993.

MICS Multiple Indicator Cluster Survey 2012-2013, UNICEF, Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh. 2014.

Ministry of Water Resources, Bangladesh. National Water Management Plan (2001), http://www.buet.ac.bd/itn/publications/sector-documents/documents/nwmpv20041.pdf

Ministry of Water, The United Republic of Tanzania. Water Sector Development Programme (2005 – 2025), http://www.pmoralg.go.tz/menu_data/Programmes/RWSP/Water_sector_development_plan.pdf

Mirza, M., & Ahmed Q.K. Climate Change and Water Resources in South Asia. Leiden: Balkema Publishers. 2005

Mirza, M., Warrick, R., Ericksen, N., & Kenny, G. Are floods getting worse in the Ganges, Brahmaputra and Meghna basins Environmental Hazards. 3, (2001): 37-48.

Mobin, M. N., Islam, M. S., Mia, M. Y. & Bakali, B. Analysis of Physicochemical Properties of the Turag River Water, Tongi, Gazipur, Bangladesh. J. Environ. Sci. & Natural Resources, (2013)

MoEF. National Forest and Tree Resources Assessment (2005-2007). Dhaka. 2008.

MoEF. Second National Communication of Bangladesh to the UNFCCC. Ministry of Environment and Forest, Government of the People's Republic of Bangladesh. 2012

Nevada Division of Water Planning. Water Resources Data Development, Collection and Management. 2013. http://water.nv.gov/programs/planning/stateplan/documents/pt3-5b.pdf

Nicholls, R.J. and S.P. Leatherman. The Implications of Accelerated Sea-Level Rise for Developing Countries: A Discussion. Journal of Coastal Research, Special Issue No. 14 Potential Impacts of Accelerated Sea-Level Rise on Developing Countries (1995): 303-323.

Nonaka, I. A dynamic theory of organizational knowledge creation. Organization science, 5(1):14-37. 1994.

Nonaka, I. and Toyama, R. The theory of the knowledge-creating firm: subjectivity, objectivity and synthesis. Industrial and Corporate Change, 14(3), p. 419- 436. 2005.

Nonaka, I., & Takeuchi, H. The knowledge-creating company: how Japanese companies create the dynamics of innovation. http://dx.doi.org/10.1016/0969-5931 (94)90027-2. 1995.

NSDS. National Development Strategy 2010-21, Dhaka: GED. Planning Commission. Bangladesh Government, 2013.

Parisi, C., Vigani, M. and Rodríguez-Cerezo, E., Agricultural Nanotechnologies: What are the current possibilities? Nano Today, Volume 10, Issue 2, April 2015, Pages 124-127. 2014.

Pasha, M.K. Mushroom. Banglapedia, 2005.

PKSF. Final Report: Development of National and Sub-National Climate Change Model for Long Term Water Resources Assessment. Dhaka: CEGIS/ Palli Karma Sahayak Foundation. 2014.

Planning Commission, General Economics Division. Bangladesh Delta Scenarios, http://bangladeshdeltaplan2100.org/wp-content/uploads/2016/02/BDP-Scenario-report-final-_18-11-2015-Final-Edit-WO-081220151.pdf 2015a.

Planning Commission, General Economics Division.Seventh Five Year Plan FY2016 – FY2020: Accelerating Growth, Empowering Citizens. 2015b.

Planning Commission, General Economics Division. Inception Report, Bangladesh Delta Plan 2100. 2014

Policy Research Institute. Inception Report, Bangladesh Delta Plan 2100, Main Report. Dhaka. 2015.

Policy Research Institute. Towards a Development Strategy for the Lower Delta Region, SPEMP. 2013

Rahman, A., Zafor, M. A. and Rahman, M. Surface water quality and risk assessment in the vicinity of Sylhet city. International Journal of Water Resources and Environmental Engineering, 2013.

Rahman, A.A., Haq, S and Conway, G.R., Environmental Aspects of Surface Water Systems of Bangladesh. 2000

Rahman, A.K.M.A. and Dhar, M. Hill Farming Practices in Chattogram- Its Constraints and Opportunities. In National Workshop on Hill Farming Practices in Bangladesh – Constraints and Opportunities. ARC, March 2008.

Rahman, AKA. Freshwater fishes of Bangladesh. 3rd ed. Dhaka: Zoological Society of Bangladesh, University of Dhaka, 394 pp, 2005.

Rahman, M. M., Ahmed, G. U. & Hasan, M. T. Seasonal variation of water quality parameters, clinical and histological observation of some small endangered open water fishes from Mymensingh and Sylhet region. Asian Journal of Medical and Biological Research, 2015.

Rahman, M.M. and Rahman M.R. Insufficiency of Drainage and Sanitation System of Rajshahi City: Impact on Human Health, Institute of Environmental Science, Unirversity of Rajshahi. 2012.

Rasel, H.M., Hasan, M.R., Ahmed, B. and Miah, M.S.U. Investigation of Soil and Water Salinity, its Effect on Crop Production and Adaptation Strategy. International Journal of Water Resources and Environmental Engineering, Vol. 5(8), (2013): 475-481.

Rasul, G. and Thapa, Gopal B. Financial and economic suitability of agroforestry as an alternative to shifting cultivation: The case of the Chattogram Hill Tracts, Bangladesh. Agricultural Systems, 91 (2006) 29-50.

Rasul, G. Ecosystem services and agricultural land-use practices: a case study of the Chattogram Hill Tracts of Bangladesh. Sustainability: Science, Practice, & Policy, Fall 2009. Volume 5, Issue 2 (2009). http://ejournal.nbii.org

REIN. Study on the Present Power Supply Situation and its impacts on the Readymade Garment Sector in Bangladesh. Renewable Energy Information Network, Bangladesh, (2009). www.iged-rein.org/archive_file/study_pw_sply_garments.pdf

Reza, A. S., & Mazumder, Q. H. Evaluation of Hydrogeological Conditions of Sapahar and Porsha Upazillas, Barind Tract, Bangladesh. Journal Life Earth Science, 1(1) (2005): 15-20.

Riches, C.R., Harris, D., Johnson, D.E. and Hardy, B. Improving Agricultural Productivity in Rice-based Systems of the High Barind Tract of Bangladesh. Manila, Philippines: IRRI. 2008.

Roads and Highways Department (RHD). 2015 http://www.rhd.gov.bd/RoadDatabase/ (Accessed: 21 December 2015)

Roy, S. Water quality of Narai canal and Balu River of Dhaka City: An impact of industrialization. J. Bangladesh Agril. Univ, 2014.

Saifullah, A. S. et al. Investigation of Some Water Quality Parameters of the Buriganga River. J. Environ. Sci. & Natural Resources, (2011).

Saifullah, A. S., Kabir, M. H., Khatun, A., Roy, S., & Sheikh, M. S. Investigation of Some Water Quality Parameters of the Buriganga River. J. Environ. Sci. & Natural Resources, (2011).

Samad M.A,. Chemical Profile and Heavy Metal Concentration in Water and Freshwater Species of Rupsha River, Bangladesh. American Journal of Environmental Protection, (2005).

Sarker, M. H. Rivers, Chars and Char Dwellers of Bangladesh. International Journal River Basin Management, 1(1), (2003): 61-80.

Sayeed, M. A., Hossain, M. A., Wahab, M. A., Hasan, M. T., Ghaffar, M. A., Das, S. K., & Mazumdar, S. K. Chemical and Pesticides uses Status in the Chalan beel, Bangladesh and Present Status of Fish Biodiversity. American Journal of Experimental Agriculture, 6(5), (2015): 267-289.

Schuman M. *The Miracle: The Epic Story of Asia's Quest for Wealth*, Harper Collins, ISBN 9780061346699. 2009.

Scott, Derek A. A Directory of Asian Wetlands, International Council for Bird Preservation (ICBP) & International Waterfowl research Bureau, 1989

Selvaraju, R. and Baas, S. Climate Variability and Change: Adaptation to Drought in Bangladesh: a Resource Book and Training Guide (Vol. 9). Food and Agriculture Organization. 2007.

Shamsuddin, S. and Hazarika, M. K. Groundwater Drought In The Northwestern Districts Of Bangladesh. Water Resource Manage 24.10: 1989-2006 (2009).

Shamsudduha, M., Chandler, R. E., Taylor, R. G. & Ahmed, K. M. Recent trends in groundwater levels in a highly seasonal hydrological system: the Ganges-Brahmaputra-Meghna Delta. Journal of Hydrology and Earth System Sciences, (2009).

Shanaz, K. Drastic fall in Chalan beel fish production. 2006. weeklyholiday.net

Siddiqi, N.A. Country Report for Assessment of Faunal Biodiversity in Bangladesh. South-Asia Cooperative Environmental Programme, Colombo, (mimeographed), (1996).

Siddiqi, N.A. Probable impact of climate change and sea level rise on mangrove forests and biodiversity of Bangladesh. Bangladesh Journal of Forest Science 31(1&2), (1996): 1-15

Siddiqui, Kamal U. Encyclopedia of Flora and Fauna of Bangladesh, Asiatic Society of Bangladesh, 2007

Siwakoti, D. G. Transboundary River Basins in South Asia: Options for Conflict Resolution. International Rivers, (2011).

Smith, B.D., Ahmed, B., Edrise, M., and Braulik, G. Status of the Ganges river dolphin or shushed Platanistagangetica in Kaptai Lake and the southern rivers of Bangladesh. Oryx 35, (2001): 61–71.

Smith, B.D., Aminul Haque, A.K.M., Hossain, M.S., and Khan, A. River dolphins in Bangladesh: conservation and the effects of water development. Environmental Management 22, (1996) 323–335.

Smith, B.D., G. Braulik, S. Strindberg, B. Ahmed, and R. Mansur. Abundance of Irrawaddy Dolphins (Orcaellabrevirostris) and Ganges River Dolphins (Platanistagangeticagangetica) Estimated using Concurrent Counts from Independent Teams in Waterways of the Sundarbans Mangrove Forest in Bangladesh. Marine Mammal Science 22(3), (2001): 527-547.

Soil Resource Development Institute (SRDI). Soil Salinity in Bangladesh – 2000. Soil Resource Development Institute, Dhaka, 2001.

Soil Resource Development Institute (SRDI). Trend in the availability of agricultural land in Bangladesh. Soil Resource Development Institute, Dhaka, 2013.

South Africa: Act No. 16 of 2013: Spatial Planning and Land Use Management Act, 2013

SRDI. Soil Salinity in Bangladesh – 2000. Dhaka: Soil Resource Development Institute. 2001.

SREDA. *Website of Sustainable and Renewable Energy Development Authority*, Power Division, Ministry of Power, Energy and Minerral Resources, Government of the People's Republic of Bangladesh, http://www.sreda.gov.bd/ 2017

Stern, N. Stern Review on the Economics of Climate Change (London: HM Treasury), 2007.

Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: IPCC, 2013.

Talukder, M. I., Fakhruddin, A. & Hossain, M. A. Environmental Impacts of Ship Breaking and Recycling Industry of Sitakunda, s.l. Canadian Research & Development Center of Sciences and Cultures. 2015.

Thompson, P.M. Sultana, P. Islam, M.N. Kabir, M.M. Hossain, M.M. and Kabir, M.S. An assessment of co-management arrangements developed by the Community Based Fisheries. In International Workshop on Fisheries Co-management. Management Project in Bangladesh, 1999, Penang, Malaysia, 1999.

Thornton, P. and L. Lipper. 'How Does Climate Change Alter Agricultural Strategies to Support Food Security? Discussion Paper #01340'. IFPRI. 2014.

Uddin, M.J., Hossain, J., Hoque, M.A. *Present Condition of Jute Sector in Bangladesh*, Banglavision Vol 14 (1), 2014.

Uddin, M. N., Alam, M. S., Mobin, M. N. & Miah, M. A. An Assessment of the River Water Quality Parameters: A case of Jamuna River. J. Environ. Sci. & Natural Resources, (2014).

UN HABITAT. State of the World's Cities 2008 / 2009 – Harmonious Cities. 2008

UN. Statistical Yearbook of 2013, Fifty Eight Issue. New York: United Nations. 2016.

UN. Statistics of Environmental Indicators. United Nations Statistics Division, United Nations. 2015 http://unstats.un.org/unsd/ENVIRONMENT/qindicators.htm

UNDP. Resilient Bangladesh: Bangladesh Annual Report (2013-2014). Dhaka: United Nations Development Programme, Bangladesh. 2014.

UNEP Guidelines for Integrated Solid Waste Management (ISWM), United Nations Environmental Programme. 2016

UNESCO. *The Properties and Availability of Water: A Fundamental Consideration for Life*. United Nations Educational, Scientific and Cultural Organization, Venice Office, Regional Bureau for Science and Culture in Europe. 2017.

UNICEF and GED. The Multiple Indicator Cluster Sample Report, 2012-13: UNICEF and General Econonomics Division, Planning Commission, Government of Bangladesh. 2014

UNICEF. Bangladesh at a Glance: Status of Children and Women, Unite for Children. UNICEF Bangladesh, Bangladesh. 2008.

Upali A., Sharma B.R., Muthuwatta L. and Khan Z.H.'*Water for Food in Bangladesh: Outlook to 2030*', (IWMI Research Report 158. 2015

van Rhee C.G. '*Handreiking Adaptief Deltamanagement. Stratelligence Decision Support*', in assignment of the Staf of the Delta commissionar, Leiden, https://deltaprogramma.pleio.nl/file/view/13006692/100812-handreiking-adm-definitief-concept-2pdf. 2012.

WARPO. Climate Change Prediction Modelling: Impact Assessment of Climate Change and Sea Level Rise on Monsoon Flooding. Dhaka: Water Resource Planning Organization.2005.

WARPO. Final Report for Maintenance, Updating and Dissemination of National Water Resources Database. Water Management Improvement Project. Dhaka: Water Resources Planning Organization. 2015.

WARPO. National Water Management Plan, Summary: Volume I. Bangladesh: Ministry of Water Resources, Government of People's Republic of Bangladesh. 2001.

WMF, Swatch of No-Ground declared protected zone (Bangladesh), Whlaes and Marine Fauna Website: https://whalesandmarinefauna.wordpress.com/2014/11/02/swatch-of-no-ground-declared-protected-zone-bangladesh/ 2014.

WHO/UNICEF Joint Monitoring Programme for Water Supply, 2014.

Wilde, K. de., Setting the Stage In: Moving Coastlines, Koen de Wilde edited, University Press Limited, Dhaka, 2011.

Winston, H. A. Climate Change Risks and Food Security in Bangladesh. London, United Kingdom: Earthscan, 2010.

World Bank. Bangladesh: Economics of Adaptation to Climate Change. Country Case Studies: EACC Publications and Reports. Washington DC: The World Bank Group. 2010.

World Bank. Bangladesh: Economics of Adaptation to Climate Change. Washingtonne DC: World Bank Group.2010.

World Bank. Climate-Smart Agriculture: Increased Productivity and Food Security, Enhanced Resilience and Reduced Carbon Emissions for Sustainable Development. Washington, DC: World Bank. 2011.

World Bank. Country wise Indicators. 2015 http://data.worldbank.org/indicator/ER.H2O.INTR.PC.

World Bank. World Development Indicators (WDI). 2015. at: http://data.worldbank.org/news/release-of-world-development-indicators-2015

Zahid, A., Balke, K. D., Hassan, M.Q., Flegr, M. (2006): Evaluation of aquifer environment under Hazaribagh leather processing zone of Dhaka city. Journal of Environmental Geology, Volume 50 (4): 495-504

Zakir, H. M. et al. Heavy Metals and Major Ionic Pollution Assessment in Waters of Bangladesh. J. Environ. Sci. & Natural Resources, (2013).

Zuthi, M., Biswas, M., & Bahar, M. Assessment of Supply Water Quality in The Chattogram City of Bangladesh. ARPN Journal of Engineering and Applied Sciences, 4(3) (2009).

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	2	River System Management
	3	Water Resources
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	7	Meghna Estuary Study
2. Disaster and Environmental Management	8	Climate Change
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5. Socio-economic Aspects of the Bangladesh Delta	19	Population Growth and Management
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	24	Regional Cooperation
	25	Financing Mechanisms
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Annex A: Technical Annex to Chapter 2

A.2.1. District Level Poverty

Table A2. 1: Coastal Zone District Level Poverty and Inequality (%)

	2000				2010			
	Head count	Gap	Severity	Gini	Head count	Gap	Severity	Gini
Upper Poverty Line (UPL)								
Coastal Zone	**48.5**	**14.6**	**5.4**	**0.32**	**32.1**	**6.9**	**2.3**	**0.33**
Bagerhat	32.3	13.2	4.3	0.28	42.8	11.2	4.1	0.31
Barguna	54.2	12.2	4.1	0.26	19.0	3.8	1.1	0.35
Bhola	68.5	15.0	5.5	0.34	33.2	5.8	1.7	0.26
Cox's bazar	40.6	7.8	2.3	0.29	32.7	5.8	1.5	0.34
Feni	44.8	9.2	3.0	0.34	25.9	3.5	1.3	0.33
Jashore	32.4	15.1	5.4	0.36	39.0	6.9	1.9	0.23
Jhalokati	33.8	9.2	2.9	0.24	40.5	10.6	4.5	0.38
Lakshmipur	57.8	19.5	8.3	0.33	31.2	6.3	1.9	0.28
Narail	74.5	22.7	8.9	0.40	20.0	2.7	0.7	0.21
Noakhali	74.6	18.8	7.8	0.32	9.6	1.3	0.4	0.33
Patuakhali	40.0	7.7	1.9	0.31	25.8	8.3	2.5	0.36
Pirojpur	51.1	16.9	6.7	0.32	44.1	12.5	4.0	0.39
Satkhira	36.7	16.3	6.2	0.30	46.3	10.3	4.2	0.22

Source: Estimate based on HIES 2000 and 2010

Table A2. 2: Barind and Drought Prone District Level Poverty and Inequality (%)

	2000				2010			
	Head count	Gap	Severity	Gini	Head count	Gap	Severity	Gini
Upper Poverty Line (UPL)								
Barind and Drought Prone	**52.8**	**23.0**	**9.8**	**0.29**	**27.3**	**6.6**	**2.1**	**0.33**
Chuadanga	35.4	13.0	4.6	0.21	27.7	4.6	1.2	0.36
Dinajpur	49.6	21.6	8.6	0.24	37.9	8.8	2.6	0.36
Joypurhat	50.3	21.2	7.7	0.19	26.7	6.5	1.8	0.23
Kushtia	67.8	27.2	11.0	0.21	3.6	0.0	0.0	0.23
Meherpur	41.4	23.0	8.8	0.37	15.2	1.3	0.3	0.25
Naogaon	46.3	18.9	7.6	0.27	16.9	3.0	0.7	0.26
Natore	42.8	15.0	4.7	0.18	35.1	8.9	2.9	0.30
Nawabganj	47.4	13.0	4.3	0.18	25.3	3.2	0.8	0.19
Panchagarh	61.0	27.0	10.1	0.19	26.7	7.4	2.4	0.26
Rangpur	69.0	35.2	18.6	0.37	46.2	11.5	4.3	0.32
Sirajganj	59.7	22.4	10.4	0.40	38.7	10.8	3.5	0.27
Thakurgaon	62.7	29.0	12.4	0.24	27.0	3.8	1.0	0.35

Source: Estimate based on HIES 2000 and 2010

Table A2. 3: River Systems and Estuaries District Level Poverty and Inequality (%)

	2000				2010			
	Head count	Gap	Severity	Gini	Head count	Gap	Severity	Gini
Upper Poverty Line (UPL)								
River Systems & Estuaries	**53.7**	**16.1**	**6.4**	**0.33**	**38.3**	**8.4**	**2.6**	**0.31**
Bogura	45.7	15.9	5.6	0.35	16.6	3.8	1.1	0.34
Chandpur	52.2	10.0	3.6	0.25	51.0	6.7	1.8	0.22
Cumilla	32.0	6.8	2.1	0.29	37.9	8.6	2.6	0.25
Faridpur	65.5	17.5	7.8	0.35	36.3	6.9	1.9	0.22
Gaibandha	*70.5*	*31.6*	*15.5*	*0.29*	*48.0*	*13.9*	*4.8*	*0.41*
Jamalpur	*56.6*	*16.6*	*5.7*	*0.23*	*51.1*	*13.2*	*4.9*	*0.24*
Kurigram	*57.8*	*26.8*	*11.5*	*0.29*	*63.7*	*17.5*	*5.5*	*0.22*
Madaripur	68.6	35.5	16.9	0.32	34.9	5.7	1.3	0.21
Manikganj	57.0	18.0	5.9	0.23	18.5	4.3	1.2	0.20
Munshiganj	49.4	12.8	3.6	0.20	28.7	6.1	1.8	0.22
Narayanganj	17.0	3.8	1.1	0.33	26.1	3.9	0.9	0.21
Pabna	*49.5*	*19.0*	*6.6*	*0.22*	*31.5*	*5.3*	*1.3*	*0.27*
Rajbari	*63.4*	*14.2*	*5.7*	*0.32*	*41.9*	*11.6*	*3.4*	*0.24*
Shariatpur	*73.3*	*29.8*	*13.3*	*0.25*	*52.6*	*10.5*	*3.1*	*0.23*
Tangail	65.6	23.5	11.0	0.37	29.7	6.2	2.0	0.29
Narshingdi	18.3	5.6	1.8	0.31	23.7	3.9	0.9	0.26
Gopalganj	69.4	26.1	11.1	0.21	42.7	9.0	2.9	0.28

Source: Estimate based on HIES 2000 and 2010

A.2.2 Sub-District Level Poverty

Table A2. 4: Coastal Zone Sub-District Level Poverty and Inequality (%)

Hotspot: Coastal Zone	2000				2010			
	Head Count	Gap	Severity	Gini	Head Count	Gap	Severity	Gini
District: Bagerhat	**56.1**	**13.2**	**4.3**	**0.28**	**43.2**	**11.2**	**4.1**	**0.31**
Sub-Districts								
Bagerhat Sadar	48.9	12.2	4.1	0.31	35.9	7.0	3.1	0.18
Chitalmari		-	-	-	50	1.1	0.3	0.24
Fakirhat		-	-	-	36.4	14.3	6.2	0.30
Mollar Hat	75.2	18.5	5.8	0.18	46.1	11.8	4.0	0.23
Morrelganj	62.2	10.2	2.9	0.21	46.5	9.6	3.2	0.22
Rampal	40.0	11.0	4.2	0.28	41.1	19.4	7.1	0.23
District: Jashore	**50.2**	**15.1**	**5.4**	**0.36**	**39.8**	**6.9**	**1.9**	**0.23**
Sub-Districts								
Abhaynagar	79.0	22.2	7.9	0.22	36.0	7.2	1.9	0.26
Chaugachha	68.3	21.6	8.8	0.25	42.8	3.7	0.7	0.12
Jhikargachha	-	-	-	-	38.9	4.8	0.8	0.17
Keshabpur	84.8	27.2	9.9	0.19	42.0	10.9	3.4	0.14
Jashore Sadar	24.2	4.9	1.2	0.37	35.3	7.0	2.2	0.25
Manirampur	38.1	9.7	2.7	0.19	40.2	7.7	2.3	0.16
Sharsha	41.8	13.4	5.3	0.25	40.8	7.3	2.1	0.15

Hotspot: Coastal Zone	2000				2010			
	Head Count	Gap	Severity	Gini	Head Count	Gap	Severity	Gini
District: Lakshmipur	**56.1**	**19.5**	**8.3**	**0.3**	**26.6**	**6.4**	**1.9**	**0.28**
Sub-Districts								
Lakshmipur Sadar	32.7	9.8	3.1	0.3	45.6	6.9	1.9	0.28
Raipur	-	-	-	-	16.7	0.5	0.1	0.22
Ramganj	45.3	16.5	7.0	0.3	21.4	18.5	7.0	0.21
Ramgati	84.9	29.6	13.5	0.2	30.4	6.6	2.0	0.27
District: Pirojpur	**55.5**	**16.9**	**6.7**	**0.32**	**45.5**	**12.5**	**4.0**	**0.39**
Sub-Districts								
Bhandaria	76.9	26.8	11.3	0.22	42.0	12.5	3.1	0.19
Kawkhali	-	-	-	-	52.2	12.5	3.6	0.20
Mathbaria	81.4	18.7	5.7	0.15	38.0	16.5	5.0	0.16
Nazirpur	30.2	8.1	3.9	0.33	51.5	11.4	4.1	0.29
Pirojpur Sadar	40.8	12.6	5.2	0.31	42.7	18.2	7.4	0.24
Nesarabad (Swarupkati)	-	-	-	-	43.3	2.9	0.6	0.14
District: Satkhira	**57.2**	**16.3**	**6.2**	**0.3**	**46.6**	**10.3**	**4.2**	**0.22**
Sub-Districts								
Assasuni	55.8	14.3	4.8	0.28	48.4	22.3	13.2	0.21
Kalaroa	-	-	-	-	46.0	6.0	1.8	0.21
Kaliganj	67.4	24.2	9.5	0.29	48.0	4.2	1.4	0.23
Satkhira Sadar	57.4	18.6	8.0	0.32	43.1	10.4	3.6	0.19
Shyamnagar	-	-	-	-	50.2	15.2	5.6	0.21
Tala	49.1	7.4	1.6	0.25	45.2	2.7	0.4	0.16

Source: Estimate based on HIES 2000 and 2010

Table A2. 5: Barind and Drought Prone-District Level Poverty and Inequality (%)

Hotspot: Barind and Drought Prone Areas	2000				2010			
	Head Count	Gap	Severity	Gini	Head Count	Gap	Severity	Gini
District: Chuadanga	**55.6**	**13.0**	**4.6**	**0.21**	**27.8**	**4.7**	**1.2**	**0.36**
Sub-Districts								
Alamdanga	47.2	9.3	2.6	0.18	26.0	5.5	1.1	0.17
Chuadanga Sadar	65.2	17.6	7.1	0.24	29.2	2.8	0.6	0.42
Damurhuda	-	-	-	-	27.1	4.8	1.1	0.18
Jibannagar	-	-	-	-	29.1	5.7	2.5	0.14
District: Dinajpur	**67.28**	**21.6**	**8.63**	**0.24**	**38.9**	**8.8**	**2.58**	**0.36**
Sub-Districts								
Birampur	-	-	-	-	35.9	13.1	3.4	0.25
Biral	-	-	-	-	38.8	21.5	8.0	0.27
Chirirbandar	70.8	28.5	13.3	0.30	38.5	2.5	0.4	0.25
Kaharole	76.4	22.8	8.7	0.18	44.3	8.0	2.4	0.15
Dinajpur Sadar	64.4	24.0	10.3	0.25	28.2	5.0	1.3	0.31
Nawabganj	78.6	16.5	4.9	0.22	37.3	9.9	2.4	0.22
Parbatipur	69.4	20.9	7.4	0.21	39.7	-	-	-
District: Joypurhat	**77.5**	**21.2**	**7.7**	**0.19**	**26.6**	**6.5**	**1.8**	**0.23**
Sub-Districts								
Joypurhat Sadar	-	-	-	-	26.0	3.3	0.5	0.18

Hotspot: Barind and Drought Prone Areas	2000				2010			
	Head Count	Gap	Severity	Gini	Head Count	Gap	Severity	Gini
Kalai	-	-	-	-	25.6	8.8	2.9	0.26
Panchbibi	87.2	26.2	9.7	0.18	28.3	7.7	2.1	0.24
District: Natore	**61.8**	**15.0**	**4.7**	**0.18**	**35.0**	**8.9**	**3.0**	**0.3**
Sub-Districts								
Bagatipara	-	-	-	-	31.6	13.8	5.5	0.20
Baraigram	83.5	18.8	5.1	0.11	36.1	3.8	0.9	0.24
Lalpur	-	-	-	-	35.7	10.7	4.0	0.20
Natore Sadar	45.4	9.2	2.4	0.14	31.8	7.3	2.0	0.29
Singra	54.9	17.0	6.9	0.25	37.8	11.8	4.1	0.25
District: Panchagarh	**84.2**	**27.0**	**10.1**	**0.19**	**26.1**	**7.5**	**2.4**	**0.26**
Sub-Districts								
Atwari	-	-	-	-	24.1	3.9	1.0	0.27
Boda	77.7	26.4	9.9	0.22	26.6	15.7	5.5	0.17
Debiganj	-	-	-	-	34.2	11.5	3.9	0.22
Panchagarh Sadar	-	-	-	-	24.2	4.3	1.2	0.23
Tetulia	91.0	27.5	10.3	0.15	21.5	2.2	0.4	0.16
District: Rangpur	**74.3**	**35.2**	**18.6**	**0.37**	**47.9**	**11.5**	**4.3**	**0.32**
Sub-Districts								
Badarganj	-	-	-	-	48.3	15.3	5.0	0.21
Gangachhara	-	-	-	-	58.3	26.7	12.1	0.18
Rangpur Sadar	45.0	18.0	7.9	0.33	37.1	8.9	3.3	0.35
Mithapukur	73.2	28.3	13.3	0.25	45.4	4.7	1.7	0.21
Pirgachha	-	-	-	-	49.7	9.8	3.6	0.17
Pirganj	100.0	52.2	29.5	0.17	46.9	6.3	1.6	0.18
Taraganj	87.2	38.5	19.6	0.23	52.4	10.6	3.6	0.14
District: Sirajganj	**62.0**	**22.4**	**10.4**	**0.4**	**38.6**	**10.8**	**3.5**	**0.27**
Sub-Districts								
Belkuchi	79.6	27.8	13.3	0.26	42.5	11.8	3.3	0.18
Kazipur	86.0	35.1	17.2	0.22	36.2	8.9	2.7	0.26
Shahjadpur	37.6	4.9	1.0	0.19	41.8	12.1	3.6	0.33
Sirajganj Sadar	37.6	12.0	4.5	0.41	36.7	12.5	4.7	0.20
Tarash	82.7	29.6	13.4	0.24	35.8	14.2	5.2	0.16
Ullahpara	88.8	40.4	21.7	0.24	36.6	5.4	1.5	0.15

Source: Estimate based on HIES 2000 and 2010

Table A2. 6: River Systems and Estuaries -District Level Poverty and Inequality (%)

Hotspot: River Systems & Estuaries	2000				2010			
	Head Count	Gap	Severity	Gini	Head Count	Gap	Severity	Gini
District: Gaibandha	**80.5**	**31.6**	**15.5**	**0.29**	**49.2**	**13.9**	**4.8**	**0.41**
Sub-Districts								
Gaibandha Sadar	91.5	34.7	15.7	0.18	44.8	14.0	4.9	0.32
Gobindaganj	83.9	34.4	19.1	0.26	45.4	3.1	0.9	0.47
Palashbari	57.5	13.4	3.8	0.26	44.8	17.5	5.9	0.21
Sadullapur	98.9	44.8	23.1	0.19	51.0			
Sughatta	66.0	32.5	18.1	0.40	52.8	8.9	2.8	0.15
Sundarganj	87.4	30.3	13.4	0.20	47.6	25.8	9.4	0.17

Hotspot: River Systems & Estuaries	2000				2010			
	Head Count	Gap	Severity	Gini	Head Count	Gap	Severity	Gini
District: Jamalpur	**64.5**	**16.6**	**5.8**	**0.23**	**51.6**	**13.2**	**4.9**	**0.24**
Sub-Districts								
Bakshiganj	-	-	-	-	50.4	8.4	2.1	0.19
Dewanganj	88.7	25.8	9.2	0.16	58.5	18.3	8.5	0.23
Islampur	63.3	20.2	7.6	0.23	55.0	19.1	7.9	0.20
Jamalpur Sadar	71.2	18.2	6.5	0.22	49.8	16.3	5.8	0.26
Madarganj	50.0	15.2	5.9	0.32	55.5	13.1	5.3	0.19
Melandaha	-	-	-	-	47.2	3.5	1.0	0.16
Sarishabari	51.9	10.9	3.1	0.18	44.7	11.5	3.1	0.27
District: Kurigram	**80.5**	**26.8**	**11.5**	**0.29**	**64.1**	**17.6**	**5.5**	**0.22**
Sub-Districts								
Bhurungamari	96.3	38.8	18.8	0.18	65.1	3.5	0.5	0.18
Phulbari	-	-	-	-	68.8	25.0	8.1	0.11
Kurigram Sadar	-	-	-	-	58.0	4.3	1.2	0.16
Nageshwari	65.8	23.0	10.0	0.29	65.0	21.2	7.1	0.18
Raomari	-	-	-	-	57.0	20.9	7.1	0.15
Ulipur	93.2	24.0	8.7	0.17	65.3	17.9	5.2	0.21
District: Pabna	**71.6**	**19.1**	**6.6**	**0.22**	**32.2**	**5.3**	**1.3**	**0.27**
Sub-Districts								
Atgharia	-	-	-	-	31.2	6.3	1.4	0.25
Bera	92.7	29.5	10.6	0.14	39.4	5.8	1.8	0.14
Chatmohar	97.9	29.7	9.7	0.08	31.4	3.0	0.7	0.20
Ishwardi	46.3	6.9	1.7	0.25	26.2	5.6	1.3	0.15
Pabna Sadar	58.8	15.2	5.9	0.24	27.8	7.9	1.7	0.35
Santhia	78.0	22.4	8.7	0.20	33.1	4.6	1.1	0.25
Sujanagar	62.0	12.5	3.7	0.13	35.4	3.3	1.0	0.14
District: Rajbari	**58.9**	**14.2**	**5.7**	**0.32**	**42.8**	**11.6**	**3.4**	**0.24**
Sub-Districts								
Baliakandi	90.0	27.5	9.8	0.15	39.7	11.7	3.3	0.14
Goalandaghat	-	-	-	-	50.5	7.5	1.8	0.17
Pangsha	-	-	-	-	45.7	17.6	5.7	0.25
Rajbari Sadar	41.2	9.7	4.3	0.33	38.7	7.7	2.0	0.27
District: Shariatpur	**82.3**	**29.8**	**13.3**	**0.25**	**52.4**	**10.5**	**3.1**	**0.23**
Sub-Districts								
Bhedarganj	-	-	-	-	56.3	14.0	3.9	0.18
Gosairhat	85.7	30.5	12.9	0.22	58.3	3.0	0.5	0.11
Naria	81.3	36.8	19.4	0.25	48.1	5.1	1.8	0.23
Shariatpur Sadar	79.8	21.3	7.3	0.24	49.8	18.1	5.6	0.26
District: Gopalganj	**73.8**	**26.1**	**11.1**	**0.21**	**42.6**	**9.0**	**3.0**	**0.28**
Sub-Districts								
Gopalganj Sadar	84.8	28.2	11.7	0.20	41.1	6.3	1.6	0.32
Kashiani	-	-	-	-	39.1	1.7	0.3	0.19
Kotalipara	65.1	20.9	7.5	0.21	43.6	13.5	4.9	0.16
Muksudpur	71.6	28.9	13.7	0.21	46.5	11.7	3.7	0.20
Tungipara	-	-	-	-	42.6	13.7	5.1	0.19

Source: Estimates from HIES

Annex B: Technical Annex to Chapter 5

Table B5. 1: Key Macroeconomic Indicators BAU Policy Option, FY2016 to FY2041

Fiscal Year	FY16	FY20	FY21	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41	Average (FY21-41)
Real Sector Indicators:						(Growth Rate)						
Real GDP growth	7.1	7.3	7.3	7.3	7.3	7.2	7.1	6.7	6.6	5.8	5.5	6.9
Inflation(CPI Base, % Change)	6.1	5.5	5.3	5.0	4.9	4.7	4.6	4.5	4.5	4.50	4.40	4.7
ICOR	4.3	4.3	4.3	4.5	4.5	4.5	4.5	4.6	4.6	4.55	4.55	4.5
Population growth	1.2	1.1	1.1	0.9	0.9	0.7	0.7	0.6	0.5	0.4	0.4	0.7
						(As % of GDP)						
Gross National Savings	31.6	34.7	35.1	36.9	37.4	39.8	40.3	42.3	42.6	44.8	45.4	40.2
Gross Domestic Savings	25.7	29.8	30.4	32.4	32.9	35.1	35.6	37.8	38.4	40.7	41.3	35.7
Gross Investment	30.1	34.1	34.7	36.7	37.2	39.4	39.9	42.1	42.7	45.0	45.6	40.0
Public Investment (Including PPP)	6.4	7.8	7.8	7.9	7.9	7.9	8.0	8.1	8.1	8.2	8.2	8.0
Private Investment (Including PPP)	23.7	26.3	26.9	28.8	29.3	31.5	31.9	34.0	34.6	36.8	37.4	32.0
Foreign Domestic Investment(FDI)	1.2	3.0	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Domestic Investment	22.5	23.3	23.9	25.8	26.3	28.5	28.9	31.0	31.6	33.8	34.4	29.0
GNI Per Capita USD	1434	1755	1899	2631	2864	4023	4703	6099	6615	9014	9676	
Population in million	163	170	172	179	181	186	188	193	194	197	198	
Fiscal Indicators:						(As % of GDP)						
Revenue and Grants	10.6	12.5	13.0	14.6	15.0	16.5	17.0	18.6	19.0	20.5	20.9	16.9
Total Revenue	10.3	12.2	12.7	14.3	14.7	16.3	16.8	18.4	18.8	20.4	20.8	16.8
Tax Revenue	9.0	10.5	10.9	12.5	12.9	14.5	14.9	16.5	16.9	18.5	18.9	14.9
NBR Tax Revenue	8.7	10.2	10.6	12.2	12.6	14.2	14.6	16.2	16.6	18.2	18.6	14.6
Non-NBR Tax Revenue	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Non-Tax Revenue	1.3	1.7	1.8	1.8	1.8	1.8	1.9	1.9	1.9	1.9	1.9	1.9
Grants	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.2
Total Expenditure	15.0	17.5	18.0	19.7	20.1	21.8	22.3	23.9	24.3	26.0	26.4	22.2
Revenue Expenditure	9.4	11.2	11.6	13.0	13.4	14.8	15.2	16.6	17.0	18.4	18.8	15.2
Development Expenditure	5.6	6.3	6.5	6.7	6.7	7.0	7.1	7.3	7.3	7.6	7.6	7.0
Overall Balance (Incl. grants)	-4.7	-5.3	-5.3	-5.4	-5.4	-5.5	-5.5	-5.5	-5.5	-5.6	-5.6	-5.5

Fiscal Year	FY16	FY20	FY21	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41	Average (FY21-41)
Financing	4.7	5.3	5.3	5.4	5.4	5.5	5.5	5.5	5.5	5.6	5.6	5.5
Net External Financing	1.1	1.6	1.7	1.8	1.8	2.0	2.0	1.8	1.7	1.7	1.7	1.8
Domestic financing	3.6	3.7	3.7	3.6	3.6	3.5	3.5	3.7	3.9	3.9	3.9	3.7
Debt Indicators:	**(As % of GDP)**											
Total Debt outstanding	36.5	37.1	37.5	38.8	39.0	39.9	40.0	40.1	40.0	39.9	39.9	39.4
External Debt	13.7	12.9	13.1	13.6	13.8	14.6	14.8	14.6	14.5	14.0	14.0	14.1
Domestic Debt	22.9	24.1	24.4	25.2	25.2	25.3	25.3	25.5	25.5	25.9	25.9	25.3
	(In billions of USD)											
Total Debt outstanding	80.6	120.7	135.1	211.5	236.8	372.3	417.0	651.2	726.7	1149.4	1290.6	
External Debt	30.2	42.2	47.1	74.3	83.6	136.1	153.9	237.5	262.9	404.2	452.2	
Domestic Debt	50.4	78.5	88.1	137.3	153.2	236.2	263.0	413.7	463.8	745.2	838.4	
Total Debt Services	3.0	3.1	3.1	3.1	3.1	3.1	3.2	3.2	3.3	3.3	3.3	3.2
External	0.9	0.9	1.0	1.0	1.0	1.1	1.2	1.2	1.2	1.2	1.2	1.1
Domestic	2.1	2.2	2.1	2.1	2.1	2.0	2.0	2.0	2.0	2.1	2.1	2.1
External debt as% export& remittance	62.7	53.7	52.5	49.0	48.6	48.1	48.2	46.7	46.3	46.8	47.3	48.1
External debt services as% export& remittance	4.1	3.8	3.9	3.6	3.5	3.6	3.8	3.7	3.9	4.0	4.1	3.8
Reserves, In Months of Import	9.1	11.9	12.0	12.4	12.5	12.9	13.0	13.4	13.5	13.9	14.0	13.0
External Indicators:	**(Growth rate or otherwise indicated)**											
Export growth	9.0	12.5	15.5	12.0	14.8	14.2	11.5	13.0	11.0	11.5	10.5	13.3
Import growth	7.0	11.0	15.3	11.5	13.8	12.6	10.5	11.6	10.3	10.4	10.2	12.3
Service growth	14.0	13.0	13.0	13.0	13.0	13.0	12.5	14.0	12.5	14.0	12.0	13.3
Income receipt growth	10.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
remittance growth	-0.5	10.0	11.0	10.5	10.0	8.5	8.1	6.5	6.1	4.5	4.1	7.9
Current Account Balance as (%) of GDP	1.7	-1.8	2.5	-1.9	2.5	2.9	-2.0	3.4	-1.8	3.7	-1.5	2.1
FDI as (%) of GDP	1.2	2.5	3.1	3.0	3.0	3.0	3.2	3.0	3.4	3.0	3.4	3.1
Net MLT as % of GDP	1.1	1.1	1.1	1.2	1.2	1.3	1.4	1.2	1.1	1.1	1.1	1.2
Monetary Indicators:	**(Growth rate or otherwise indicated)**											
Broad Money	15.8	16.3	16.4	16.5	16.7	16.9	16.7	17.2	17.0	17.4	17.2	16.9
Net Foreign Assets	18.2	11.6	13.4	12.9	12.9	13.2	12.5	13.6	12.0	13.9	11.0	13.1
Private sector	13.2	13.8	16.5	14.5	16.7	16.4	14.2	16.0	14.0	15.6	13.5	15.9

Source: GED Projections

Table B5. 2: Key Macroeconomic Indicators Delta Plan Policy Option, FY2016 to FY2041

Fiscal Year	FY16	FY20	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41	Avg (21-41)
Real Sector Indicators:	(Growth rate)										
Real GDP growth	7.1	8.0	8.5	8.6	8.9	9.0	9.4	9.5	9.8	9.9	9.0
Inflation(CPI Base, % Change)	6.1	5.5	5.0	4.9	4.7	4.6	4.5	4.5	4.5	4.4	4.7
Inflation(Deflator Base)	6.1	5.5	5.0	4.9	4.7	4.6	4.5	4.5	4.5	4.4	4.7
ICOR	4.3	4.4	4.5	4.5	4.6	4.6	4.6	4.7	4.7	4.7	4.6
Population Growth	1.2	1.1	0.9	0.9	0.7	0.7	0.6	0.5	0.4	0.4	0.7
	(As % of GDP)										
Gross National Savings	31.6	35.8	38.1	38.6	41.0	41.6	43.6	43.9	46.1	46.7	41.4
Gross Domestic Savings	25.7	29.9	31.9	32.4	35.0	35.6	38.3	38.8	41.9	42.7	35.8
Gross Investment	30.1	35.2	37.9	38.4	40.6	41.2	43.4	44.0	46.3	46.9	41.2
Public Investment (Including PPP)	6.4	9.0	9.2	9.2	9.3	9.4	9.5	9.5	9.6	9.6	9.3
Private Investment (Including PPP)	23.7	26.1	28.6	29.2	31.3	31.8	34.0	34.5	36.7	37.3	31.9
Foreign Domestic Investment(FDI)	1.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Domestic Investment	22.5	23.1	25.6	26.2	28.3	28.8	31.0	31.5	33.7	34.3	28.9
Index of Real per capita Consumption	100	126	182	197	265	286	390	423	581	630	321
GNI Per Capita USD	1434	1964	3079	3389	5040	5579	8476	9438	14679	16994	6904
Population in million	163	170	179	181	186	188	193	194	197	198	
Fiscal Indicators:	(As % of GDP)										
Revenue and Grants	10.6	14.7	17.0	17.5	19.2	19.7	21.5	22.0	23.7	24.2	19.7
Total Revenue	10.3	14.4	16.7	17.2	19.0	19.5	21.3	21.8	23.6	24.1	19.5
Tax Revenue	9.0	12.4	14.7	15.1	16.9	17.4	19.2	19.6	21.4	21.9	17.4
NBR Tax Revenue	8.7	12.0	14.3	14.7	16.5	17.0	18.8	19.2	21.0	21.5	17.0
Non-NBR Tax Revenue	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Non-Tax Revenue	1.3	2.0	2.1	2.1	2.1	2.2	2.2	2.2	2.2	2.2	2.1
Grants	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.2
Total Expenditure	15.0	19.1	21.5	22.0	23.8	24.3	26.1	26.7	28.5	29.0	24.3
Revenue Expenditure	9.4	12.2	14.2	14.6	16.2	16.6	18.2	18.6	20.2	20.6	16.6
Development Expenditure	5.6	6.9	7.3	7.4	7.6	7.7	7.9	8.1	8.3	8.3	7.7
Overall Balance (Incl. grants)	-4.7	-4.7	-4.8	-4.8	-4.8	-4.8	-4.8	-4.9	-4.9	-4.9	-4.8

Fiscal Year	FY16	FY20	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41	Avg (21-41)
Financing	4.7	4.7	4.8	4.8	4.8	4.8	4.8	4.9	4.9	4.9	4.8
Net External Financing	1.1	1.1	1.2	1.2	1.3	1.4	1.2	1.1	1.1	1.1	1.2
Domestic financing	3.6	3.7	3.6	3.5	3.5	3.5	3.7	3.8	3.8	3.8	3.6
Debt Indicators:	**(As % of GDP)**										
Total Debt outstanding	36.5	36.5	36.8	36.8	36.9	37.0	37.2	37.2	37.2	37.2	37.0
External Debt	13.7	11.7	10.7	10.6	10.6	10.7	10.2	9.9	9.3	9.2	10.3
Domestic Debt	22.9	24.8	26.1	26.2	26.3	26.3	27.0	27.3	27.9	28.0	26.6
Debt Indicators:	**(In billions of USD)**										
Total Debt outstanding	80.6	118.9	200.7	223.2	344.6	384.9	603.4	676.1	1072.0	1204.6	
External Debt	30.2	38.2	58.4	64.4	99.0	110.9	165.0	180.6	268.1	298.0	
Domestic Debt	50.4	80.7	142.2	158.7	245.6	274.0	438.3	495.5	803.9	906.6	
Total Debt Services	3.0	3.3	3.3	3.2	3.2	3.3	3.3	3.4	3.4	3.4	3.3
External	0.9	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.1
Domestic	2.1	2.3	2.2	2.2	2.1	2.1	2.2	2.2	2.2	2.2	2.2
External debt as% export& remittance	62.7	48.6	38.6	37.4	35.0	34.7	32.5	31.8	31.1	31.2	35.4
External debt services as% export& remittance	4.1	4.3	3.8	3.8	3.7	3.8	3.7	3.8	3.9	4.0	3.9
External Indicators:	**(Growth rate or otherwise indicated)**										
Export growth	9.0	15.2	14.9	14.8	14.2	14.0	13.0	12.8	11.5	11.5	13.7
Import growth	7.0	13.5	14.1	13.8	12.6	12.3	11.6	11.0	10.4	10.0	12.6
Service growth	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Income receipt growth	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Remittance growth	-0.5	10.0	10.5	10.0	8.5	8.1	6.5	6.1	4.5	4.1	7.9
Current Account Balance as (%) of GDP	1.7	2.6	2.5	2.5	2.9	3.1	3.4	3.6	3.7	3.9	3.1
FDI as (%) of GDP	1.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Net MLT as % of GDP	1.1	1.1	1.2	1.2	1.3	1.4	1.2	1.1	1.1	1.1	1.2
Reserves in months of imports	9.1	11.9	12.4	12.5	12.9	13.0	13.4	13.5	13.9	14.0	13.0
Monetary Indicators:	**(Growth Rate)**										
Broad Money	15.8	16.3	16.6	16.7	16.9	16.9	17.2	17.2	17.4	17.5	16.9
Net Foreign Assets	18.2	11.6	12.9	12.9	13.2	13.3	13.6	13.6	13.9	14.0	13.3
Private sector	13.2	16.0	16.8	16.7	16.4	16.3	16.0	15.9	15.6	15.5	16.3

Source: GED Projections

Table B5. 3: Employment and Poverty Outcomes under Business as Usual (BAU) Option, FY2016- FY2041

Fiscal Year	FY16	FY20	FY21	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Indicators:											
Real GDP Growth (%)	7.1	7.3	7.3	7.3	7.3	7.2	7.1	6.7	6.6	5.78	5.48
Capital Stock, in billion USD	207.1	314.6	348.4	509.4	557.6	791.3	862.2	1212.4	1319.5	1851.19	2015.26
of which: capital loss, in billion USD	0.0	3.6	4.1	6.1	6.7	9.6	10.5	15.0	16.4	18.30	18.80
Labor force, In million	65.6	72.2	73.9	80.4	82.0	88.4	90.2	96.6	98.2	104.18	105.67
Employed	62.5	68.3	69.8	75.1	76.5	81.1	82.4	86.4	87.2	89.72	90.20
Unemployed	3.1	3.9	4.1	5.3	5.6	7.3	7.8	10.3	11.0	14.46	15.47
New Unemployment, in million	0.0	0.5	0.7	1.6	1.9	3.3	3.8	6.0	6.7	9.87	10.81
Labor force Participation rate (%)	58.9	60.1	60.5	61.8	62.2	63.5	64.0	65.6	66.0	67.58	68.00
Loss of Real GDP, in billion USD	0.0	3.2	4.4	11.6	14.3	30.2	36.0	70.0	82.2	153.18	178.32
of which: Loss due to Natural Disasters	0.0	0.7	0.7	0.9	1.0	1.3	1.4	1.8	2.0	2.67	2.87
Nominal GDP per capita, in USD	1354.2	1775.5	1928.8	2696.0	2933.0	4107.8	4461.5	6164.9	6665.7	8933.88	9536.59
Head count Poverty Ratio (%)											
Extreme Poverty	12.9	10.2	9.6	7.4	6.9	5.3	5.0	3.8	3.6	2.86	2.72
Moderate Poverty	23.2	20.3	19.6	17.2	16.7	15.0	14.7	13.7	13.5	12.83	12.70
Memorandum :											
population, in million	162.9	170.5	172.3	179.1	180.6	186.5	187.8	192.5	193.5	197.13	197.89
Real GDP, in billion taka	8829.4	11524.3	12364.3	16398.2	17596.4	23272.2	24929.3	32560.9	34710.9	44027.00	46439.14
Exchange rate	78.4	88.7	91.3	101.2	103.6	113.7	116.3	126.7	129.4	140.93	143.97
GDP Deflator index	195.9	245.9	258.9	315.6	331.1	399.4	417.8	498.7	521.1	621.45	648.79
Population growth (%)	1.2	1.1	1.1	0.9	0.9	0.7	0.7	0.6	0.5	0.42	0.38

Source: GED Projections

Table B5. 4: Employment and Poverty Outcomes in the Delta Plan Option, FY2016- FY2041

Fiscal Year	FY16	FY20	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Indicators:										
Real GDP Growth (%)	7.1	8.0	8.5	8.5	8.9	9.0	9.4	9.5	9.81	9.90
Investment- GDP (%)	30.1	35.2	37.9	38.4	40.6	41.2	43.4	44.0	46.29	46.88
Real Capital Stock, in billion USD	207.1	318.3	515.5	564.2	800.9	872.7	1227.4	1335.9	1874.40	2040.58
Labour force, In million	65.6	72.2	80.4	82.0	88.4	90.2	96.6	98.2	104.18	105.67
Employed	62.5	68.8	76.7	78.3	84.4	86.2	92.4	93.9	99.59	101.02
Unemployed	3.1	3.4	3.7	3.7	4.0	4.0	4.3	4.3	4.59	4.66
Labour force participation rate (%)	58.9	60.1	61.8	62.2	63.5	64.0	65.6	66.0	67.58	68.00
Nominal GDP per capita, in USD	1354.2	1919.4	3062.2	3373.9	5031.5	5571.0	8471.2	9434.0	14676.96	16421.85
Head count Poverty Ratio (%)										
Extreme Poverty	12.9	8.9	1.8	1.3	0.3	0.2	0.0	0.0	0.01	0.00
Moderate Poverty	23.2	19.0	14.3	13.4	10.4	9.8	7.5	6.9	5.18	4.80
Memorandum :										
population, in million	162.9	170.5	179.1	180.6	186.5	187.8	192.5	193.5	197.13	197.89
Real GDP, in billion taka	8829.4	11807.6	17575.3	19077.9	26708.4	29112.1	41434.4	45350.0	65615.57	72111.51
Exchange rate	78.4	88.7	101.2	103.6	113.7	116.3	126.7	129.4	140.93	143.97
GDP Deflator index	195.9	245.9	315.6	331.1	399.4	417.8	498.7	521.1	621.45	648.79

Source: GED Projections

Table B5. 5: Resource Requirements to Mitigation and Adaption Measures in Delta Plan Option, FY2016- FY2041

Fiscal Year	FY16	FY20	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Gross resource requirements: BAU Scenario	**(As % of GDP)**									
Gross Investment	**30.1**	**33.5**	**36.0**	**36.6**	**38.7**	**39.3**	**41.5**	**42.0**	**44.3**	**44.9**
Public Investment	6.4	7.8	7.9	7.9	7.9	8.0	8.1	8.1	8.2	8.2
Private Investment	23.7	25.7	28.1	28.7	30.8	31.3	33.4	33.9	36.1	36.7
	(As % of GDP)									
Additional Delta resource requirements	**0.8**	**2.7**	**3.1**	**3.1**	**3.2**	**3.2**	**3.3**	**3.3**	**3.3**	**3.3**
of which:										
Additional Public Investment(Water resources)	0.0	1.2	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.4
Public Investment (Water resources)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Maintenance cost(Recurrent Budget)	0.0	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Private Investment	0.0	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6
Gross resource requirements in Delta Plan Scenario	**(As % of GDP)**									
Gross Investment	30.1	35.2	37.9	38.4	40.6	41.2	43.4	44.0	46.3	46.9
Public Investment	6.4	9.0	9.2	9.2	9.3	9.4	9.5	9.5	9.6	9.6
Private Investment (Including mitigation measures)	23.7	26.1	28.6	29.2	31.3	31.8	34.0	34.5	36.7	37.3

Source: GED Projection

Table B5. 6: Population Dynamics Delta Plan Policy Options, FY2016 - FY2041

Fiscal Year	FY16	FY20	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Region:	**In Million**									
Haor	16.4	17.3	18.2	18.4	19.1	19.3	19.8	20.0	20.4	20.5
Coastal	27.4	28.0	28.5	28.6	28.7	28.8	28.7	28.7	28.4	28.3
CTG Hill	1.8	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4
Urban	30.2	32.5	35.4	36.0	38.2	38.8	40.8	41.3	43.2	43.6
Drought Prone	24.6	25.5	26.5	26.6	27.3	27.4	27.8	27.9	28.2	28.2
Rivers & Estuaries	44.3	45.9	47.6	47.9	48.9	49.2	49.9	50.0	50.4	50.4
Less Risky Region	18.1	19.3	20.7	20.9	22.0	22.2	23.2	23.4	24.2	24.4
Bangladesh	162.9	170.5	179.1	180.6	186.5	187.8	192.5	193.5	197.1	197.9
	(Share of Population, % of Total)									
Haor	10.1	10.1	10.2	10.2	10.2	10.3	10.3	10.3	10.4	10.4
Coastal	16.8	16.4	15.9	15.8	15.4	15.3	14.9	14.8	14.4	14.3
CTG Hill	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Urban	18.5	19.1	19.8	19.9	20.5	20.6	21.2	21.3	21.9	22.0
Drought Prone	15.1	14.9	14.8	14.7	14.6	14.6	14.5	14.4	14.3	14.3
Rivers & Estuaries	27.2	26.9	26.6	26.5	26.2	26.2	25.9	25.8	25.6	25.5
Less Risky Region	11.1	11.3	11.5	11.6	11.8	11.8	12.0	12.1	12.3	12.3

Source: GED Projections

Table B5. 7: Population Dynamics BAU Policy Option, FY2016- FY2041

Fiscal Year	FY16	FY20	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Region:	**In Million**									
Haor	16.4	17.2	18.2	18.3	19.0	19.1	19.6	19.7	20.2	20.2
Coastal	27.4	27.3	26.9	26.7	26.1	25.9	25.0	24.7	23.5	23.2
CTG Hill	1.8	1.9	2.1	2.1	2.2	2.2	2.2	2.3	2.3	2.3
Urban	30.2	34.1	39.2	40.3	44.4	45.4	49.4	50.4	54.3	55.3
Drought Prone	24.6	25.3	25.9	26.1	26.4	26.5	26.6	26.7	26.6	26.6
Rivers & Estuaries	44.3	45.5	46.5	46.7	47.1	47.2	47.3	47.3	47.1	47.0
Less Risky Region	18.1	19.1	20.3	20.5	21.3	21.5	22.3	22.4	23.0	23.2
Bangladesh	162.9	170.5	179.1	180.6	186.5	187.8	192.5	193.5	197.1	197.9
Region:	**(Share of Population, % of Total)**									
Haor	10.1	10.1	10.1	10.1	10.2	10.2	10.2	10.2	10.2	10.2
Coastal	16.8	16.0	15.0	14.8	14.0	13.8	13.0	12.8	11.9	11.7
CTG Hill	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Urban	18.5	20.0	21.9	22.3	23.8	24.2	25.7	26.0	27.6	27.9
Drought Prone	15.1	14.8	14.5	14.4	14.2	14.1	13.8	13.8	13.5	13.4
Rivers & Estuaries	27.2	26.7	26.0	25.8	25.3	25.1	24.6	24.4	23.9	23.8
Less Risky Region	11.1	11.2	11.3	11.4	11.4	11.5	11.6	11.6	11.7	11.7

Source: GED Projections

Table B5. 8: Labour Force Dynamics Delta Plan Policy Option, FY2016 - FY2041

Fiscal Year	FY16	FY20	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Region:	(In million)									
Haor	6.6	7.3	8.2	8.4	9.1	9.3	10.0	10.1	10.8	11.0
Coastal	11.0	11.9	12.8	13.0	13.6	13.8	14.4	14.5	15.0	15.1
CTG Hill	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.3
Urban	12.2	13.8	15.9	16.4	18.1	18.6	20.5	21.0	22.8	23.3
Drought Prone	9.9	10.8	11.9	12.1	12.9	13.2	14.0	14.2	14.9	15.1
Rivers & Estuaries	17.8	19.4	21.4	21.8	23.2	23.6	25.0	25.4	26.6	26.9
Less Risky Region	7.3	8.2	9.3	9.5	10.4	10.7	11.6	11.9	12.8	13.0
Bangladesh LFS	65.6	72.2	80.4	82.0	88.4	90.2	96.6	98.2	104.2	105.7
of which:										
Unemployed	3.1	3.4	3.7	3.7	4.0	4.0	4.3	4.3	4.6	4.7
Employed	62.5	68.8	76.7	78.3	84.4	86.2	92.4	93.9	100	101
Assumption:										
Male Participation rate (%)	81.9	81.9	82	82	82	82.2	82.2	82.2	82.2	82.2
Female Participation rate (%)	35.5	37.9	41.4	42.1	44.9	45.7	48.9	49.7	52.9	53.7
Total Participation rate (%)	58.9	60.1	61.8	62.2	63.5	64.0	65.6	66.0	67.6	68.0
Unemployment rate (%)	4.7	4.7	4.6	4.5	4.5	4.4	4.4	4.4	4.4	4.4

Source: GED Projections

Table B5. 9: Labour Force Dynamics BAU Policy Option, FY2016 - FY2041

Fiscal Year	FY 16	FY20	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Region: (In million)										
Haor	6.6	7.3	8.2	8.3	9.0	9.2	9.9	10.0	10.7	10.8
Coastal	11.0	11.6	12.1	12.1	12.4	12.4	12.5	12.5	12.4	12.4
CTG Hill	0.7	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2
Urban	12.2	14.5	17.6	18.3	21.0	21.8	24.8	25.6	28.7	29.5
Drought Prone	9.9	10.7	11.7	11.8	12.5	12.7	13.4	13.5	14.1	14.2
Rivers & Estuaries	17.8	19.2	20.9	21.2	22.3	22.7	23.8	24.0	24.9	25.1
Less Risky Region	7.3	8.1	9.1	9.3	10.1	10.3	11.2	11.4	12.2	12.4
Bangladesh LFS	65.6	72.2	80.4	82.0	88.4	90.2	96.6	98.2	104.2	105.7
of which:										
Unemployed	3.1	3.9	5.3	5.6	7.3	7.8	10.3	11.0	14.5	15.5
Employed	62.5	68.3	75.1	76.5	81.1	82.4	86.4	87.2	89.7	90.2
Assumption:										
Male Participation rate (%)	81.9	81.9	82.0	82.0	82.0	82.2	82.2	82.2	82.2	82.2
Female Participation rate (%)	35.5	37.9	41.4	42.1	44.9	45.7	48.9	49.7	52.9	53.7
Total Participation rate (%)	58.9	60.1	61.8	62.2	63.5	64.0	65.6	66.0	67.6	68.0
Unemployment rate (%)	4.7	5.4	6.6	6.8	8.3	8.6	10.6	11.2	13.9	14.6

Source: GED Projections

Table B5. 10: Migration Dynamics Delta Plan Policy Option, FY2016 – FY2041

Fiscal Year	FY16	FY20	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Region:	**(In million)**									
Haor	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.6
Coastal	-0.5	-1.2	-2.2	-2.4	-3.2	-3.5	-4.3	-4.5	-5.4	-5.7
CTG Hill	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
Urban	0.7	1.7	3.0	3.3	4.5	4.8	6.0	6.3	7.5	7.8
Drought Prone	-0.2	-0.4	-0.7	-0.8	-1.0	-1.1	-1.4	-1.4	-1.7	-1.8
Rivers & Estuaries	-0.3	-0.8	-1.5	-1.6	-2.2	-2.3	-2.9	-3.1	-3.7	-3.9
Less Risky Region	0.2	0.6	1.0	1.1	1.5	1.6	2.0	2.1	2.6	2.7

Source: GED Projections

* All negative values represents migration to urban region

Table B5. 11: Migration Dynamics BAU Policy Option, FY2016 – FY2041

	FY16	FY20	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Region:	**(In million)**									
Haor	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3
Coastal	-0.5	-1.9	-3.8	-4.2	-5.9	-6.3	-8.1	-8.5	-10.3	-10.7
CTG Hill	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Urban	0.7	3.3	6.8	7.6	10.6	11.4	14.6	15.4	18.6	19.4
Drought Prone	-0.2	-0.6	-1.2	-1.4	-1.9	-2.0	-2.6	-2.7	-3.3	-3.4
Rivers & Estuaries	-0.3	-1.3	-2.6	-2.9	-4.0	-4.3	-5.5	-5.8	-7.0	-7.3
Less Risky Region	0.2	0.4	0.6	0.7	0.9	0.9	1.2	1.2	1.4	1.5

Source: GED Projections

Table B5. 12: Moderate Poverty Dynamics, FY2016 -FY2041

Fiscal Year	FY16	FY20	FY21	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Delta Plan Scenario:	**Head-Count Poverty Ratio (%)**										
Haor Region	18.1	14.9	14.1	11.2	10.6	8.3	7.7	5.9	5.5	4.1	3.8
Coastal Region	22.7	18.2	17.1	13.3	12.5	9.5	8.8	6.5	6.1	4.4	4.1
Chittagong Hill Tract	20.8	17.3	16.4	13.2	12.4	9.8	9.2	7.1	6.6	5.0	4.6
Urban	13.1	11.0	10.4	8.5	8.1	6.4	6.0	4.7	4.4	3.4	3.1
Drought	13.8	11.2	10.6	8.3	7.8	6.1	5.7	4.3	4.0	2.9	2.7
River estuary	29.2	23.7	22.4	17.6	16.5	12.7	11.9	9.0	8.3	6.2	5.7
Less risky area	27.0	22.5	21.3	17.2	16.2	12.8	12.0	9.3	8.7	6.6	6.1
Bangladesh	23.2	19.0	18.0	14.3	13.4	10.4	9.8	7.5	6.9	5.2	4.8
BAU Scenario:											
Haor Region	18.1	15.9	15.3	13.5	13.0	11.8	11.5	10.7	10.6	10.1	10.0
Coastal Region	22.7	19.5	18.7	16.2	15.6	14.0	13.8	12.9	12.7	12.4	12.4
Chittagong Hill Tract	20.8	18.4	17.8	15.7	15.2	13.9	13.6	12.8	12.6	12.1	12.0
Urban	13.1	11.9	11.7	10.6	10.3	9.5	9.3	8.8	8.6	8.2	8.1
Drought	13.8	11.9	11.4	9.9	9.5	8.4	8.2	7.5	7.4	6.9	6.8
River estuary	29.2	25.4	24.5	21.3	20.6	18.6	18.2	17.0	16.8	16.1	16.0
Less risky area	27.0	23.6	22.8	19.9	19.3	17.2	16.9	15.5	15.2	14.3	14.1
Bangladesh	23.2	20.3	19.6	17.2	16.7	15.0	14.7	13.7	13.5	12.8	12.7
Assumptions:											
Elasticity Ratio(growth to poverty)											
Delta Plan Scenario	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77	-0.77
BAU Scenario	-0.60	-0.55	-0.55	-0.50	-0.50	-0.40	-0.30	-0.25	-0.25	-0.20	-0.20
Real Per capita GDP Growth											
Delta Plan Scenario	5.8	6.8	7.0	7.5	7.6	8.1	8.2	8.7	8.9	9.4	9.5
BAU Scenario	5.8	6.1	6.2	6.3	6.4	6.4	6.4	6.1	6.0	5.3	5.1

Source: GED Projections

Table B5. 13: Extreme Poverty Dynamics, 2016-2041

Fiscal Year	FY16	FY20	FY21	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Delta Plan Scenario:	**Head-Count Poverty Ratio (%)**										
Haor Region	17.6	13.0	9.6	2.7	1.9	0.5	0.3	0.1	0.0	0.0	0.0
Coastal Region	22.1	15.6	11.1	2.6	1.8	0.4	0.2	0.0	0.0	0.0	0.0
Chittagong Hill Tract	20.3	15.2	11.4	3.4	2.4	0.6	0.4	0.1	0.1	0.0	0.0
Urban	12.8	9.7	7.4	2.4	1.8	0.5	0.4	0.1	0.1	0.0	0.0
Drought	13.4	9.7	7.1	1.8	1.3	0.3	0.2	0.0	0.0	0.0	0.0
River estuary	28.4	20.5	14.8	3.8	2.7	0.6	0.4	0.1	0.1	0.0	0.0
Less risky area	26.4	19.8	14.9	4.5	3.3	0.9	0.6	0.1	0.1	0.0	0.0
Bangladesh	12.9	8.9	6.5	1.8	1.3	0.3	0.2	0.0	0.0	0.0	0.0
BAU Scenario:											
Haor Region	17.6	14.0	13.1	10.2	9.5	7.3	6.9	5.3	5.0	4.0	3.8
Coastal Region	22.1	16.8	15.6	11.7	10.9	8.3	7.7	6.1	5.8	5.2	5.2
Chittagong Hill Tract	20.3	16.3	15.3	12.0	11.3	8.9	8.4	6.7	6.3	5.3	5.1
Urban	12.8	10.9	10.4	8.6	8.2	6.6	6.3	5.0	4.7	3.8	3.5
Drought	13.4	10.3	9.6	7.2	6.6	4.9	4.5	3.3	3.0	2.2	2.0
River estuary	28.4	22.2	20.7	15.8	14.8	11.3	10.6	8.3	7.8	6.5	6.3
Less risky area	26.4	20.8	19.5	14.9	13.9	10.5	9.7	7.2	6.7	5.0	4.6
Bangladesh	12.9	10.2	9.6	7.4	6.9	5.3	5.0	3.8	3.6	2.9	2.7
Assumptions:											
Elasticity Ratio (growth to poverty)											
Delta Plan Scenario	-1.19	-1.19	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8	-3.8
BAU Scenario	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
Real Per capita GDP Growth											
Delta Plan Scenario	5.8	6.8	7.0	7.5	7.6	8.1	8.2	8.7	8.9	9.4	9.5
BAU Scenario	5.8	6.1	6.2	6.3	6.4	6.4	6.4	6.1	6.0	5.3	5.1

Source: GED Projections

Table B5. 14: Nominal GDP per Capita, FY2016 -FY2041

	FY16	FY20	FY21	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Delta Plan Scenario:	(In USD)										
Haor Region	826	1165	1275	1849	2035	3021	3341	5058	5627	8716	9742
Coastal Region	1125	1635	1802	2692	2985	4569	5093	7956	8922	14274	16085
Chittagong Hill Tract	1022	1429	1559	2240	2460	3619	3994	5993	6652	10215	11392
Urban	1874	2577	2802	3966	4339	6293	6920	10243	11332	17177	19096
Drought	1145	1637	1797	2641	2916	4387	4868	7469	8337	13088	14678
River estuary	1407	2014	2212	3255	3596	5420	6017	9247	10325	16238	18218
Less risky area	1504	2095	2285	3273	3591	5268	5810	8693	9642	14765	16456
Bangladesh	1354	1919	2102	3062	3374	5031	5571	8471	9434	14677	16422
BAU Scenario:	(In USD)										
Haor Region	826	1140	1238	1734	1887	2652	2884	4015	4352	5919	6352
Coastal Region	1125	1610	1764	2540	2781	3962	4310	5890	6311	7770	7959
Chittagong Hill Tract	1022	1400	1517	2100	2278	3149	3407	4619	4966	6455	6821
Urban	1874	2416	2584	3418	3674	4944	5328	7222	7798	10594	11417
Drought	1145	1625	1779	2573	2827	4139	4554	6688	7365	10808	11872
River estuary	1407	1972	2149	3043	3320	4687	5096	7034	7589	9957	10522
Less risky area	1504	2085	2270	3212	3509	5036	5514	7962	8735	12668	13886
Bangladesh	1354	1776	1929	2696	2933	4108	4461	6165	6666	8934	9537

Source: GED Projections

Table B5. 15: Impact on Capital and Employment due to Environmental Degradation, 2016 -2041

Fiscal Year	FY16	FY20	FY21	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Region:	(In billions of Taka)										
Haor Region	0.0	19.8	22.3	34.8	38.5	57.1	62.7	90.4	98.9	140.3	152.9
Coastal Region	0.0	94.1	108.2	182.1	206.0	331.5	372.2	587.3	657.4	1030.1	1152.3
Chittagong Hill Tract	0.0	2.8	3.2	5.0	5.5	8.1	8.8	12.5	13.5	18.5	20.0
Urban	0.0	50.2	57.2	92.9	104.1	161.9	180.3	275.2	305.6	464.1	515.1
Drought	0.0	30.7	35.2	58.5	66.0	104.8	117.3	182.8	204.0	315.5	351.8
River estuary	0.0	107.5	123.4	206.0	232.5	371.0	415.7	650.5	726.7	1129.2	1260.5
Less risky area	0.0	17.8	20.3	33.4	37.5	59.0	65.8	101.4	112.9	172.7	192.0
Bangladesh	0.0	322.8	369.8	612.5	690.1	1093.4	1223.0	1900.2	2119.0	3270.4	3644.6
No of new of Unemployed	(In Millions of Person)										
Haor Region	0.00	0.05	0.07	0.16	0.19	0.34	0.38	0.62	0.69	1.02	1.13
Coastal Region	0.00	0.13	0.18	0.41	0.48	0.84	0.95	1.48	1.63	2.37	2.58
Chittagong Hill Tract	0.00	0.01	0.01	0.02	0.02	0.05	0.05	0.09	0.10	0.14	0.16
Urban	0.00	0.06	0.09	0.21	0.25	0.45	0.52	0.84	0.95	1.44	1.60
Drought	0.00	0.05	0.07	0.15	0.18	0.32	0.36	0.57	0.64	0.94	1.03
River estuary	0.00	0.17	0.23	0.54	0.63	1.12	1.27	2.00	2.22	3.27	3.58
Less risky area	0.00	0.03	0.04	0.10	0.12	0.21	0.25	0.40	0.44	0.67	0.74
Bangladesh	0.00	0.51	0.68	1.58	1.87	3.32	3.78	6.00	6.67	9.87	10.81

Source: GED Projections

Table B5. 16: Income Loss due to Environmental Degradation, 2016 -2041

Fiscal Year	FY16	FY20	FY21	FY25	FY26	FY30	FY31	FY35	FY36	FY40	FY41
Region:	(In billions of Taka)										
Haor Region	0.0	17.4	24.5	72.3	91.1	211.5	257.5	546.8	655.7	1331.2	1583.1
Coastal Region	0.0	65.3	92.2	272.3	343.0	797.5	971.3	2065.2	2477.4	5036.9	5992.3
Chittagong Hill Tract	0.0	2.7	3.9	11.6	14.6	34.3	41.9	89.6	107.6	219.8	261.8
Urban	0.0	50.0	70.6	207.1	260.5	602.9	733.5	1553.2	1861.5	3772.1	4484.3
Drought	0.0	24.2	34.1	100.3	126.2	292.5	356.0	754.7	904.7	1834.5	2181.2
River estuary	0.0	104.3	147.1	432.7	544.6	1262.1	1536.0	3256.4	3903.8	7916.7	9413.0
Less risky area	0.0	19.4	27.4	80.7	101.6	235.4	286.6	607.6	728.4	1477.4	1756.7
Bangladesh	0.0	283.3	399.7	1177.1	1481.5	3436.2	4182.8	8873.5	10639.1	21588.6	25672.4

Source: GED Projections

Table B5. 17: Net Cultivable Land Area, FY2016 -FY2041

Fiscal Year	2016	2021	2026	2031	2036	2041
Region:	(In Thousands of Hectare)					
Haor Region	2149112	2043785	1943619	1848362	1757774	1688511
Coastal Region	1964705	1868415	1776844	1689761	1606946	1543626
Chittagong Hill Tract	738545	702349	667927	635192	604061	580259
Urban	1489561	1416557	1347132	1281109	1218322	1170315
Drought	2699365	2567069	2441257	2321611	2207829	2120832
River estuary	5319887	5059160	4811210	4575413	4351172	4179719
Less risky area	3438984	3270439	3110155	2957727	2812769	2701934
Bangladesh	**17800159**	**16927774**	**16098145**	**15309175**	**14558874**	**13985196**

Source: GED Projections

Table B5. 18: Bangladesh: Loss of Flood and Cyclone, FY2016 -FY2041

Calendar Year	**2016**	**2020**	**2021**	**2025**	**2026**	**2030**	**2031**	**2035**	**2036**	**2040**	**2041**
Component:	**(In Millions of USD)**										
Loss in Flood	79.4	102.7	109.9	145.1	155.8	207.9	223.7	300.5	323.6	435.1	468.5
Loss in Cyclone	19.2	28.2	31.0	45.4	49.9	73.1	80.4	117.7	129.5	189.6	208.5

Source: GED Projections

Previous Attempts to Estimate Economic Impacts of Climate Change

The literature on assessing the economic impacts of climate change in Bangladesh is not extensive. In a recently concluded project – 'Ecosystem services for poverty alleviation (ESPA)' – under the aegis of Institute of Water Modeling and Flood Management (IWMFM) at BUET, an attempt has been made to quantify impact on livelihood and poverty. The project acknowledged that achieving populous Deltas development goals by 2100 is a complicated and complex problem. The project team used a dynamic integrated model titled "Delta Dynamic Integrated Emulator Model (ΔDIEM)" to assist poverty alleviation planning in Coastal Bangladesh.

The model's scope is to test plausible future scenarios and quantify interdependencies of

- the bio-physical environment and ecosystem services,
- rural livelihoods, poverty & health
- associated governance

The model operates at the Unions level on a daily time step. Unions are the smallest rural administrative and local government units in Bangladesh. There are 4550 Unions in Bangladesh from which a subset of 653 Unions was simulated by ΔDIEM. These 653 unions were in the agriculture dominated South-West coastal zone. A daily time step was used to resolve the soil water and salt balance dynamic due to environmental drivers (e.g. rainfall, flooding, and evapotranspiration) and human activities (agriculture, aquaculture).

The model was developed in a genuine participatory approach including five main groups of participants. At the very beginning, a broad set of stakeholders (more than 50 agencies) provided the narratives of three plausible future scenarios (termed Business as Usual, More Sustainable and Less Sustainable) that would like to explore. A comprehensive seasonal survey of more than 1500 households provided the ground knowledge about interdependencies between different archetypes of households and ecosystem services. An ESPA Deltas team of more than 100 specialist and students provided detailed assessment of future trends and changes of the natural and socio-economic systems. The quantitative sectoral assessment provided by the ESPA Deltas team was then integrated into the ΔDIEM that allows users to explore a broad range of interventions under the three different scenarios **(http://www.espadelta.net/ddiem/).**

Although it is a commendable effort to integrate climate change issues to poverty situation, the model may not be readily appropriate for national level planning due to following reasons:

- It is a regional model and expanding it to national level will take time.
- The economic side of the model does not cover all aspect of planning model such as savings, investment, fiscal, monetary and debt blocks.
- Due to lack of fiscal, monetary, debt and investment blocks, the model is incapable of estimating investment requirement for mitigation and adaptation projects.

In another paper, Ahmed (2006)[55] tried to synthesize the modeling efforts in Bangladesh to climate change impact and vulnerability. In this paper he described climate change scenarios from the perspective of use of different types of models. He argued that "for Bangladesh, efforts have been made to develop climate change scenarios using various generic methods. In early stages of assessing climate change impacts, in the absence of appropriate models and modeling facilities, researchers have used 'expert judgments' to come up with climate scenarios. With the proliferation of computer assisted Atmosphere-Ocean Global Circulation Models (AOGCM), scientifically more rigorous and acceptable scenarios have been developed at the second stage. Only in recent times, with further development of regional models as well as strengthening of computational capabilities, scenarios have been developed by using Regional Climate Models (RCM)."

Three alternative scenarios have been developed for Bangladesh using these models. These are discussed briefly below.

1. Speculative Scenario Development: this is based on 'expert judgments' portrayed speculative future climate. More specifically, scientists have developed these speculative scenarios and posed key questions: 'what would happen' to the bio-geo-physical system 'if' climate parameter(s) change by a given extent.
2. General Circulation Models: Validation and Outputs: in early 1990s, several attempts have been made to generate climate change scenarios by the use of available General Circulation Models (GCM). The outcomes of various modeling efforts were collated under this section. Among others it provides data and projections on sea level rise; temperature and precipitation for 1990; 2030 and 2075. Rainfall change patterns were also provided for 2030; 2050 and 2100.
3. The Use of Regional Climate Models: 'In Bangladesh, two different Regional Climate Models, RegCM and PRECIS are now being attempted. Initial validations are in progress. Both the models are capable of resolving climatology at 50Km X 50Km scale, with a possibility of going further down up to 30Km X 30Km resolution. It is found that both the RCMs show cold bias towards resolving temperature over the country. The interesting common feature of RCM modeling is that, both the models could reasonably estimate total annual rainfall. However, large scale discrepancies have been observed in resolving winter, pre-monsoon and monsoon seasonal precipitations. Following parameterization of both models in manners suitable for generating local climatology, it is expected that the models will produce/yield climate change data for any given time in future.'

In another section of this paper, the impacts of climate change have also been attempted. The focus was mainly on analyzing the impacts of climate change on Bio-geophysical systems. Even though the focus was on the Bio-geophysical systems, the paper also tried to provide impacts on rice production, aquaculture, coastal shrimp culture, livestock, human and infrastructure. However, the outcomes

[55] Ahmed A U (2006), "Bangladesh Climate Change Impacts and Vulnerability A Synthesis", Climate Change Cell, Department of Environment, Comprehensive Disaster Management Programme, Government of the People's Republic of Bangladesh.

presented here may not readily be appropriate for national level planning as (i) the economic side of the model does not cover all aspect of planning model such as savings, investment, fiscal, monetary and debt blocks; and (ii) due to lack of fiscal, monetary, debt and investment blocks, the model is incapable of estimating investment requirement for mitigation and adaptation projects.

Calculation of Loss Parameters

This framework assumes a Cobb-Douglas production function with constant returns to scale in the following form

$$\mathbf{Y = f(K, L, N) = AK^{a}L^{b}N^{c}, \quad a+b+c=1}$$

Where, Y= real output,

K = net capital stock,

L = labour,

N = net cultivable area,

a = output elasticity of capital,

b = output elasticity of labour,

c = output elasticity of net cultivable area.

Because of unavailability of reliable research estimates and assuming our output is more capital responsive; in this framework, a=0.5, b=0.3 and c=0.2 are set.

Now, the variables such as loss due to cyclone, loss due to flood, loss due to salinity, loss due to siltation in water-ways and loss due to water shortage for the period from 2016 to 2041 are calculated using the assumptions illustrated in the earlier section.

To calculate income loss due to river erosion, sea level rise and drought the following equation was employed

$$\mathbf{M_t = rGDP_t * ((c * s_t)/100)}$$

Where,

M_t = Loss of income due to land loss at period t,

$rGDP_t$ = Delta Plan(DP) Scenario real GDP at period t,

c = Output elasticity of net cultivable area,

s_t = Percentage decrease in 1% decrease in net cultivable area.

To calculate Real GDP in case of BAU scenario, we consider the following equation

$$\mathbf{rGDP^{s}_{t} = rGDP^{b}_{t} - TL_t}$$

$$\mathbf{TL_t = L_t + (1+i) * TL_{t-1}}$$

Where,

$rGDP^s_t$ = Real GDP in BAU scenario, at period t

$rGDP^b_t$= Real GDP in DP scenario, at period t

i = percentage loss in t period's income due to income loss in t-1 period (in this model it is assumed that, i= 17.0%).

L_t = Loss of income due to environmental impacts at period t,

TL_t =Total Loss of income at period t.

Table B5. 19: Capital Stock in Bangladesh at Constant Prices (Billions of Taka)

Year	Capital Stock (In Billion Taka)
2008	8304
2009	10506
2010	11771
2011	13167
2012	14654
2013	16237
2014	17929
2015	19734

Source: GED estimates based on BBS

Calculation of Investment Requirements:

To calculate investment requirement to overcome the losses due to natural disasters, the following equation is used

$$I_t = L_t * ICOR$$

Where,

I_t = Investment requirement at period t

L_t = Loss due to natural disaster at period t

ICOR = Incremental capital output ratio (this projection assumes an ICOR of 4.4 on an average)

Calculation of Head Count Poverty Ratio**:**

To project head count ratio of poverty, this study employs the following equation

$$P_t = P_{t-1} * (1 + prg_t * e_t)$$

Where,

P_t=Poverty head count ratio at period t

prg_t = per capita real GDP growth rate

e_t = Percentage change in poverty because of one percent change in per capita real GDP.

Table B5. 20: Historical Threshold Values for Determination of Income Group

Year	Low Value (in UM)	High Value (in UM)	Median Value	Low Value (in UM) Growth	High Value (in UM) Growth
1997	3126	9655	6390	0.32	0.10
1998	3031	9360	6195	-3.04	-3.06
1999	2996	9265	6130	-1.15	-1.01
2000	2996	9265	6130	0.00	0.00
2001	2976	9205	6090	-0.67	-0.65
2002	2936	9075	6005	-1.34	-1.41
2003	3036	9385	6210	3.41	3.42
2004	3256	10065	6660	7.25	7.25
2005	3466	10725	7095	6.45	6.56
2006	3596	11115	7355	3.75	3.64
2007	3706	11455	7580	3.06	3.06
2008	3856	11905	7880	4.05	3.93
2009	3946	12195	8070	2.33	2.44
2010	3976	12275	8125	0.76	0.66
2011	4036	12475	8255	1.51	1.63
2012	4086	12615	8350	1.24	1.12
2013	4126	12745	8435	0.98	1.03
2014	4126	12735	8430	0.00	-0.08
2015	4036	12475	8255	-2.18	-2.04
2016	3955	12235	8483	-2.01	-1.92
Average Annual Growth Rate				1.24	1.23

Source: World Bank

Table B5. 21: Forecasted Threshold Values for Determination of Income Group

Year	*Low Value (in UM)*	*High Value (in UM)*
2017	4004	12386
2018	4053	12538
2019	4103	12693
2020	4154	12849
2021	4205	13008
2022	4257	13168
2023	4310	13330
2024	4363	13495
2025	4417	13661
2026	4472	13829
2027	4527	14000
2028	4583	14172
2029	4639	14347
2030	4697	14524
2031	4755	14703
2032	4814	14884
2033	4873	15067
2034	4933	15253
2035	4994	15441
2036	5056	15631
2037	5118	15824
2038	5182	16019
2039	5246	16216
2040	5310	16316
2041	5376	16420

Source: GED Projections

Table B5. 22: Quantification of socio-economic developments - all scenarios (productive, resilient, moderate, active)

Socio-economic developments		**2015 *(reference)***	**2020**	**2030**	**2040**	**2050**	**2100**
Population *Million inhabitants*	Productive	160	171	185	194	200	165
	Resilient	160	168	175	174	170	125
	Moderate	160	173	188	200	210	190
	Active	160	176	197	217	230	260
Urbanization *urban inhabitants (%)*	Productive	34	38	49	58	70	85
	Resilient	34	38	45	54	60	75
	Moderate	34	35	40	46	52	70
	Active	34	35	39	44	48	60
GDP Growth *Average annual real GDP growth rates (%)*	Productive	6.3	7.4	8.0	7.5	6.8	3.0
	Resilient	6.3	6.4	6.5	5.8	5.0	2.5
	Moderate	6.3	6.0	5.0	4.5	4.0	1.5
	Active	6.3	4.9	4.0	3.0	2.0	2.0
GDP per capita *Constant prices of 2010 ($)*	Productive	866	1,158	2,290	4,542	8,586	54,000
	Resilient	866	1,125	2,008	3,469	5,723	30,000
	Moderate	866	1,072	1,685	2,519	3,585	12,000
	Active	866	1,000	1,323	1,611	1,893	4,500
Agricultural share GDP *GDP contribution agricultural sector (%)* *Reference year: 2014*	Productive	16	15	13	11	8	5
	Resilient	16	15	13	12	10	8
	Moderate	16	17	17	15	13	10
	Active	16	16	16	15	15	14
Agriculture employment share *% of people employed in agriculture sector*	Productive	47	40	30	25	20	10
	Resilient	47	42	35	30	25	15
	Moderate	47	47	46	45	45	35
	Active	47	48	50	50	47	40
Poverty *Poverty headcount ratio at $1.25 a day (PPP) (%)* *Reference year: 2010*	Productive	43	32	24	18	14	0
	Resilient	43	35	30	25	20	2
	Moderate	43	38	35	32	30	15
	Active	43	41	39	37	35	25
Total freight transport *bln ton-km*	Productive	36	51	110	229	445	2,311
	Resilient	36	49	91	160	267	973
	Moderate	36	48	82	131	195	590
	Active	36	46	68	91	113	304
Inland waterway freight transport *bln ton-km*	Productive	5	8	23	53	108	695
	Resilient	5	7	16	30	53	243
	Moderate	5	6	11	20	31	112
	Active	5	5	7	9	12	36
Inland waterway freight transport *modal share (%)*	Productive	14	15	21	23	24	28
	Resilient	14	14	18	19	20	25
	Moderate	14	13	14	15	16	19
	Active	14	11	10	10	11	12
Land use developments		**2010**	**2020**	**2030**	**2040**	**2050**	**2100**
Agriculture land *% surface area*	Productive	60	--	--	--	-	0
	Resilient	60	-	-	-	0	+
	Moderate	60	-	-	-	-	-
	Active	60	--	--	--	--	--
Urban / industrial land	Productive	3	++	++	++	++	+

Socio-economic developments		2015 *(reference)*	2020	2030	2040	2050	2100
% surface area	Resilient	3	+	+	+	+	+
	Moderate	3	+	+	+	+	+
	Active	3	+	+	+	+	+
Rural settlements *% surface area*	Productive	12	--	--	--	--	--
	Resilient	12	-	-	-	-	--
	Moderate	12	+	+	+	+	-
	Active	12	++	++	++	++	++
Mangrove / forests *% surface area*	Productive	10	--	-	-	0	+
	Resilient	10	-	-	0	+	+
	Moderate	10	--	--	--	--	-
	Active	10	--	--	--	--	-

Climate change		2015 *(reference)*	2030	2040	2050	2100
Sea level rise *Mean sea level rise in cm*	Productive	7,100	10-20	15-25	20-30	40-60
	Resilient	7,100	15-30	30-40	40-60	80-125
	Moderate	7,100	10-20	15-25	20-30	40-60
	Active	7,100	15-30	30-40	40-60	80-125
Temperature *Mean max temperature degrees change (°C)*	Productive	25	+0.5	+0.75	+1	+2
	Resilient	25	+1.5	+1.75	+2	+4
	Moderate	25	+0.5	+0.75	+1	+2
	Active	25	+1.5	+1.75	+2	+4
Monsoon rainfall *% change mean total monsoon (June-September) precipitation*	Productive	1,750	0	5	10	15
	Resilient	1,750	15	18	20	40
	Moderate	1,750	0	5	10	15
	Active	1,750	20	18	20	40
Dry season rainfall *% change mean total dry season (December-February) precipitation*	Productive	36	0	0	0	0
	Resilient	36	-10	-10	-10	-20
	Moderate	36	0	0	0	0
	Active	36	-10	-10	-10	-20
Longest dry day period *Increase of mean number of consecutive dry days*	Productive		0	0	0	+5
	Resilient		+5	+8	+10	+20
	Moderate		0	0	0	+5
	Active		+5	+8	+10	+20
Rainfall intensity *% change of mean total precipitation*	Productive		10	10	10	20
	Resilient		20	20	20	50
	Moderate		10	10	10	20
	Active		20	20	20	50
Cyclone intensity *% change*	Productive		25		45	90
	Resilient		70		90	100
	Moderate		25		45	90
	Active		70		90	100

Peak Discharges	Scenario	2015 *(reference, m³/s)*	2030	2050	2100
Ganges					
Peak discharge *% change of mean annual maximum at Hardinge Bridge*	Productive	51,130	15	20	30
	Resilient	51,130	30	40	70
	Moderate	51,130	15	20	30

Socio-economic developments	2015 *(reference)*	2020	2030	2040	2050	2100
		Active	51,130	30	40	70
Brahmaputra						
Peak discharge *% change of mean annual maximum at Bahadurabad*		Productive	67,490	5	10	15
		Resilient	67,490	15	20	30
		Moderate	67,490	5	10	15
		Active	67,490	15	20	30
Meghna						
Peak discharge *% change of mean annual maximum at Bhairab bazar*		Productive	13,370	5	10	15
		Resilient	13,370	15	20	30
		Moderate	13,370	5	10	15
		Active	13,370	15	20	30

Upstream Abstractions	Scenario	2015 *(reference, m^3/s)*	2030	2050	2100
Ganges					
Change Average dry season flow *% change (minus) at Hardinge Bridge*	Productive	750	*controlled by Ganges Water Treaty*		
	Resilient	750			
	Moderate	750			
	Active	750			
Average dry season flow *m^3/s at Hardinge Bridge*	Productive	750	*controlled by Ganges Water Treaty*		
	Resilient	750			
	Moderate	750			
	Active	750			
Brahmaputra					
Change Average dry season flow *% change (minus) at Bahadurabad*	Productive	3,000	-5%	-15%	-30%
	Resilient	3,000	-15%	-30%	-50%
	Moderate	3,000	-10%	-25%	-40%
	Active	3,000	-20%	-40%	-60%
Average dry season flow Brahmaputra *m^3/s at Bahadurabad*	Productive	3,000	2,850	2,550	2,100
	Resilient	3,000	2,550	2,100	1,500
	Moderate	3,000	2,700	2,250	1,800
	Active	3,000	2,400	1,800	1,200

- *Scenario Analysis has been done using Quadrate Method where X Axis denotes the Climatic factors (water condition and others) and Y Axis denotes the socio-economic development and land use change. Resilient, Active, Moderate and Productive Scenarios considered for each quadrate clockwise where Reselient scenario is expected through BDP 2100.*

Source:* *Unnikrishnan and Shankar (2007), Hinkel et al. 2014 (IPCC, AR5), BMD, EU-Watch/Combine 2013/climate change baseline, IPCC 2013; BWDB (Yu et al. 2010), ISI-MIP & VIC (van Vliet and Ludwig, 2013)

Annex C: Technical Annex to Chapter 6

C1. Flood Risk Concepts

The terms Flood Risk and Flood Hazard are used frequently to discuss characteristics and consequences of a flood. Flood Hazard refers to the combination of 'probability' (return period) and 'flood characteristics' (water depth, flow velocities and duration). In turn, these, combined with the vulnerability of the area, community or economic sector constitute the 'Flood Risk', often expressed in a monetary value. The relationship between the different Flood Risk concepts is illustrated in **Figure C6.1**.

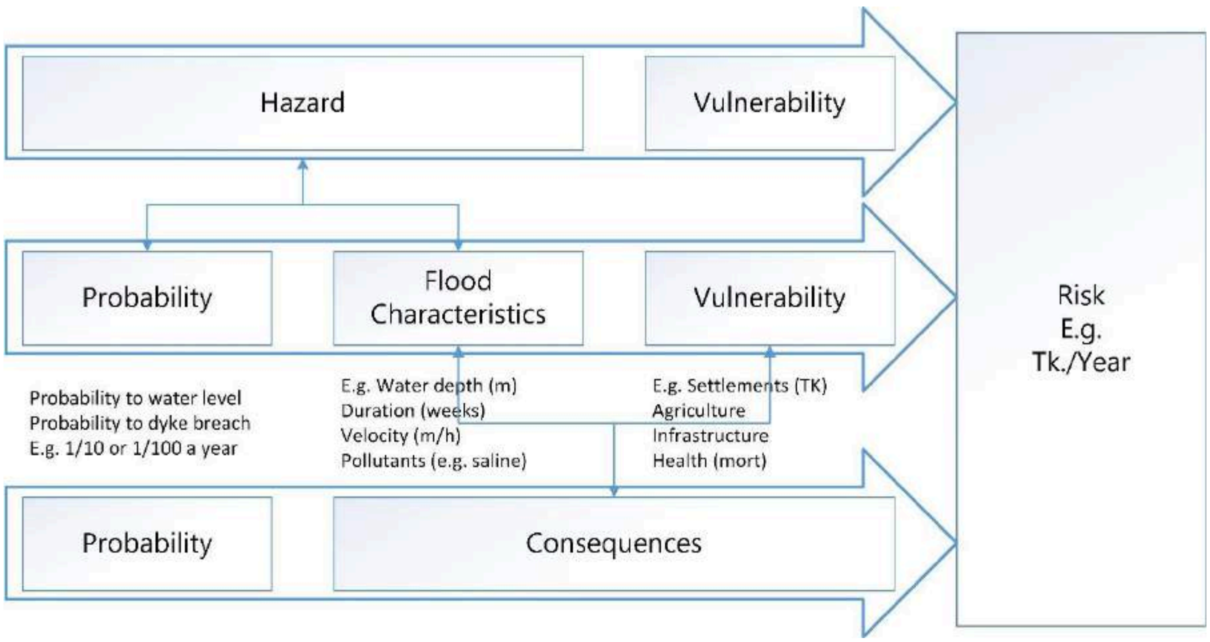


Figure C6.1: Flood risk concepts

Source: BDP 2100 Technical Team Analysis, GED, 2015

C2. Water Pollution Situation

Prolonged pollution, especially in the Hazaribagh industrial area, also leads to contamination of sediments, the shallow and, in due course, the deeper aquifers. According to Zahid (2006) the risk to groundwater contamination in Hazaribag is mitigated by the occurrence of the thick clay layers of the Madhupur tract, where the DMA is located. Recent data on groundwater quality show elevated and increasing levels of dissolved solids, both in the upper aquifer (5 to 200 m below surface) and the lower (below 200 m) aquifer (DWASA, 2015).

A large number of the rivers around Dhaka are almost anoxic showing black water with a pungent smell and allowing no aquatic life. During the Monsoon (July-August data) the water quality gets somewhat better. However, DO levels varying from 2 to 4 mg/l still do not meet water quality standards. The same data set also shows that the nutrient concentration in the rivers is very high. Ammonia levels up to 15 mg/l can be found. Phosphorus concentrations vary between 1 and 6 mg/l.

During long low flow periods these high nutrients levels lead to severe problems of eutrophication. Recent monitoring data show the impact that pollution is having on this key indicator in the DMA. The red areas, in which DO levels fall below 1 mg/l, during the dry months from January to March, occur primarily in the Buriganga, Tongi Khal, Balu and Shitalakhya Rivers.

A similar picture can be drawn for Bogura. Industries are rapidly growing due to the development of the government initiated establishment of an economic zone. Bogura is situated on the banks of the Karatoa River, which is heavily polluted by industrial and municipal effluents. The DO of Karatoa River is around 0.4 mg/l (Zakir et al., 2013).

Agricultural contamination, although still relatively low, is affecting the water quality of ponds and beels countrywide. About 1.6 million tonnes of chemical fertilizers and 4-5 thousand tonnes of pesticides are used in agriculture annually. Though illegal, the notorious 'dirty dozen' group of illegally imported 9 out of 12 Persistent Organic Pollutants (POPs) are also being used for agricultural & household purposes.

Domestic contamination in rural areas, amongst others with faecal coliforms, although not well quantified, is a serious form of contamination, due to the untreated disposal of human waste into ponds, beels and rivers. A recent report by BAPA indicated that in the Chattogram area some 150000 hanging latrines were discharging their wastes directly into the Karnaphuli River (Water Resources Baseline Study, BDP 2100, 2015).

There are at least three types of direct negative impacts of water pollution: i) increasing health problems of the rural and urban population, also leading to increased deaths; ii) loss of agricultural and industrial productivity; and iii) environmental degradation, leading to a series of further impacts. All of these lead to an increasing economic cost, both because of productivity loss and because of the need for- more expensive,alternatives to the environmental services offered by the water system. A comprehensive national survey on these impacts has not yet been undertaken, but results from regional studies, especially for the DMA, show a clear and worrying pattern: i) health care cost due to pollution represent 21.5% of annual income in Hazaribagh area. (IWM, 2007); ii) The loss of amenities associated with contaminated surface water amounts to about 0.5% of the region's GDP (World Bank, 2010); and iii) 45% of households in polluted areas of the DMA report persistent losses in the production of rice and more than 20% experience production losses in vegetable crops. Less than 15% of households in highly polluted areas allow livestock to drink river water, compared with more than half in the past. It is estimated that agricultural and fisheries production in the DMA may be reduced by about one third because of poor water quality (Bangladesh Environmental Management Project, BEMP, 2005). Estimated annual costs amount to some US$ 400 million (BEMP, 2005) linked to poor surface water quality, including lost agricultural and fisheries production (17%), costs to industry (22%), lost amenity (21%), and health costs (40%).

There are important institutional constraints to reducing pollution, enhancing enforcement and improving water quality in the country. Key constraints include: i) lack of compliance by industries, municipalities and other polluters with the environmental legislation in place; ii) low enforcement capacity with DoE; iv) the existence of many small and medium sized heavy polluting industries, all operating in a highly competitive market with low returns; v) sparse coverage of monitoring on a national level; vi) insufficient knowledge base (modelling, monitoring data) to assess the effectiveness of mitigation and improvement measures; and last but not least: vii) low public priority awarded to water quality. The latter is partly due to the low level of environmental awareness among the local government bodies, industries and the public.

C3. Groundwater Decline Situation

The Bangladesh Integrated Water Resources Assessment Project, carried out by CSIRO, CEGIS, IWM and BCAS, carried out a country-wide analysis of groundwater trends in 2013-2014 (except for the Chattogram Hill Tracts). 709 groundwater wells were analyzed across the country and two factors were assessed in detail: i) the number of wells below the 'critical depth' of 8 m; and ii) recovery of groundwater tables during the monsoon season, an indicator of long term groundwater use sustainability. To analyze the latter, 4 'types' of wells were distinguished: type 1: having both minimum and maximum groundwater levels declining with little recovery; type 2: both minimum and maximum groundwater levels declining with some recovery; type 3: dry season maximum declining and monsoon stable; and type 4: both dry and monsoon season stable.

Wells below critical depth

The northcentral and northwest region have the highest number of well's readings below the critical depth of 8 meters, as illustrated in **Table C6.1**. The third highest number of readings are recorded in the southwest regions. The total relative number of wells in each type category can be found in **Table C6.2** and **Table C6.3**. Short term trends indicate that the rate of decline is accelerating. For the North West as example, the number of type 1 wells (with both minimum and maximum levels declining with no recovery) is twice as high for the 2000- 2010 period as compared to the long term average. Women are most affected by this development, having to travel much longer distances to collect safe water for their families.

Table C6.1: Number of readings exceeding 8m (normalised)

Hydrological Region	No readings exceeding 8 m per well (normalised)
North central	220.9
North West	169.9
South West	62.0
North East	13.9
South East	38.6
South Central	12.0

Source: CSIRO, 2015

Table C6.2: Percentage (%) of wells in each type category, long term trend (1985 -2010)

Type of wells	NW	NC	SW	Total
Type 1	14	24	1	10
Type 2	46	41	60	46
Type 3	23	23	22	23
Type 4	18	18	17	21

Source: CSIRO, 2015

Table C6.3: Percentage (%) of wells in each type category; short term trend (2000 – 2010)

Type of wells	NW	NC	SW	Total
Type 1	39%	30%	32%	31%
Type 2	42%	50%	50%	45%
Type 3	15%	9%	15%	17%
Type 4	4%	5%	3%	6%

Source: CSIRO, 2015

Wells declining with no or little recovery

Both preand post-monsoon levels for a large number of wells in the NW shows a declining trend, as illustrated in **Figure C6.2** and **Figure C6.3**. Two important factors contribute to this trend: a relatively low rate of recharge and a very high abstraction rate. Recharge in the Barind tract is traditionally low as compared to other areas of the country, along with the Madhupur tract.

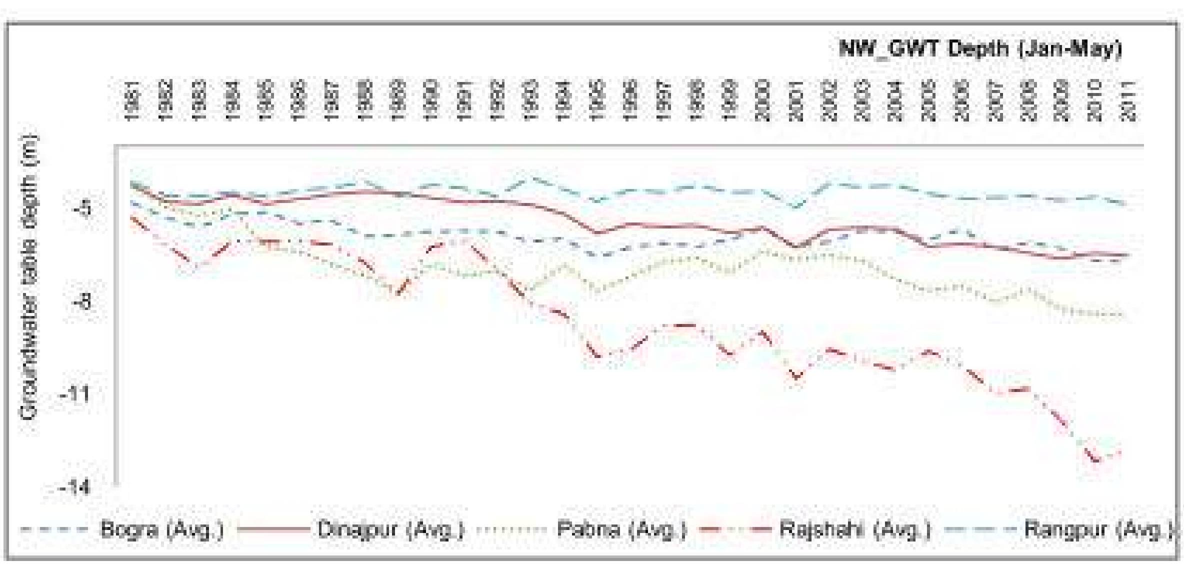


Figure C6.2: Decline of the groundwater table in the Northwest

Source: CSIRO, 2015

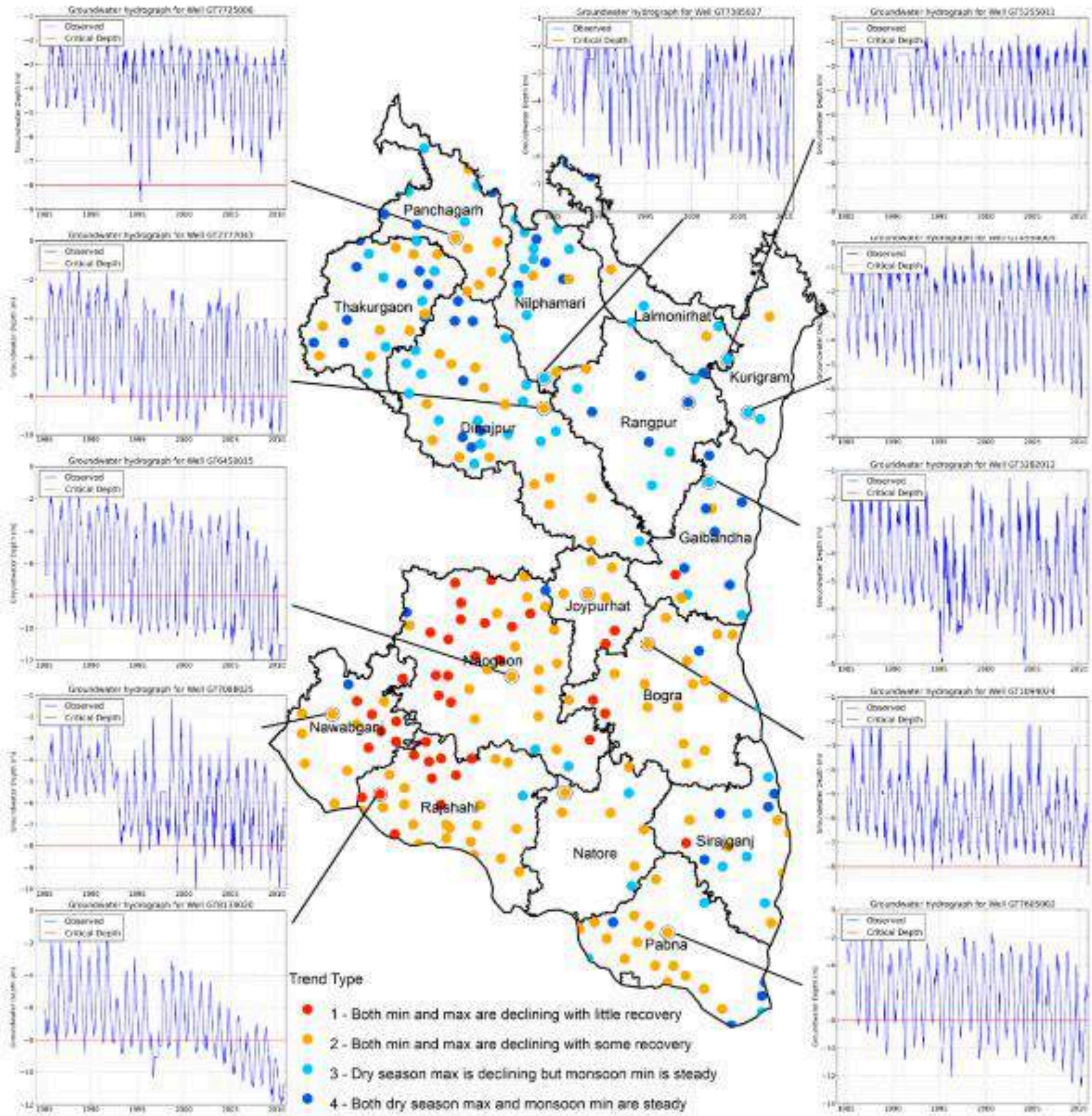


Figure C6.3: Trends in groundwater recovery in the NW Region, 1985 - 2010

Source: CSIRO, 2015

Figure C6.3 illustrates that the northwest region can be divided into two distinct sub-regions, almost coinciding with the current day divisions of Rajshahi and Rangpur. In the northern part, mostly type 3 and 4 wells occur, with few type 2 and no type 1 wells. In the southern part (corresponding to the large part of the Barind Tract), types 1 and 2 dominate most wells. The physiography plays an important role in explaining this difference. The northern part is dominated by alluvial fan deposits (Tista alluvial fan) with thin upper silt and clay layers. The southern sub-region includes the Barind Tract and areas of thicker clay layers associated with type 1 and type 2. The trends in the districts Naogaon, Joypurhat, Nawabganj and Rajshahi have a high proportion of wells with strongly declining trends indicating that groundwater resources in this region are at risk if abstraction continues to grow.

C4. The Blue Economy

C4.1 Context

With the adoption of the 7th FYP and Sustainable Development Goals (SDGs), development in 'Blue Economy' forms an integral part of the BDP 2100 for both economic growth and food security. With the settlement of maritime border disputes with neighbouring states Myanmar and India in 2014, the Government of Bangladesh started to consider options to unlock the potentials of the sea. Territorial waters is now considered as a new 'development space' in Bangladesh.

In this section, efforts have been made to quantify the value of blue economy sectors, a qualitative assessment of the potential, approaches and actions for high value sectors, concept notes in Bangladesh Delta Investment Programme, identifying challenges and approach to build on current opportunities and regional partnership.

Extent of Territorial Waters and EEZ of Bangladesh

At the end of the final settlement of maritime border disputes with neighbouring states Myanmar and India in 2012 and 2014 respectively, Bangladesh has received entitlement on 118,813 km^2 in the BoB comprising her territorial sea, Exclusive Economic Zone (EEZ) and Continental shelf (MoFA, 2014). The shallow shelf sea constitute about 20% and 35% respectively, the rest (45%) lying in deeper waters (**Figure C6.4**).

Blue economy in National Plans & SDGs

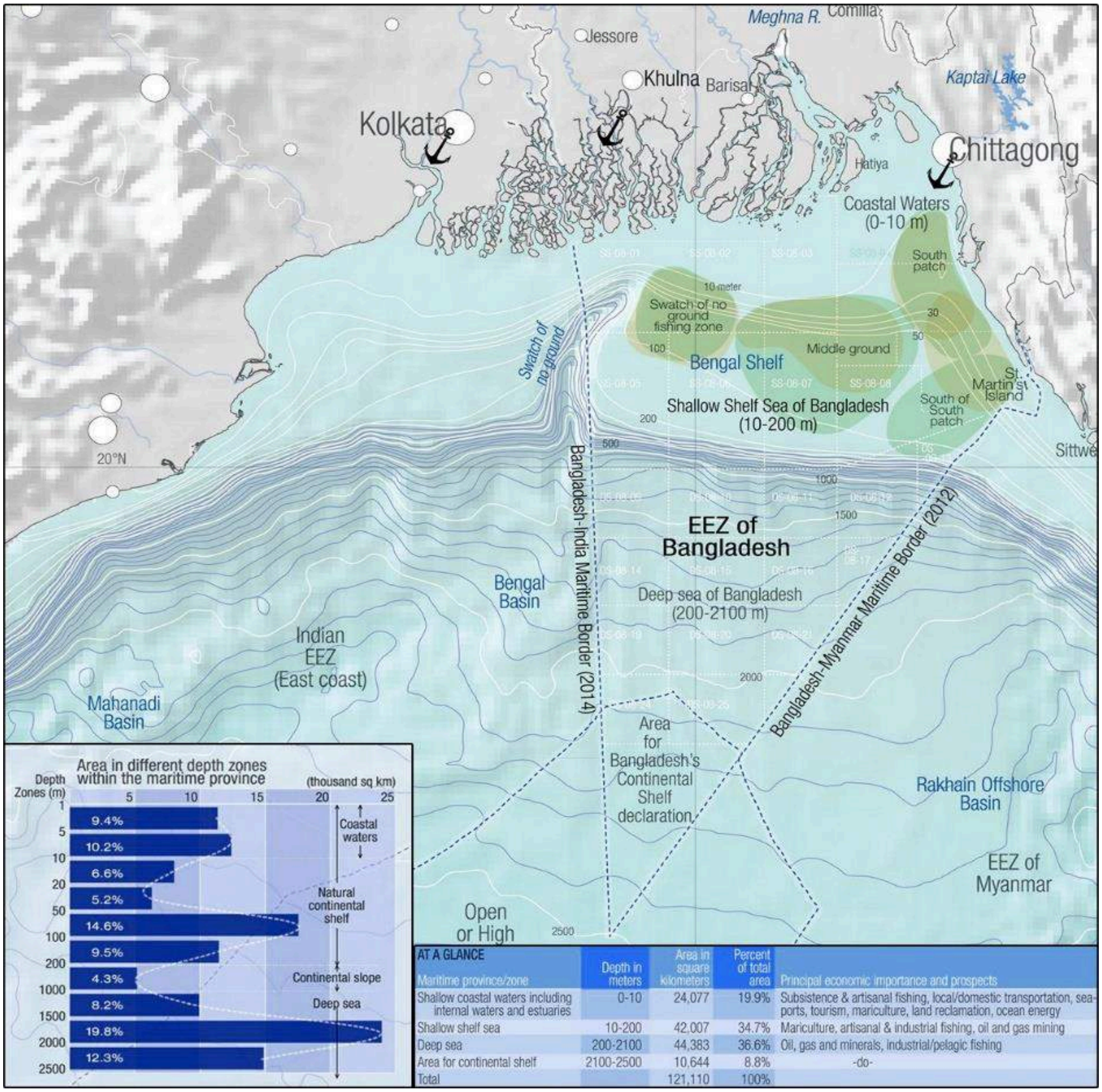
The 7th Five Year Plan

The Plan emphasizes on the prospect of 'Blue Economy' (GoB 2015) as: Blue economy concept has ushered in a new horizon for economic development of the coastal countries through utilizing the sea and marine resources at national and international level. Blue economy comprises of activities that directly or indirectly takes place in the seas, oceans and coasts using oceanic resources and eventually contributing to sustainable, inclusive economic growth, employment, well-being, while preserving the health of the ocean. It includes activities such as exploration and development of marine resources, appropriate use of ocean and coastal space, use of ocean products, provision of goods and services to support ocean activities and protection of ocean environment. The Blue Economy approach emphasizes that ideas, principles, norms of Blue Economy lend significant contribution towards eradication of poverty, contributing to food and nutrition security, mitigation and adaptation of climate change and generation of sustainable and inclusive livelihoods. It is needless to say that for most developing economies particularly for Bangladesh, making transition to Blue Economy would entail fundamental and systemic changes in their policy-regulatory-management-governance framework(s) and identification of various maritime economic functions.

The newly opened development window of the Blue Economy can significantly contribute in the socio-economic development of Bangladesh as a growth driver during 7th FYP period.

Sustainable Development Goals (SDGs)

Bangladesh is committed to achieve SDGs by 2030. The Sustainable Development Goal, particularly SDG 14 deals with oceans and articulated as "Conserve and sustainably use the oceans, seas and marine resources for sustainable development". The aim is to achieve the following parameters and targets (**Table C6.4**).



Maritime province/zone	Depth in meters	Area in square kilometers	Percent of total area	Principal economic importance and prospects
Shallow coastal waters including internal waters and estuaries	0-10	24,077	19.9%	Subsistence & artisanal fishing, local/domestic transportation, sea-ports, tourism, mariculture, land reclamation, ocean energy
Shallow shelf sea	10-200	42,007	34.7%	Mariculture, artisanal & industrial fishing, oil and gas mining
Deep sea	200-2100	44,383	36.6%	Oil, gas and minerals, industrial/pelagic fishing
Area for continental shelf	2100-2500	10,644	8.8%	-do-
Total		121,110	100%	

Figure C6.4: Maritime Area of Bangladesh

Source: Chowdhury, 2014

In order to achieve SDG 14, recommendations from a Blue Economy Forum may be considered (**Box C6.1**).

Table C6.4: Sustainable Development Goal 14

Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development
14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution
14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans
14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels
14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics
14.5 By 2020, conserve at least 10% of coastal and marine areas, consistent with national and international law and based on the best available scientific information
14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation
14.7 By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism
14.a Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries
14.b Provide access for small-scale artisanal fishers to marine resources and markets
14.c Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of The Future We Want

Box C6.1: Recommendations from Blue Economy Forum held on 2 June 2016 on SDG 14

Considering present status of Bangladesh's coastal and marine ecosystems the priority targets should be:

- By 2020, start the restoration process for degraded marine and coastal ecosystems in appropriate cases, i.e. Chakaria Sundarban and establish sustainable management.
- By 2020, achieve science based management plan for sustainable marine fisheries through assessment of marine fish stock and determining Maximum Sustainable Yield (MSY) by intensive field investigation.
- By 2025, Bangladesh needs to achieve institutional capacity and establish infrastructure capable of surveying, monitoring and removal of marine debris, reducing micro-plastic pollution by consumer products and other industrial waste, vessel based pollution like ballast water and invasive aquatic species.
- By 2030 Bangladesh needs to ensure full access of marine resources to small-scale artisanal fishers. Establishing a Monitoring, Surveillance and Control regime for huge fleets of artisanal fishing boats should be the first priority. Institutional coordination between the Department Fisheries and Marine Mercantile Department is necessary to run registration and licensing activity. In the long term, ways to motivate, facilitate and promote small-scale artisanal fishing cooperatives in deep sea fishing.

Source: Bangladesh Blue Economy Forum, 2016

C4.2 Recent Initiatives

The Government of Bangladesh has undertaken development initiatives and some of these are in the process of being initiated in different sectors. These include: shipping, fisheries, environment, research, etc. The aim is to either boost economic growth or to manage the capital resources more sustainably. Among notable developments in the shipping sector, besides modernization of existing ports, a new sea-port is being constructed at Payra in Patuakhali district. The port was inaugurated and opened for limited operational activities with the arrival of MV Fortune Bird on August 13, 2016. The port is expected to become fully operational by the end of 2018 and will enable vessels with drafts from 8-10m to anchor. In addition, an Inland Container Terminal (ICT) has been constructed near Dhaka and container transport by ships to and from Chattogram Port is being carried out.

Additional developments in marine fisheries sector particularly with respect to conservation and sustainable exploitation have been undertaken. A proportion of the bottom trawls have already been converted to mid-water trawls to lessen pressure on the demersal fish stocks, reduce destruction of sea-bottom habitats, and to exploit the mid-water fish stocks. Temporary ban on fishing in a certain period of the year is being imposed for several years now to allow breeding and recruitment of important fishes, specifically Hilsa. In order to carry out regular fish stock assessment, the Department of Fisheries has procured a survey vessel. It is expected that stock assessment survey will be initiated soon.

In 2014, the Government of Bangladesh declared the country's first Marine Protected Area, Swatch of No Ground, to safeguard whales, dolphins, sea turtles, sharks, and other oceanic species under the Wildlife (Conservation and Security) Act, 2012. Spanning some 672 square miles (1,738 km^2) in size with a depth of 900+ meters, the Swatch of No Ground Marine Protected Area includes deep waters at the head of the submarine canyon as well as coastal waters offshore from the world's largest mangrove forest in the Sundarbans. Destructive fishing methods and gears, e.g., set bag net, have been completely banned from operation. Vessel Tracking and Monitoring System (VTMS) with satellite communication links are going to be installed soon in fishing vessels in phases, in order to monitor and control their manoeuvre at sea for various management purposes.

In the environment sector, several Ecologically Critical Areas (ECA) have been enforced in various coastal ecosystems to maintain critical habitats, biodiversity, marine turtle breeding and conservation, and mangrove restoration and growth. Mangrove afforestation in newly accreted intertidal areas is going on for decades now.

Recently the National Oceanographic Research Institute (NORI) has been founded for coastal and oceanic research. Also, a Chief Hydrographer's Officer position has been established at the Armed Forces Division of the Prime Minister's Office to coordinate and lead hydrographic surveys and other related research activities in the Bay of Bengal.

C4.3 Quantifying Value of the Blue Economy

The Blue economy approach lend significant contribution towards eradication of poverty, contributing to food and nutrition security, mitigation and adaptation of climate change and generation of sustainable and inclusive livelihoods. Thus Blue Economy requires a balanced approach between conservation, development and utilisation of marine and coastal eco-systems, all oceanic resources and services with a view to enhancing their value and generates decent employment, secure productive marine economy and healthy marine eco-systems. Primarily, blue economy should have adequate focus on well-being and livelihood of people. It is needless to say that for Bangladesh, making transition to Blue Economy would entail initially for identification of various maritime economic functions.

Maritime functions in the context of Blue economy are not just economic sectors; they cover the relevant maritime value chains – including backward and forward linkages (GoB 2015). This is important since large parts of the economic activities take place not in core sectors themselves, but in adjacent economic activities. Twenty six maritime economic functions can be identified from among the fishery, maritime trade and shipping, energy, tourism, coastal protection, maritime monitoring and surveillance. Many studies have quantified the value of blue economy in Bangladesh (Hossain et. al 2014[56] Alam 2015[57]).

C4.4 Qualitative Assessment of Sectors in Blue Economy

Based on quantification made in previous section, a qualitative assessment (**Table C6.5**) of sectors in blue economy has been made based on expert judgement. In this table, the columns indicate:

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[56] Hossain S.M., Chowdhury S.R., Navera U.K., Hossain M.A.R., Imam, B and Sharifuzzaman, S.M 2014. Opportunities and Strategies for Ocean and River Resources Management. Prepared for FAO of the UN and used as Background paper for the preparation of the 7th FYP. December 2014

[57] Alam M. Khurshed, 2015. Ocean/Blue Economy For Bangladesh, http://www.mofa.gov.bd/content/about-blue-economy

- Current importance: how many jobs, value added, other indicators like tonnes of fish catched, number of ships, etc.
- Future potential: the extent to which the sector can grow in the future.
- Existing Capacity: this is about how strong or weak is the industry and overall society to capture these opportunities. Some opportunities like marine biotechnology are so far away from its capabilities (e.g. no manufacturing base, no R&D, no investors ready, that it will be very unlikely to become a major economic activity in the near future.
- Strategic priority: Based on current importance, future potential and existing capacity, strategic priorities have been assigned. Value chain approach for the economy has been considered for priority assignment.

Table C6.5: Qualitative assessment of sectors in blue economy

Type	Sectors	Current importance	Future Potential	Existing Capacity	Strategic Priority
Transportation	Shipping	++	++++	+	High
	Coastal shipping	++	+++	+	High
	Sea Ports	+++	++++	++	High
	Ship recycling	++++	+++	++++	High
	Ship building	+	+++	+	High
Food	Marine fishery	+	+++	+	High
	Marine aquaculture & mariculture	0	++	0	Medium
	Marine aquatic products	0	+	0	Low
	Marine biotechnology	0	+	0	Low
	Sea salt	++	+++	+	High
Energy	Oil & gas	+	+++	+	Medium
	Ocean renewable energy	0	+	0	Low
	Ocean Thermal Energy Conversion (OTEC)	0		0	Low
Minerals	Mining (minerals & sand)	0	+	0	Medium
Leisure	Coastal tourism	++	+++	++	High
	Recreational water sports	0	+	0	Low
	Cruise tourism	0	+	0	Medium
Water	Desalinization	0	?	0	Medium
Others	Land reclamation	+	++	++	High
	Coastal Greenbelt	++++	+++	+++	Medium
	Maritime surveillance	++	+++	+	High
	Maritime Spatial Planning	0	++	0	Medium
	Human Resources Development	+	+++	+	High
	Research & Studies	+	++	+	Medium
	Governance	++	+++	+	High

Source: BDP 2100 Technical Team Analysis, GED, 2015

From the qualitative assessment, it appears that, at this stage, shipping and shipping related activities have comparative advantages for development with existing capacity, current importance and future potential. Marine fishery and coastal tourism have certain capacity and importance but have high future potential.

Many of the sectors of Blue Economy have relative good potential in Bangladesh and deserve attention.

Sectors that have been accorded low priorities at this stage may have positive potentials but require solid research and assessments. Also sectors with high or medium potentials would benefit from further research.

According to the 7th FYP (GoB 2015), the economic development utilizing ocean resources appears promising for Bangladesh. Available evidence suggests that while there are some prospects for oil and gas resources, the potential is most promising for marine fishing, transportation and tourism.

C4.5 Building a Regional Partnership

Bangladesh began to prioritize the Blue Economy in its foreign policy after it peacefully settled maritime disputes with India and Myanmar. Dhaka now regards the Bay of Bengal as its "third neighbour", considering the richness of its marine resources.

In 2014, the Government of Bangladesh hosted an international workshop on Blue Economy. The workshop recommended that in many of the Large Marine Eco-systems (LME) across the world, including the Bay of Bengal LME, conservation and development of marine resources need to be pursued. This can be achieved by taking forward existing international obligations through coordinated strategic frameworks e.g. Strategic Action Program (FAO, Aug 2014), Integrated Management of the Marine Ecosystem (IMME), etc. To-date, UNCLOS provides the most widely accepted legal instrument in governance of all aspects of oceans and seas, including marine resources. At the workshop, it was also highlighted that the existing regional and international regimes and arrangements could further complement the global efforts and objectives towards conservation and sustainable use of oceans and seas and their resources by the State parties. Hence, Bangladesh places high importance to regional partnership.

MoUs with India to develop blue economy

A joint declaration between Bangladesh and India was announced on 7 June 2015 at the conclusion of visit by Prime Minister Mr. Narendra Modi, Prime Minister of India to Bangladesh. Section 44 of the Joint Declaration states that "the two Prime Ministers expressed satisfaction at the amicable settlement of the maritime boundary between the two countries. To harness the vast economic opportunities this has opened up, they agreed to work closely on the development of ocean-based Blue Economy and Maritime Cooperation in the Bay of Bengal and chart out the ways for future cooperation".

During the visit, 12 bilateral documents were signed, exchanged, adopted and handed over. Three of these were:

- Agreement on Coastal Shipping between Bangladesh and India.
- Memorandum of Understanding on Blue Economy and Maritime Cooperation in the Bay of Bengal and the Indian Ocean
- Memorandum of Understanding between University of Dhaka, Bangladesh and Council of Scientific and Industrial Research, India for Joint Research on Oceanography of the Bay of Bengal

The first meeting of Joint Working Group (JWG) to operationalize the Memorandum of Understanding (MoU) on Blue Economy was held in May 2016. Discussions pertained to cooperation in capacity building and training, sharing of information and joint research in several areas, including marine biotechnology, green tourism and hospitality, marine aquaculture, deep sea fishing, maritime pollution response, ocean disasters and services, for mutual benefit.

China's interest to assist in developing the Blue Economy

China has expressed its desire to help Bangladesh in the field of Blue Economy and has put forward a cooperation proposal. The possible future cooperation can be done under an MoU or a joint working group can be formed. The government is considering all options. The State Oceanic Administration of China has already signed a memorandum of understanding with Oceanography Department of the Dhaka University and offered several scholarships including PhD programmes and will also provide equipment to the Department.

The Indian Ocean Rim Association (IORA), a group of 20 member countries along the rim of the Indian Ocean and six development partners including the US, Germany and China has awarded full funding for two projects: 'Small scale inland and/or coastal aquaculture project in the Indian Ocean Region' and 'Exploration of economically important marine flora from the Bay of Bengal: a pilot study'.

Other Partnerhsip opportunities for developing the Blue Economy

The European Union also showed interest to work with Bangladesh in this area. In November 2015, the Embassy of Bangladesh in collaboration with IUCN organised a thematic consultation with representatives from 11 countries on the "Blue Economy for Climate Change Resilience: Towards Partnerships and Collaboration" in Bangkok, Thailand.

Blue Economy is being considered as an agenda for cooperation in SAARC meetings. The Blue Economy approach recognises and places renewed emphasis on the critical need for the international community to address effectively the sound management of resources in and beneath international waters by further development and refinement of international law and ocean governance mechanisms. Every country must take its share of the responsibility to protect the high seas.

Annex D: Technical Annex to Chapter 11

Table D11.1: Public Sector Allocation to the Water Sector

	FY12	FY13	FY14	FY15	FY16(RB)	FY17(B)
	(% of GDP)					
Total expenditure	14.4	14.5	14.0	13.5	15.3	17.3
of which: Water resource and development	**0.5**	**0.6**	**0.6**	**0.6**	**0.8**	**0.8**
Agriculture	1.4	1.6	1.3	1.1	1.1	1.2
Of which: Water Resource (Irrigation, FCD, etc)	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Defense	1.2	1.0	1.0	1.2	1.2	1.1
Public administration	1.0	0.7	1.1	0.8	1.4	2.4
Social security and welfare	0.9	0.8	0.8	0.7	1.0	1.0
Of which: Relief and Disaster Management	**0.4**	**0.4**	**0.4**	**0.3**	**0.4**	**0.4**
Public order and security	0.8	0.8	0.9	0.9	1.0	1.1
Housing	0.1	0.1	0.1	0.1	0.2	0.2
Health	0.7	0.7	0.7	0.7	0.9	0.9
Recreation, culture and religion	0.1	0.1	0.1	0.1	0.1	0.1
Industrial and economic services	0.1	0.2	0.2	0.2	0.2	0.2
Education and information technology	1.8	1.8	2.0	2.0	2.3	2.7
Interest	1.9	2.0	2.1	2.0	1.8	2.0
Transport and communication	0.9	1.0	1.1	1.3	1.5	1.9
of which: Inland Water Transport	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**
Local government and rural development	1.0	1.2	1.1	1.2	1.2	1.2
of which: Water supply and sanitation	**0.2**	**0.2**	**0.2**	**0.3**	**0.3**	**0.3**
Energy and power	0.8	0.9	0.8	0.4	1.0	0.8
Miscellaneous expenditure	1.6	1.5	0.8	0.9	0.4	0.6
	(% of Total Expenditure)					
Agriculture	9.6	11.3	9.2	7.8	7.0	6.7
Of which: Water Resource	**1.4**	**1.4**	**1.5**	**1.4**	**1.4**	**1.4**
Defense	8.0	6.9	7.4	8.6	7.8	6.5
Public administration	7.2	4.6	7.7	6.0	9.0	13.9
Social security and welfare	5.9	5.8	6.0	5.5	6.4	5.8
Of which: Relief and Disaster Management	**2.8**	**3.0**	**3.1**	**2.3**	**2.9**	**2.3**
Public order and security	5.7	5.5	6.2	6.4	6.6	6.2
Housing	0.9	0.8	0.9	1.0	1.5	0.9
Health	5.0	4.9	5.0	5.1	5.6	5.1
Recreation, culture and religion	1.0	1.0	1.0	0.9	0.9	0.8
Industrial and economic services	1.0	1.5	1.3	1.3	1.0	1.0
Education and information technology	12.5	12.2	14.1	14.8	14.9	15.6
Interest	13.4	13.7	15.0	15.2	12.0	11.7
Transport and communication	6.2	7.2	7.6	9.3	10.1	11.0
of which: Inland Water Transport	**0.7**	**0.9**	**1.3**	**1.4**	**1.3**	**1.2**
Local government and rural development	7.2	8.1	7.7	8.7	8.1	6.9
of which: Water supply and sanitation	**1.6**	**1.6**	**1.6**	**1.9**	**2.2**	**2.0**
Energy and power	5.2	5.9	5.6	2.9	6.3	4.4
Miscellaneous expenditure	11.0	10.5	5.4	6.6	2.9	3.5
Memorandum Item:						
Nominal GDP	**10552**	**11989**	**13437**	**15158**	**17296**	**19681**

Source: Ministry of Planning and Budget Documents of Ministry of Planning, Bangladesh.

Table D11.2: Integrated & Holistic Water Resources Management Approach

BDP 2100 has adopted an integrated and holistic delta management approach to formulate the projects in order to translate its vision, goals and strategies for implementation in reality over a period of time till 2100. Each of the projects will address the management of water security, food security, climate change impact, environmental sustainability, economic growth, social and institutional development.

Water Security	CC Impact & Env. Sustainability	Food Security & Livelihood
• Water resources management • Flood risk management • Drought risk management • Disaster risk management • Climate change impact management • Public health, water supply and sanitation	• Biodiversity • Forestry • Environment Pollution • CC Adaptation • CC Mitigation • DRRM	• Crop production • Livestock production • Fisheries production • Secured Livelihood
Economic Growth	**Social Development**	**Institutional & Knowledge Dev.**
• Integrated transportation management (road, river and rail) • Market linkage • Energy and power	• Poverty reduction • Women and development	• Water Management Organizations • Land management • Knowledge development, Management and update

List of Notable Publications by General Economics Division (GED) Bangladesh Planning Commission since 2009

1. Policy Study on Financing Growth and Poverty Reduction: Policy Challenges and Options in Bangladesh (May 2009)
2. Policy Study on Responding to the Millennium Development Challenge Through Private Sectors Involvement in Bangladesh (May 2009)
3. Policy Study on The Probable Impacts of Climate Change on Poverty and Economic Growth and the Options of Coping with Adverse Effect of Climate Change in Bangladesh (May 2009)
4. Steps Towards Change: National Strategy for Accelerated Poverty Reduction II (Revised) FY 2009-11 (December 2009)
5. Millennium Development Goals: Bangladesh Progress Report 2009 (2009)
6. Millennium Development Goals: Needs Assessment and Costing 2009-2015 Bangladesh (July 2009)
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