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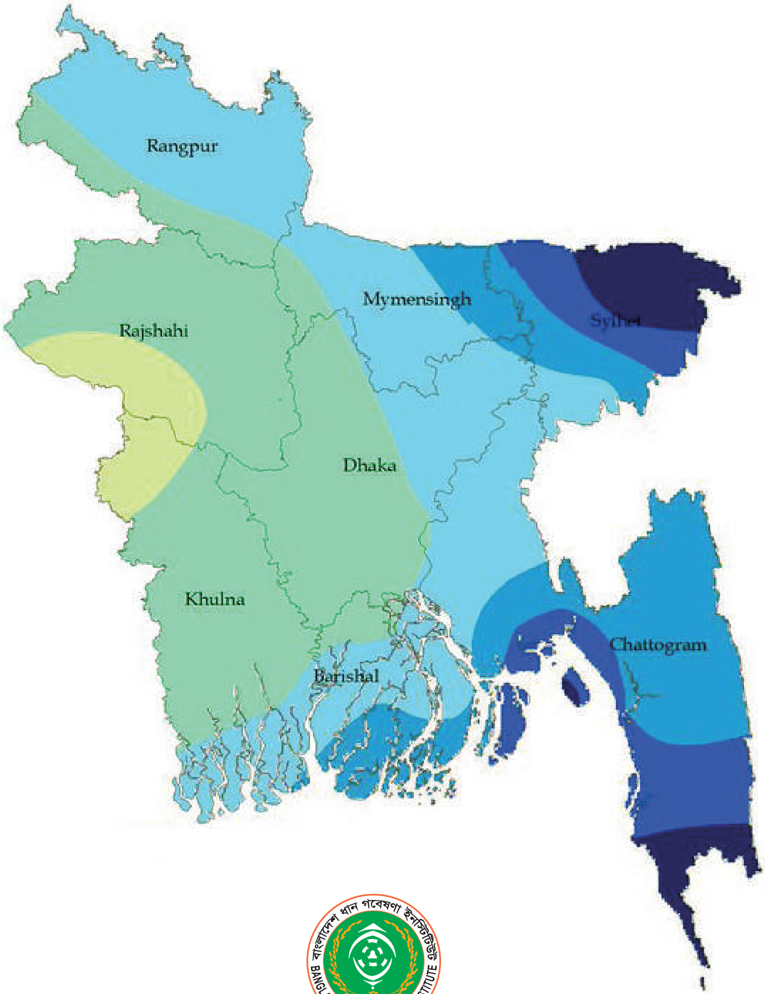
Present and Future Precipitation Scenario of Bangladesh

Bangladesh Rice Research Institute

Present and Future Precipitation Scenario of Bangladesh



Bangladesh Rice Research Institute (BRRI)

Bangladesh

Editor	Md. Abul Kashem Md. Rasel Rana
Acknowledgement	Bangladesh Rice Research Institute (BRRI) Gazipur 1701, Bangladesh
Publication No.	354, February 2023
Number of Copies	200
Copyright	Bangladesh Rice Research Institute (BRRI) Gazipur-1701, Bangladesh.
Cover Page Design	Niaz Md. Farhat Rahman Md. Abdullah Aziz
Communication	Publication and Public Relation Division (PPR) BRRI, Gazipur 1701, Bangladesh
Authors Contribution	**Md. Abdullah Aziz** and **Niaz Md. Farhat Rahman** conceptualized and performed analyses, prepared the maps and figures, and wrote the full manuscript. **Rokib Ahmed** assembled all datasets. **Sheikh Arafat Islam Nihad** contributed to the Introductory part of the manuscript. **Md. Shahjahan Kabir** and **Md. Chhiddikur Rahman** edited the manuscript critically. **Md. Ismail Hossain, Md. Abdul Qayum** and **Md. Abdullah Al Mamun** participated in editing the paper.
Citation	Aziz, M A., Rahman, N M F., Rahman, M C., Nihad S A I., Ahmed, R., Qayum, M A., Mamun, M A A., Hossain, M I., Kabir, M S. (2023). *Present and Future Precipitation Scenario of Bangladesh.* Bangladesh Rice Research Institute (BRRI), Bangladesh.
ISBN	978-984-35-3975-5
DOI	https://doi.org/10.59036/978-984-35-3975-5
Printed by	SRL Printing Press

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ISBN 978-984-35-3975-5;
DOI https://doi.org/10.59036/978-984-35-3975-5

Bangladesh Rice Research Institute (BRRI), imprint is published by the SRL printing press. The registered company address is: Kataban, Dhaka-1205, Bangladesh.

Acknowledgements

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Printing
SRL Printing Press, Katabon, Dhaka, Bangladesh

Foreword by Dr. Md Shahjahan Kabir

Rice is one of the major crops of the agricultural sector in Bangladesh. Farmers have been cultivating this crop from time immemorial. This sector played a major role in the areas of food security.

The agricultural sector predominantly depends on the climate; as an Agro-based country. As a result, the adverse impact of climate change creates an enormous threat to this prominent sector. This country is severely affected by the adverse effects of ongoing climate change. The continuous development activities are responsible for generating more greenhouse gases into the atmosphere that has increased up to 50% compared to 1990. Precipitation is one of the significant parts of agricultural practices that are also affected by climate change. To minimize the adverse effects of future climate change in the long run, prediction is one way to cope them, and it plays a major role in ensuring agricultural productivity for future generations in a sustainable way.

The Father of the Nation, Bangabandhu Sheikh Mujibur Rahman, as the greatest Bangali of all time, emphasized more to build up Golden Bangladesh through the golden crops from the agriculture sector. To continue this process, government has been implementing relevant action plans, such as the National Agriculture Policy 2018, Sustainable Development Goals (SDG) 2030, Vision 2041, and Bangladesh Delta Plan 2100.

The scientists from the Agricultural Statistics Division and Agromet Lab of BRRI were involved in preparing this book. I am so happy for the team who has presented amazing work and I am also acknowledging their enormous effort to make a valuable contribution that will be helpful to update the current Agricultural plan and policy framework to ensure food security.

May Bangladesh live forever!

Director General

Foreword by Dr. Mohammad Khalequzzaman

The continuous industrial revolution creates an enormous threat to our planet earth by generating an enormous amount of greenhouse gas (GHGs) emissions. The continuous GHGs emission results in global warming that alters the natural changing pattern of climate, eventually it affects the prominent climate parameters such as temperature and precipitation. The ongoing adverse effect of climate change makes the weather pattern distorted resulting in a reduction in crop production.

The Government of Bangladesh is following the worldwide action plans of the sustainable development goal (SDG) of the United Nation to safeguard food security by ensuring climate-resilient crop production. The historical data and future prediction on precipitation in Bangladesh may help the policymakers to update the existing policies and regulations for the development of future climate-resilient agricultural crops using technologies through the ongoing innovation of the fourth industrial revolution (4IR).

I am happy to know that Agricultural Statistics Division is going to publish a book on "Present and Future Precipitation Scenario of Bangladesh" that has taken initiative to studies on future precipitation scenarios of 2050 throughout the country and into its divisional level to generate a clear idea of the precipitation pattern of every region of this country. I highly appreciate the valuable contribution of the research team from Agricultural Statistics Division and Agromet Lab for their valuable contribution for this publication. My heartfelt gratitude to those who worked extensively to bring out this publication.

I sincerely hope that the outcome of this study can be implemented to update the current policies and regulations to ensure the food security of this country in order to achieve a sustainable future in the long run.

May Bangladesh live forever!

Director (Research) Current Charge

Foreword by Dr. Md Ismail Hossain

A study to analyse the average monthly total historic and present precipitation scenario in Bangladesh was conducted by Agricultural Statistics Division and Agromet Lab of BRRI. After that it also predicted the average monthly precipitation for 2050, using the state of art predicting methods (e.g., RCP 2.6, 4.5, 6.0, and 8.5 models.

The study has found the seasons and areas that are most vulnerable due to the extreme weather event. It also found the possible shifting onset of monsoon and dry seasons. However, the situation varies from region to region within the country.

The finding of this publication would be useful to update the current planning on the agricultural sector to minimize the adverse effects of climate change. The study also recommended identifying and predicting other climate parameters e.g., maximum and minimum temperature, humidity, sunshine hour etc.

The project was funded by BRRI. I sincerely congratulate all concerned colleagues working in the Agricultural Statistics Division and Agromet Lab of BRRI for their continuous effort and dedication in compiling the publication.

Long live Bangladesh!

CSO and Head, Agricultural Statistics Division

Preface

Bangladesh is predominantly dependent on crop production and its agricultural sector has gone through some unpredicted impact due to the ongoing climate change. Without forecasting future climate change, it will be difficult to make planning for smart agriculture and to be adopted with the certain change of climate in the long run. There are several climatic factors that are directly related to the production of agricultural crops, such as, temperature, precipitation, atmospheric CO2, and solar radiation. Precipitation is one of the important climate factors that play a significant role in agriculture production. It would be useful to conduct predictions on precipitation for agricultural planners and decision-makers.

The food security of Bangladesh predominantly depended on rice crop production. Rice production required a sufficient supply of water to start irrigation for better production. Rainfall is an important factor in rice crop cultivation. The cropping season of Bangladesh is divided into three seasons namely Kharif-1 (March to June), Kharif-II (June-July to October- November), and Rabi season (October-November to March-April). (Chowdhury and Hassan 2013). Some seasons and regions of this country seem to be in vulnerable situations due to climate change.

To ensure the food security of this country, it is essential to predict future climate conditions to adapt to the ongoing climate change. The future forecast of precipitation will be helpful to take an appropriate plan of action to ensure SDG targets. This study has been aimed to predict the future precipitation scenario of 2050 at different divisions of this country and all over the country. It will help the agricultural planners to plan for the regions and predict the regional scenarios intensively. The findings will play a significant role to formulate an agricultural plan to address the ongoing trend of climate change in Bangladesh.

We are highly grateful to BRRI authorities for providing all kinds of support to publish the book.

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Md Abdullah Aziz MS in Applied Statistics. Mr. Aziz also received the Post Graduate Diploma in Remote Sensing & Geographic Information System (RS & GIS) from the Centre for Space Science and Technology Education in Asia Pacific (CSSTEAP), Indian Institute of Remote Sensing (IIRS)-ISRO, India, in 2019. He is Senior Scientific Officer at Bangladesh Rice Research Institute (BRRI). His research interest includes the application of remote sensing and GIS in the field of agricultural science, cropping pattern modeling, crop area mapping, crop yield forecasting, land use land cover change, vegetation dynamics, climate change and unmanned aerial system.

Niaz Md. Farhat Rahman

Niaz Md. Farhat Rahman is a PhD scholar under National Agricultural Technology Program (NATP) funded by World Bank at Shahjalal University of Science and Technology, Sylhet, Bangladesh. He is working as a Principal Scientific Officer in Bangladesh Rice Research Institute (BRRI), Bangladesh. BRRI established an Agro-Meteorology and Crop Modelling lab in 2016 and he is one of the establishment members and Coordinator as well. Mr. Niaz's current research focuses on agricultural meteorology, crop modeling, quantitative genetics, and statistical modeling for agricultural and climate change research. He has written over 50 publications (journals and books) in national and international scientific domains. He got Digital Bangladesh Award 2022 from Prime Minister Sheikh Hasina for the innovation of Integrated Rice Advisory System (IRAS) for Sustainable Productivity in Bangladesh.

Mohammad Chhiddikur Rahman

Mohammad Chhiddikur Rahman, Ph.D. in Agricultural Economics. Dr. Rahman received his Ph.D. in Agricultural Economics from the University of the Philippines Los Baños (UPLB), Philippines under the Lee Foundation Rice Scholarship Program of the International Rice Research Institute (IRRI). Prior to that he obtained Bachelor and Master degrees in Agricultural Economics from Bangladesh Agricultural University (BAU), Bangladesh. He is working as a Senior Scientific Officer in Bangladesh Rice Research Institute (BRRI), Bangladesh. His research interest includes production economics, agricultural marketing, impact assessment, climate change and adaptation.

Sheikh Arafat Islam Nihad

Sheikh Arafat Islam Nihad received MSc degree in Crop Botany from Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur-1701, Bangladesh. Mr. Nihad is now a Scientific Officer of Plant Pathology Division, Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh. He is working on molecular biology of plants and pathogens mainly focusing on resistant breeding, pathogen identification and detection through the molecular marker, screening of advanced lines against diseases, and on plant-pathogen-environment interaction. He is interested to conduct in-depth study on plant-pathogen interaction and response of the diseases and pathogens in relation to environmental factors and climate change.

Rokib Ahmed

Rokib Ahmed received the M.Sc. degree in Statistics from the University of Rajshahi, Bangladesh, in 2011. Mr. Ahmed also completed Fundamental on GIS course from Department of Geography and Environment, University of Dhaka, Bangladesh. He is working as a Cartographer in Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh. His research interest includes the application of remote sensing and GIS in the field of agriculture science, cropping pattern modeling, land use land cover change, crop suitability mapping, climate change, data management and data processing.

Md. Abdul Qayum

Md. Abdul Qayum is an Employee of Bangladesh Rice Research Institute and held the Position of Senior Scientific Officer at Agricultural Statistics Division. He received the M.Phil. degree in Statistics from the University of Rajshahi, Bangladesh in 2021. He also obtained M.Sc. degree in Statistics with first class from the same University in 2009. Mr. MA Qayum got the second position in his four years bachelor (B. Sc.) degree with first class. He is now work on service automation, service process simplification and service digitization and already developed more than six web application for internal service digitization. His is very much interest of using the 4IR technologies in rice research. his research interest also includes Experimental Design, Modeling and Forecasting in Time and Frequency Domain and uses of Remote Sensing in agricultural research sector.

Md. Abdulllah Al Mamun

Md. Abdullah Al Mamun is a Scientific Officer of the Agricultural Statistics Division at Bangladesh Rice Research Institute (BRRI). He obtained his Master of Science degree in Statistics from the University of Rajshahi, Rajshahi, Bangladesh. Mr. Mamun is proficient in experimental design, stochastic analysis, statistical methodology, data mining, time series modelling and forecasting, environmental statistics and multivariate analysis. He has consistently increased expertise in different statistical software such as Programming R, SPSS, STAR, PBTools, Statistix10, GenStat, MS Excel, CropStat, Meta-R, C, C++ and FORTRAN 77. He has over 28 research articles published in prestigious national and international journals.

Dr. Md. Ismail Hossain

Md. Ismail Hossain, Ph.D. in the field of Sample survey and sampling design of statistics from Jahangirnagar University, Department of Statistics, Savar, Dhaka, Bangladesh, 2011; Dr. Hossain also received M.Phil in the field of sampling techniques of Statistics from the same university. Dr. Hossain is member in different societies such as External in B.Sc (Ag.), M.Sc (ag.) and Ph.D Level, Bangabhandu Sheikh Mujibur Rahman Agriculture University (BSMRAU), Bangladesh. Expert member of the Syllabus committee in B.Sc (Ag.), M.Sc (ag.) level, Department of Agricultural Statistics, BBA and MBA level in Agribusiness, Faculty of Agribusiness, Sher-e-Bangla Agriculture University (SAU), Dhaka, Bangladesh. He is Chief Scientific Officer and Head of Agricultural Statistics Division at Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh.

Dr. Md. Shahjahan Kabir

Dr. Md. Shahjahan Kabir is the Director General of Bangladesh Rice Research Institute (BRRI) where he devoted his whole career as a rice scientist. He undertook his PhD research on "Geo-Statistical Modelling" with the Cornell University, USA and received degree from the Jahangirnagar University, Bangladesh. Dr. Kabir is one of the senior scientists in the National Agricultural Research System (NARS) of the country and a pioneer in geo-statistical modelling. His research interests include stochastic modeling, statistical dynamics for rice experiments, climate change, GIS and rice policy. He has written over 101 publications (journals and books) in national and international scientific domains.

Content

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List of Acronyms

AR	Assessment Report
BBS	Bangladesh Bureau of Statistics
BER	Bangladesh Economic Review
BMD	Bangladesh Meteorological Department
BRRI	Bangladesh Rice Research Institute
CMIP	Coupled Model Intercomparison Project
CO_2	Carbondyoxide
GCMs	Global Climate Models
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GIS	Geographic Information System
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
MM	Millimetres
RCP	Representative Concentration Pathway
SDGs	Sustainable Development Goals

1. KEY MESSAGES

In 2050 Precipitation will be heavier in every month except April, August, and November.

The eastern portion of Bangladesh will get the maximum amount of precipitation, while the north-western side will see the least amount.

Although different RCP models imply different results, the discrepancies are not very noticeable.

2. INTRODUCTION

2.1 Background

The economy of Bangladesh is based on agriculture (BER, 2020; Rahman et al., 2020). The contribution of the agriculture sector to GDP is 13.02 percent (BBS, 2020; Alam et al., 2020). The performance of the agricultural sector is subject to the weather condition of any country (Aziz et al., 2021). As the sector is always vulnerable to weather variability and climate conditions (Parker et al., 2019; Rahman et al., 2015). The impact of climate change on agriculture is one of the major deciding factors influencing future food security (Rahman et al., 2023; Rahman et al., 2022). It is worth mentioning that rice is the staple food of Bangladesh, occupying nearly 90% of the total net cropped area (Islam et al., 2019). Temperature, rainfall, atmospheric CO 2, and solar radiation are the important climate parameters of rice production (Nyangau, 2014; Amin et al. 2015; Ali et al. 2017). A change in any climate parameters such as precipitation patterns increases the likelihood of short-run crop failures and that may influence long-run production declines (IFPRI, 2009, Aziz et al., 2022). Considering high confidence, increasing concentrations of global greenhouse gas is a major cause of global warming during the previous century (Yang et al., 2012). Global warming has a direct impact on precipitation and temperature, which causes more evaporation and hence surface drying, extending the drought's intensity and duration (Trenberth, 2011).

2.2 Regional Context

The food security of Bangladesh is basically rice security (Rahman et al., 2021). Rice is a plant that requires enough irrigation for better production. Therefore, precipitation is a crucial factor for supplying irrigation in rice production as well as reducing the pressure on groundwater. Bangladesh has three consecutive cropping seasons namely Kharif-1 (March to June), Kharif-II (June-July to October-November), and Rabi seasons (October-November to March-April) (Chowdhury and Hassan 2013). Bangladesh, like the rest of the globe, is suffering from the devastating impacts of climate change. Our climate system is undergoing long-term changes as a result of global warming, which might have permanent consequences if we do nothing. As a result, the United Nations launched the Sustainable Development Goals (SDGs), where Goal 13 addresses the actions to combat climate change issues and consequences (Rahman, 2021). These steps must be taken in parallel with attempts to include disaster risk reduction, sustainable natural resource management, and social protection in national development plans. It is still conceivable to restrict global mean temperature rise to two degrees Celsius over pre-industrial levels, aiming for 1.5°C, given the strong political will, greater investment, and existing technology, but this would need quick and ambitious collective action. These actions would also address the 4th Industrial Revolution's (4IR) climate issues (Cole, 2021).

Kharif-I (March to June) season is the most vulnerable season in Bangladesh. High temperature, evapotranspiration, hailstorm, cloudy weather, and low intensity of rainfall made this season vulnerable to crop production (Shelley et al., 2016). Aus rice, jute, groundnut, maize, soybean, etc. are the major crops of the Kharif-I season in Bangladesh. Lack of rainfall during March-April hampers the land preparation of Aus rice as well as for other crops (Shelley et al. 2016). April is the hottest month (average maximum temperature is 33°C) in Bangladesh and excessive temperature without rainfall during this month causes drought in different parts of Bangladesh (Nissan et al. 2017; Mamun et al. 2018). Under drought conditions, crops failed to survive and ultimately wilting occurs and the plant dies (Bodner et al. 2015).

Kharif-II is the rainy season or monsoon of Bangladesh when the highest precipitation occurs. Aman is the main crop of this season and the area coverage of Aman rice is higher compared to the other two rice seasons

(Aus and Boro) (Kabir et al., 2020) . Delay of rainfall during June-July hampers the seedbed preparation and heavy rainfall during July-August causes flash flood in different parts of Bangladesh and delay the transplanting of Aman rice (World Bank, 2000) . Delay planting reduces the Aman rice yield and declines rice production. Heavy rainfall and windstorm also hamper the establishment of crops in the field. Prevailing high temperatures (<35°C) and lack of rainfall during the flowering and grain-filling stages (August-September) may create heat shock and hamper yield of rice plants (Yoshida, 1981) .

Rabi season (October-November to March-April) is the mostly diversified cropping period and the crops growing in this season are known as winter crops in Bangladesh. The seeding of rabi crops such as Boro rice, wheat, cauliflower, cabbage, potato, carrot, radish, broccoli, tomato etc. start from October-November and their seeding also varied according to the location of Bangladesh. In the northern region, winter comes earlier, therefore seeding starts earlier there compared to other parts of the country. For maximum crops temperature varied from 10-20°C. On average temperature of winter of Bangladesh is 17°C to 20°C which is favorable for winter crops cultivation. However, due to climate change, spatio-temporal climatic variables changes are noticeable. Extreme cold during October to November hampers the seed germination as well as seedling establishment (Ansari and Ahmed 2017). On the contrary, winter is dry season but due to climate change sudden rainfall during October to November or even in December damages the seed germination and crop establishment. January is the coldest month of Bangladesh and extreme cold during January and February is the main mason of spikelet sterility of rice and wheat and lower production of winter vegetables (azm et al. 2018; Rashid and Yasmeen 2018; Sharmin et al. 2018).

To reconcile human society with natural systems, policymakers require the most up-to-date information on the projected future impacts of climate change (Miao et al., 2014). Climate models are essential for analyzing the climate system's response to diverse factors, providing seasonal to decadal climate forecasts, and making climate projections for the next centuries and even beyond (Flato et al., 2013).

2.3 Climate Modelling Initiative (CMI)

CMI is a collaborative research effort aimed at improving the accuracy of climate models and advancing our understanding of Earth's climate system. The initiative involves scientists from several institutions, including the University of Chicago, Argonne National Laboratory, and the Computation Institute.

The CMI was established in 2013 with the goal of improving climate modeling by bringing together researchers from diverse fields, including computer science, mathematics, and atmospheric science. The initiative is focused on developing new mathematical and computational tools for modeling the complex interactions between the atmosphere, oceans, land surface, and ice sheets.

One of the key projects of the CMI is the development of a new generation of climate models that incorporate more detailed information about the interactions between different components of the climate system. This includes models that can simulate the behavior of clouds, which are one of the most challenging aspects of climate modeling due to their complexity and variability.

The CMI has also developed new techniques for analyzing climate data, including advanced statistical methods and machine learning algorithms. These tools can help scientists better understand the causes of climate variability and the impacts of climate change on different regions of the world.

2.4 Coupled Model Intercomparison Project (CMIP)

CMIP is a collaborative effort among climate scientists to improve our understanding of the Earth's climate system by using a standardized set of global climate models (van Vuuren et al. 2011). CMIP is organized by the World Climate Research Program (WCRP) and is designed to provide a framework for comparing and evaluating climate models (WCRP, 2022).

The CMIP project began in the mid-1990s and has since undergone several phases. The most recent phase, CMIP6, started in 2016 and is ongoing (Eyring, 2016). In CMIP, climate modeling groups from around the world use a common set of scenarios, or Shared Socioeconomic Pathways (SSPs), to simulate the Earth's climate over a set period of time. These simulations are then used to assess the impact of various factors, such as greenhouse gas emissions and land use change, on the Earth's climate.

The standardized approach of CMIP allows for consistent comparison of model output across different research groups and regions of the world. This helps to identify commonalities and differences in climate model output, which can then be used to improve our understanding of the Earth's climate system and make more accurate predictions of future climate change.

CMIP has played a significant role in advancing our understanding of climate change. For example, CMIP5 was used to develop the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), which provided important information about the causes and impacts of climate change, as well as strategies for mitigation and adaptation. The fifth phase of the CMIP5 produces a cutting-edge multi-model dataset aimed at improving our understanding of climate variability and change. CMIP5 simulations are being carried out by more than 20 modeling groups utilizing more than 50 models (Taylor, 2011).

Overall, the CMIP project provides an essential framework for evaluating and improving our understanding of the Earth's climate system and is a critical tool for informing climate policy and decision-making.

2.5 Representative Concentration Pathways (RCPs)

RCPs are a set of scenarios used in climate modeling to project future concentrations of greenhouse gases and other radiative forcing agents in the Earth's atmosphere. The RCPs were developed by the Intergovernmental Panel on Climate Change (IPCC) as part of its Fifth Assessment Report (AR5) to provide a standardized set of scenarios for climate modelers.

There are four RCPs: RCP2.6, RCP4.5, RCP6, and RCP8.5. The numbers in the RCP names refer to the radiative forcing (in Watts per square meter) associated with each scenario by the year 2100. For example, RCP2.6 assumes a radiative forcing of 2.6 W/m^2 by 2100, while RCP8.5 assumes a radiative forcing of 8.5 W/m^2 by 2100 (IPCC, 2014).

Each RCP includes assumptions about future human activity, such as population growth, economic development, and energy use, as well as assumptions about the deployment of various technologies, such as renewable energy and carbon capture and storage. These assumptions are used to project future emissions of greenhouse gases and other radiative forcing agents.

The RCPs are used as inputs to climate models to project future climate change under different scenarios. For example, the RCP8.5 scenario assumes a business-as-usual trajectory, in which greenhouse gas emissions continue to increase throughout the 21st century, leading to significant warming and other impacts. The RCP2.6 scenario assumes a rapid transition to low-carbon energy sources, resulting in lower emissions and less severe climate impacts.

The RCPs are not predictions, but rather plausible scenarios for the future that can help policymakers and the public understand the potential impacts of different emissions pathways on the Earth's climate system.

2.6 Observed Changes in Global Climate

Global climate change can be traced back to the industrial revolution in the late 18th and early 19th centuries when the widespread use of fossil fuels led to a significant increase in greenhouse gas emissions (Santos et al., 2022). These emissions trap heat in the Earth’s atmosphere and cause the planet’s average temperature to rise, leading to what is now referred to as global warming. In Bangladesh, the impacts of climate change have been felt for decades, with the country experiencing increased frequency and intensity of natural disasters such as floods, cyclones, and droughts. The 1980s and 1990s saw a significant increase in the severity of these events, and in recent years the country has been grappling with the impacts of rising sea levels, changing temperature and rainfall patterns, and increased salinity of its freshwater sources (Alam et al., 2018). Despite these challenges, Bangladesh has made some progress in addressing the impacts of climate change, including through the implementation of disaster risk reduction programs, the promotion of sustainable agriculture, and the adoption of renewable energy sources (Smith et al., 2021). However, much more needs to be done to ensure the country is adequately prepared for the challenges of the future.

2.7 Projected Changes in Global Climate

Very few studies have investigated and forecasted the precipitation scenario of Bangladesh. Rahman et al. (2019) has shown a climate simulation model of Bangladesh over 1979–2006. Dastagir (2015) has prepared a climate change modeling where precipitation spatial regulation was very high, i.e., 20km to 50km, which make the confidence level of the model very poor. Bosu (2020) has produced projected precipitation map of Bangladesh for 2050-74, also Mondal (2020) showed mean annual rainfall of Bangladesh for 2041-60, but those maps were in annual precipitation where monthly precipitation scenario are absent.

2.8 Synthesis of Regional Climate Change

The impacts of climate change are not limited to any one region and are affecting countries and communities across the world in different ways. In general, the impacts of climate change are more severe in low-lying coastal regions, small island states, and in areas with weak infrastructure and limited resources. In the South Asian region, countries such as Bangladesh, India, and Pakistan are among the most vulnerable to the impacts of climate change due to their high populations, low-lying coastal areas, and limited resources to adapt. These countries are facing challenges such as increased frequency and intensity of floods and cyclones, rising sea levels, and changing temperature and rainfall patterns, which are affecting agriculture, food security, and the livelihoods of millions of people (Rees, 2021). In response to these challenges, regional initiatives such as the South Asian Association for Regional Cooperation (SAARC) have been established to address the impacts of climate change in the region (Mishra et al., 2014). These initiatives aim to promote cooperation and coordination between countries to share knowledge, resources, and best practices, and to work together to find solutions to the challenges posed by climate change. Overall, the impacts of climate change are a major concern for the South Asian region, and it is crucial that countries work together to address this global challenge and ensure the well-being of their populations in the face of changing climate conditions.

2.9 Scope

This book provides a detailed overview of climate change in Bangladesh. The objectives are to provide a state-of-the-art assessment of how and why Bangladesh's climate is changing, changes that are projected for the future, uncertainties and knowledge gaps, and identification of areas that require greater research. This book will be useful to advance public awareness of Bangladesh's changing climate and to inform mitigation and adaptation decision making. While it is meant to be policy relevant, this book is not intended to be policy prescriptive.

3. STUDY AREA

Bangladesh's latitude ranges from 20°34'N to 26°38'N, while its longitude ranges from 88°01'E to 92°41'E. The majority of the nation is a low-lying plain land, except for the mountainous southeast. The Assam Hills to the east, the Meghalaya Plateau to the north, and the steep Himalayas to the north surround it. The Bay of Bengal is to the south, and the West Bengal Plain and the Gangetic Plain are to the west (Chowdhury et al., 2021).

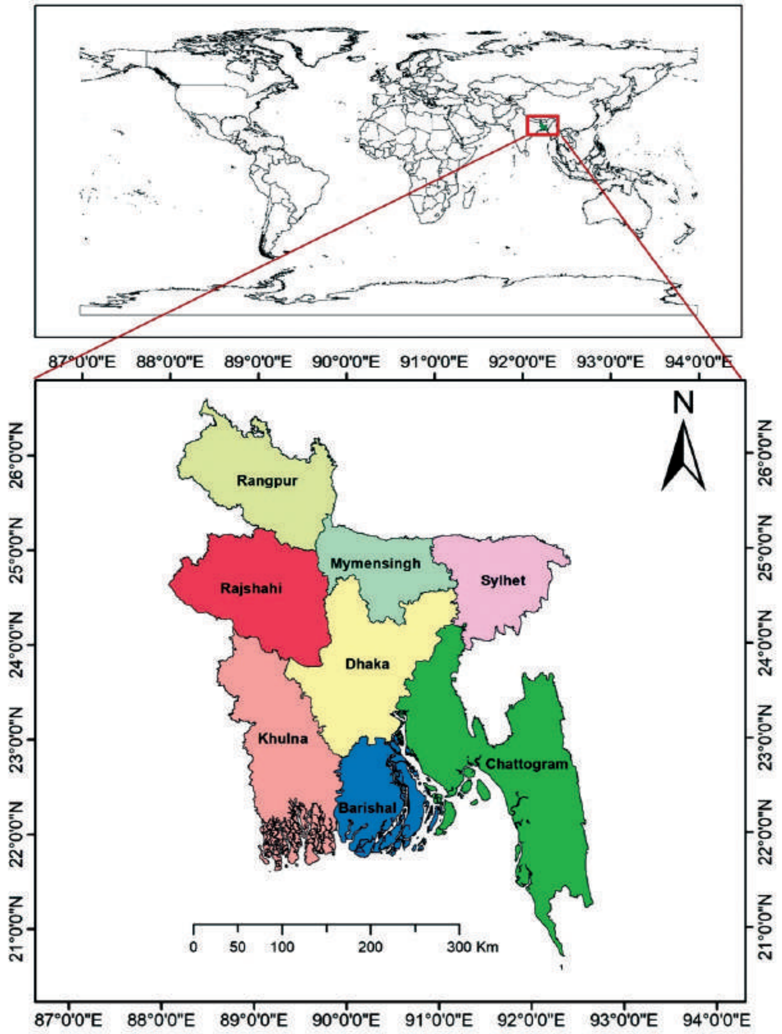


Figure 1: Study Area Map

Bangladesh's climate is characterized by tropical monsoon with large seasonal changes in precipitation, high temperatures, and high humidity. The yearly cycle of precipitation, on the other hand, has a unique seasonal pattern that is far more prominent than the yearly cycle of temperature. Annual rainfall varies by region, ranging from 150 cm in the west-central section of the country to over 400 cm in the northeastern and southeastern regions. The northern section of Sylhet district and the southeastern section of the country (Cox's Bazar and Bandarban districts) have received the most rainfall (Wheeler, 1999).

4. MATERIALS

In this study, we used the most recurrently used source of freely available, high resolution, downscaled, bias-corrected, and long-term climate raster dataset with global coverage, WORLDCLIM 1.4, for past (1970-2000) and future (2040-2060 or 2050), its updated version 2.1 (Fick and Hijmans 2017) present (2010-2018) for precipitation. All the data are in raster with a high spatial resolution of 2.5 arc minutes.

Table 1. List of datasets used in this study

Climate Period	Climate Dataset	CMIP Phase	Author	Data Format	Obtained Spatial Resolution	Obtained Source
Past (1970-2000)	WORLDCLIM1.4	CMIP6	Hijmans et al., 2005	Raster	2.5 arc minutes resolution	https://www.worldclim.org/data/monthlywth.html
Present (2010-2018)	WORLDCLIM2.1	CMIP6	Fick and Hijmans 2017	Raster	2.5 arc minutes resolution	https://www.worldclim.org/data/worldclim21.html
Future (2040-2060)	WORLDCLIM1.4	CMIP5	Hijmans et al., 2005	Raster	2.5 arc minutes resolution	https://www.worldclim.org/data/monthlywth.html

Pixels composed raster data, which are also so referred to as grid cells, are commonly squared and evenly spaced, but they are not required to be. Because each pixel has its value or class, Rasters frequently appear pixelated (GISGeography, 2021).

In total 19 CMIP5 Global Climate Models (GCMs) were collected from WORLDCLIM 1.4 (Fick and Hijmans 2017) for future precipitation projection.

Table 2: List of CMIP5 global climate models used for forecasting projected precipitation in this study

Model	Resolution	Modeling group	Obtained Source	Obtained Resolution
ACCESS1-0 (#)	1.9° × 1.3°	CSIRO-BOM, Australia	WORLDCLIM 1.4 (https://www.worldclim.org/data/monthlywth.html)	2.5 arc minutes resolution
BCC-CSM1-1	2.8° × 2.8°	Beijing Climate Center, China Meteorological Administration, China		
CCSM4	1.3° × 0.9°	National Center for Atmospheric Research (NCAR), USA		
CESM1-CAM5-1-FV2	1.3° × 0.9°	National Science Foundation, Department of Energy, NCAR, USA		
CNRM-	1.4° × 1.4°	Centre National de Recherches Meteorologiques, France		
GFDL-CM3	2° × 2°	NOAA/Geophysical Fluid Dynamic Laboratory, United States		
GFDL-ESM2G	2° × 2°	NOAA/Geophysical Fluid Dynamic Laboratory, United States		
GISS-E2-R	2° × 2°	NASA Goddard Institute of Space Studies, United States		
HadGEM2-AO	1.9° ×.3°	National Institute of Meteorological Research/Korea Meteorological Administration, Korea		
HadGEM2-CC	1.9° × 1.3°	Met Office Hadley Centre (additional HadGEM2-ES realisations contributed by Instituto Nacional de Pesquisas Espaciais), UK		
HadGEM2-ES	1.9° × 1.3°	Met Office Hadley Centre (additional HadGEM2-ES realisations contributed by Instituto Nacional de Pesquisas Espaciais), UK		
INMCM4	2° × 1.5°	Institute for Numerical Mathematics, Russia		
IPSL-CM5A-LR	3.8° × 1.9°	Institut Pierre-Simon Laplace, France		

Model	Resolution	Modeling group	Obtained Source	Obtained Resolution
MIROC-ESM-CHEM (#)	2.8° × 2.8°	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies, Japan		
MIROC-ESM (#)	2.8° × 2.8°	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies, Japan		
MIROC5 (#)	1.4° × 1.4°	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology, Japan		
MPI-ESM-LR	1.8° × 1.8°	Max Planck Institute for Meteorology (MPI-M), Germany		
MRI-CGCM3	1° × 1°	Meteorological Research Institute, Japan		
NorESM1-M	2° × 2°	Norwegian Climate Centre, Norway		

The study focuses on future precipitation projections for all four Representative Concentration Pathways (i.e., RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5). The three RCPs constitute 'low' (RCP 2.6),'medium' (RCP 4.5), 'high' (RCP 6.0), and 'very high' (RCP 8.5) scenarios with radiative forcing's of 2.6, 4.5, 6.0, and 8.5 W m2, respectively, by 2100 (Miao et al., 2014).

A Representative Concentration Pathway (RCP) is an Inter governmental Panel on Climate Change (IPCC)-adopted greenhouse gas concentration (rather than emissions) trajectory. For the IPCC's Fifth Assessment Report (AR5) in 2014, four paths were employed for climate modeling and research. The paths depict various climatic futures that are all regarded as plausible based on the number of greenhouse gases (GHG) emitted in the coming years (Moss et al., 2008).

4.1 RCP 2.6

According to the Intergovernmental Panel on Climate Change (IPCC), calls for carbon dioxide (CO2) emissions to begin dropping by 2020 and reach zero by 2100. It also aims for methane reduction (CH4) emissions to half of what they were in 2020, and a reduction in sulfur dioxide (SO2) emissions to 10% of what they were in 1980–1990. By 2100, RCP 2.6 is expected to keep global temperature rise below 2 degrees Celsius (IPCC, 2014: Climate Change 2014: Synthesis Report).

4.2 RCP 4.5

RCP 4.5 is classified as an intermediate scenario by the Inter governmental Panel on Climate Change (IPCC). Emissions peak about 2040 in RCP 4.5 and then decline. RCP 4.5 is more likely than not to result in a 2–3-degree Celsius increase in global temperature by 2100, with a 35% greater mean sea level rise than RCP 2.6 (Core Writing Team, 2015).

4.3 RCP 6.0

It is a stabilization scenario in which total radiative forcing is stabilized beyond 2100 without overshoot using a variety of technologies and tactics to reduce greenhouse gas emissions (Fujino et al., 2006).

4.4 RCP 8.5

In RCP 8.5, emissions continue to rise throughout the 21st century. RCP 8.5 was based on an overestimation of expected coal production, which is often used to simulate worst-case climate change scenarios. The RCP8.5 scenario is becoming "increasingly implausible with every passing year," according to one research. (Hausfather & Peters, 2020).

5 METHOD

In this study, the methodology is subdivided into two steps by using raster statistics, raster extraction, and zonal statistics GIS techniques in different steps.

5.1 Step-1: Compilation and Processing of Climate Data

The various Global Climate Model (GCMs) data in raster format collected from the data source and imported into the GIS software (ArcGIS 10.8 version) and undergoes raster statistics processing. Cell statistics function from the raster statistics tool has been used in this study to average multiple monthly precipitation raster model files of different years to a single raster file for each of the months. Cell statistics calculates statistics on a pixel-by-pixel basis from several rasters. The value of each position on the output raster is derived as a function of the cell values from all of the inputs at that place for the cell statistics tool. We used the mean statistics function to obtain the mean value of all input raster data.

5.2 Step-2: Preparation of Precipitation Projection Map

In this step, we use the raster extraction process to obtain our specific location data. The extract by mask procedure adopted for the study, which extracts the cells of the average raster that correspond to our study area designated by masking from the average raster. Then zonal statistics tool has been introduced to obtain the division-wise (admin boundary) precipitation projection data from that average raster file. The mean statistics type is used in this study to calculate specific division-wise data. After that whole country and division-wise precipitation map for the past (1970-2000) and future (2040-2060 or 2050) prepare using ArcGIS 10.8 software.

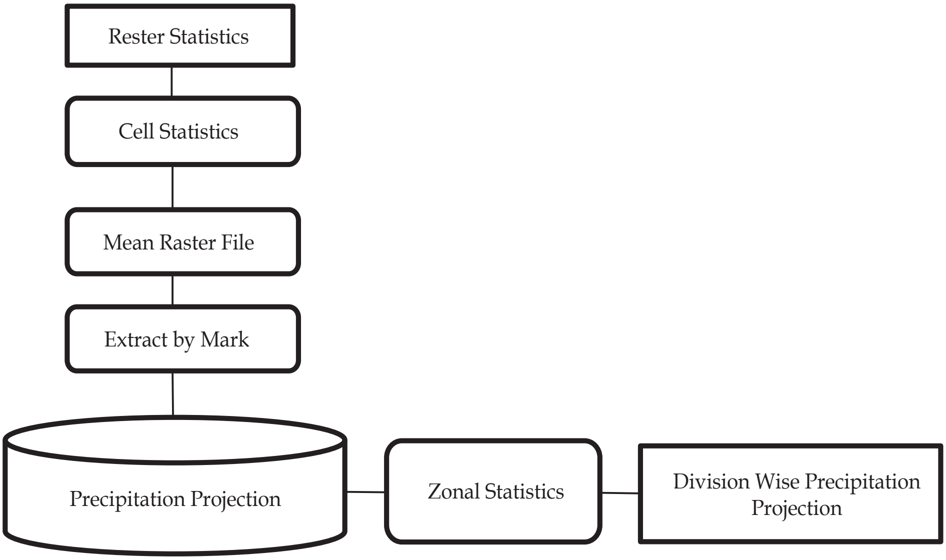


Figure 2: Methodological Framework

6 RESULTS

6.1 Past (1970-2000), Present (2010-2018), and Future (2050) Precipitation Scenario of January

6.2 Past (1970-2000), Present (2010-2018), and Future (2050) Precipitation Scenario of February

6.3 Past (1970-2000), Present (2010-2018), and Future (2050) Precipitation Scenario of March

6.4 Past (1970-2000), Present (2010-2018), and Future (2050) Precipitation Scenario of April

6.5 Past (1970-2000), Present (2000-2018), and Future (2050) Precipitation Scenario of May

6.6 Past (1970-2000), Present (2000-2018), and Future (2050) Precipitation Scenario of June

6.7 Past (1970-2000), Present (2000-2018), and Future (2050) Precipitation Scenario of July

6.8 Past (1970-2000), Present (2000-2018), and Future (2050) Precipitation Scenario of August

6.9 Past (1970-2000), Present (2000-2018), and Future (2050) Precipitation Scenario of September

6.10 Past (1970-2000), Present (2000-2018), and Future (2050) Precipitation Scenario of October

6.11 Past (1970-2000), Present (2000-2018), and Future (2050) Precipitation Scenario of November

6.12 Past (1970-2000), Present (2000-2018), and Future (2050) Precipitation Scenario of December

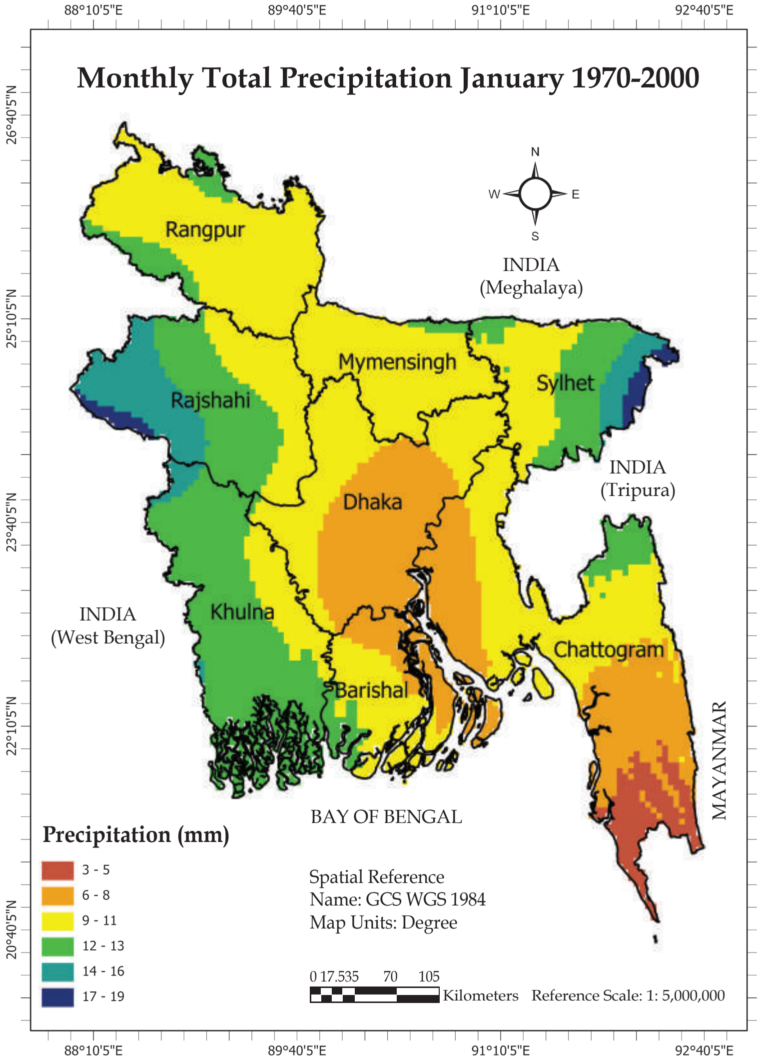


Figure 3. Average of total precipitation for January 1970-2000

Figure 3 shows the average total precipitation for January during 1970-2000 in Bangladesh. The high precipitation had observed in the north-eastern and lower part of the north-western side of Bangladesh. The central part of the country experienced moderate precipitation and the lowest precipitation was in the south-eastern side of Bangladesh.

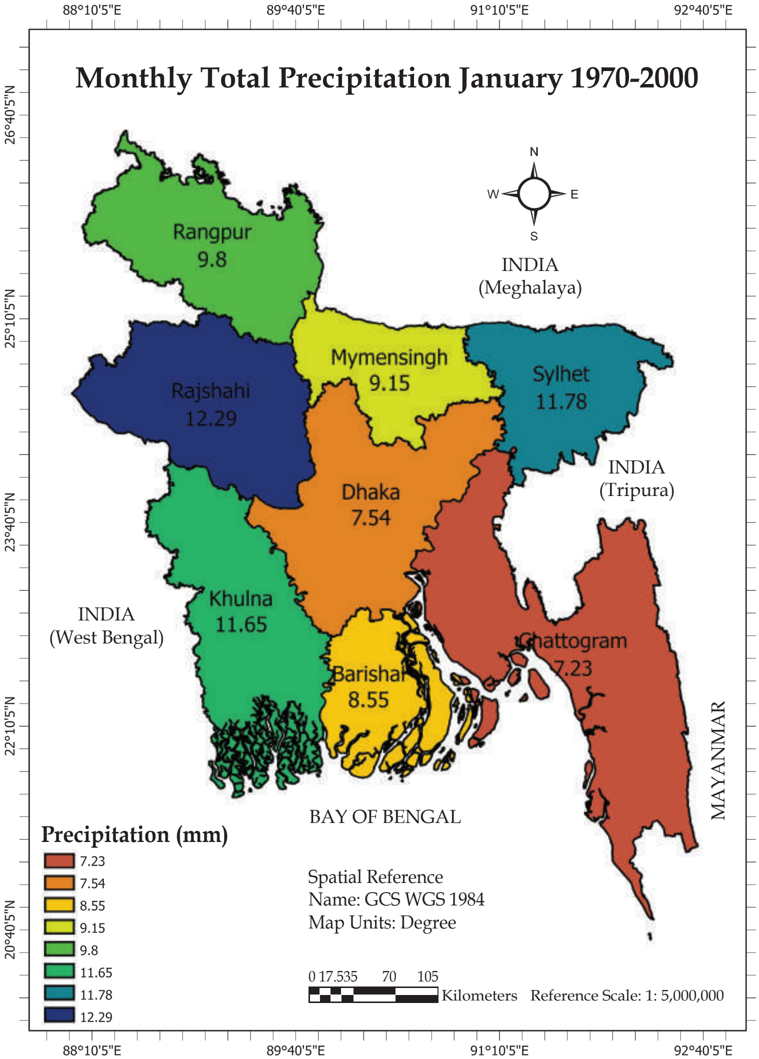


Figure 4. Division wise average of total precipitation for January 1970-2000

A division-wise analysis shows that Rajshahi division had the highest precipitation (12.29 mm), followed by Sylhet division (11.78 mm) and the lowest precipitation was in Chattogram with an average of 7.23 mm (Figure 4).

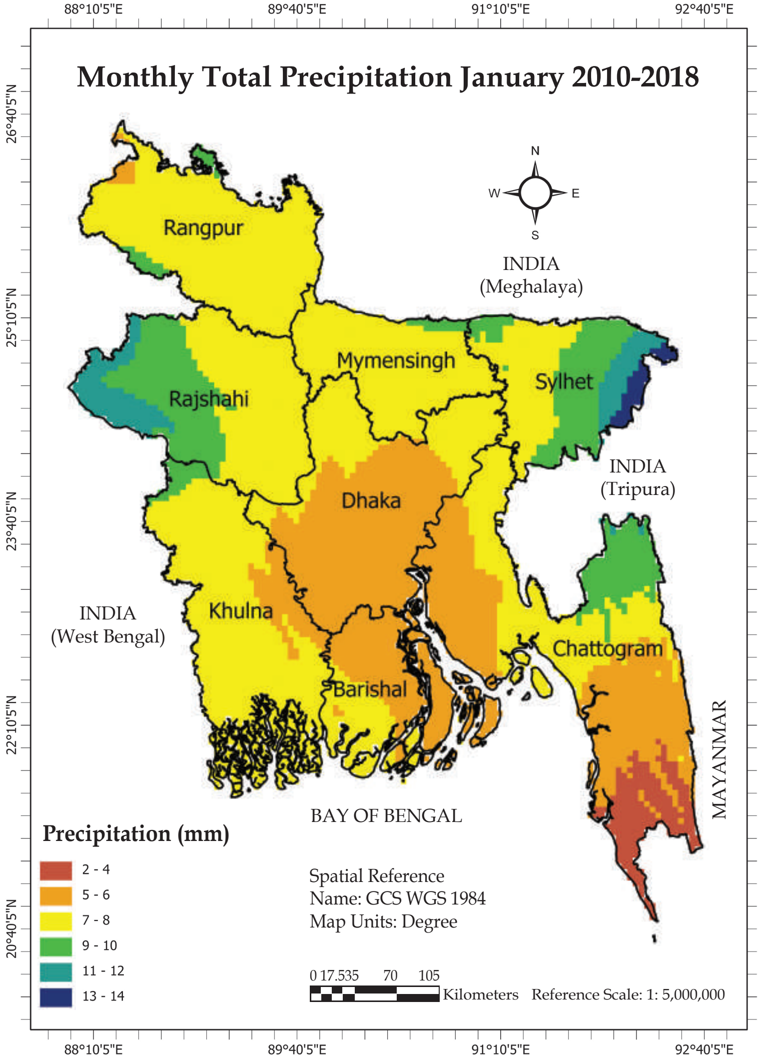


Figure 5. Average of total precipitation for January 2010-2018

Figure 5 is showing the average of total precipitation for January month during 2010-2018 in Bangladesh, where the highest precipitation was observed in the north-eastern side of Bangladesh, followed by the lower part of the north-western side of the country. The central part experienced moderate and the south-eastern side experienced the lowest precipitation.

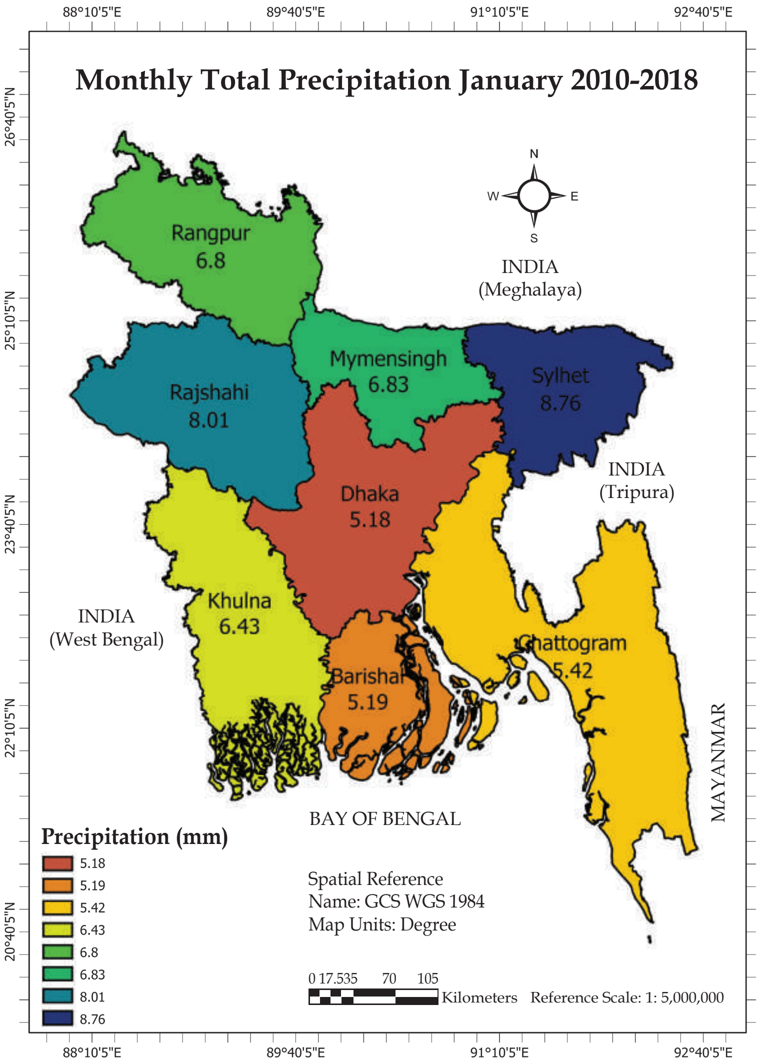


Figure 6. Division wise average of total precipitation for January 2010-2018

Figure 6 shows a division-wise analysis of January month average precipitation during 2010-2018 in Bangladesh. Sylhet division experienced the highest precipitation (8.76 mm) followed by Rajshahi (8.01 mm). Earlier analysis (1970 to 2000) showed Rajshahi as the highest precipitated division, it also showed that the lowest precipitated division shifted from Chattogram to Dhaka (5.18 mm).

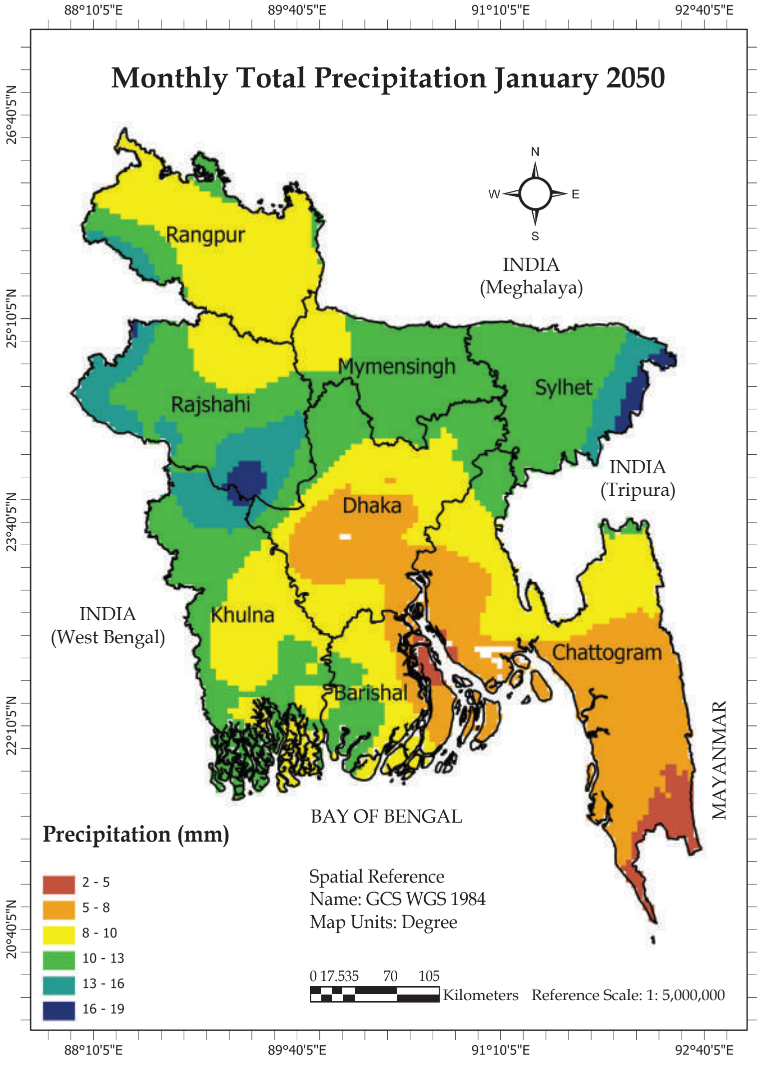


Figure 7. Average of total precipitation for January 2050 according to RCP 2.6

Figure 7 describing the forecasted (2050) January month average precipitation of Bangladesh using RCP 2.6 model. The results show that highest precipitation will be in the north-eastern and lower part of the north-western side of Bangladesh, the central part will have moderate, and the south-eastern side of Bangladesh will have the lowest precipitation.

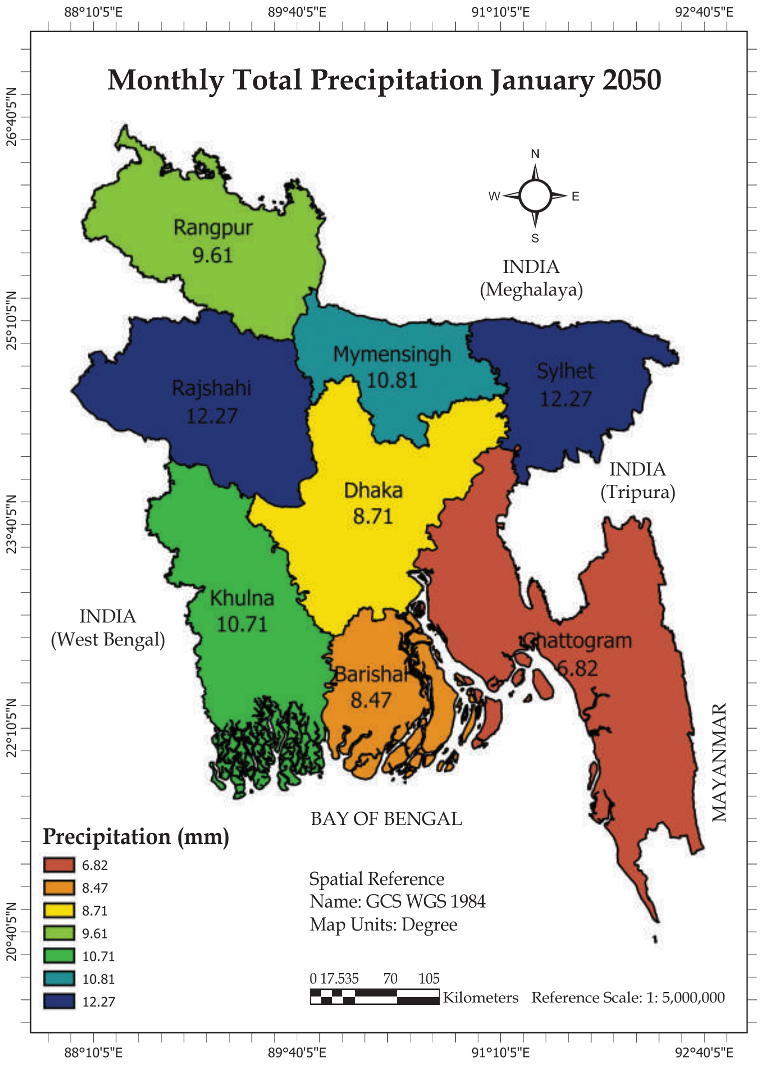


Figure 8. Division-wise average of total precipitation for January 2050 according to RCP 2.6

Figure 8 is showing the division-wise forecasted (2050) January month average precipitation of Bangladesh. The findings conclude that Sylhet and Rajshahi will be the highest precipitated division (12.27 mm) and Chattogram division will be the lowest (6.82 mm).

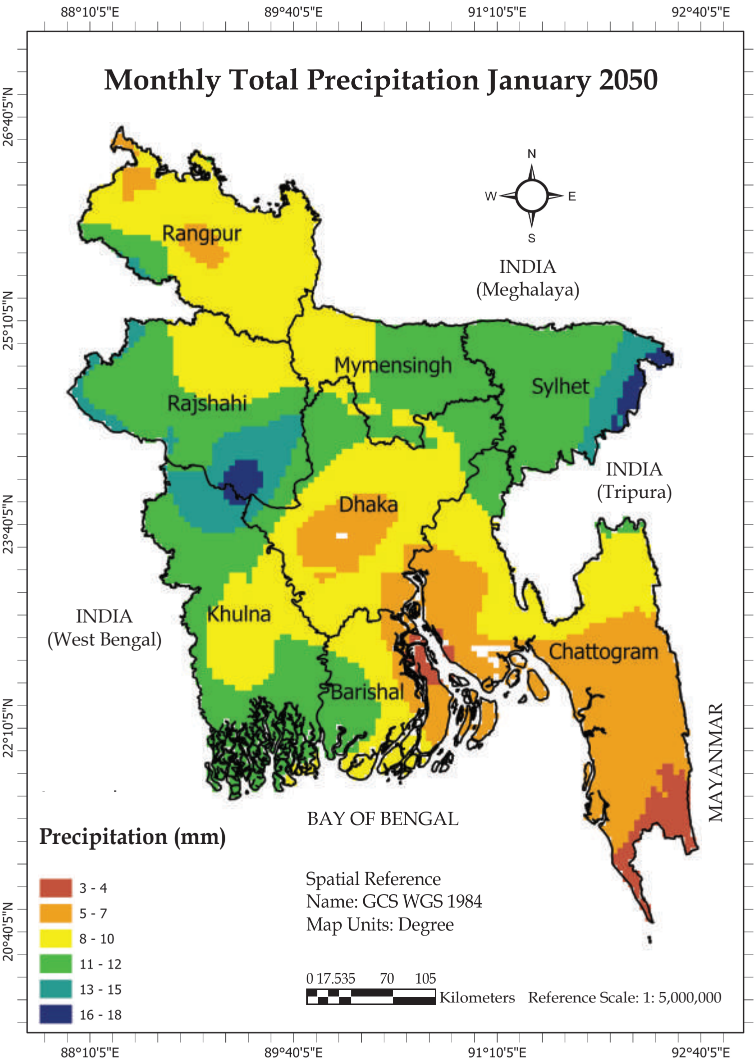


Figure 9. Average of total precipitation for January 2050 according to RCP 4.5

Figure 9 presents the forecasted (2050) January month average precipitation of Bangladesh according to RCP 4.5 model. The forecasted results are showing that precipitation condition of Bangladesh is more or less similar with the RCP 2.6 model.

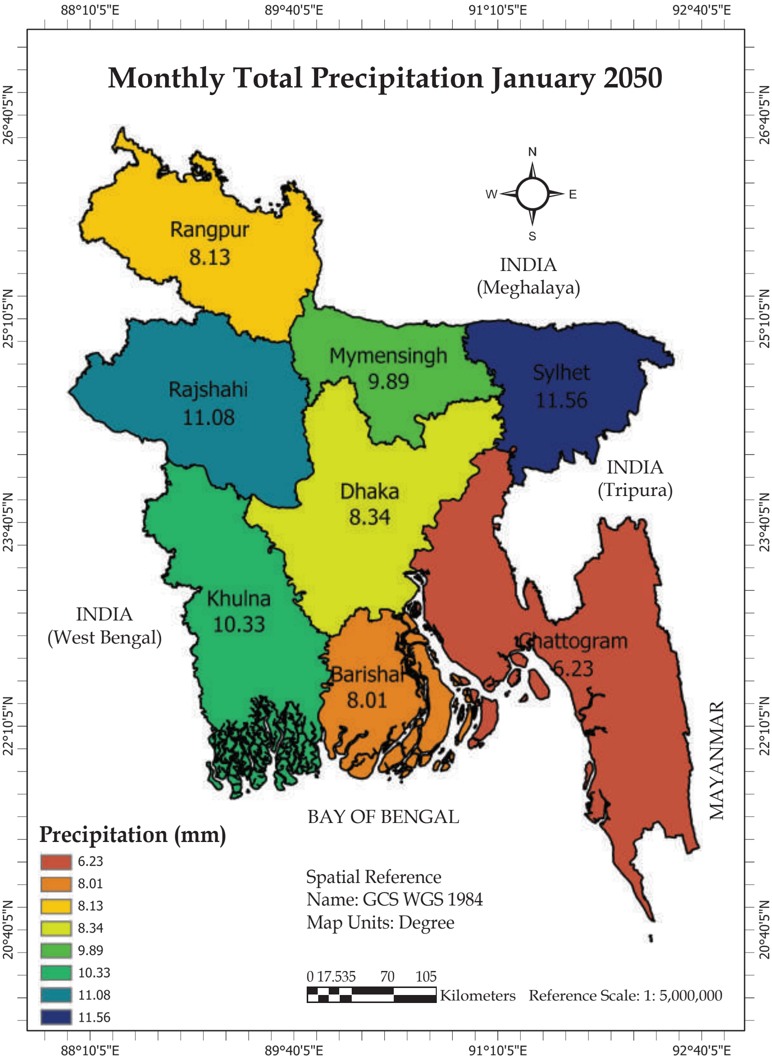


Figure 10. Division-wise average of total Precipitation for January 2050 according to RCP 4.5

Figure 10 is a division-wise forecasted precipitation representation of January month. The highest precipitated division will be Sylhet (11.56 mm) followed by Rajshahi (11.08 mm) and the lowest precipitated division will be Chattogram (6.23 mm).

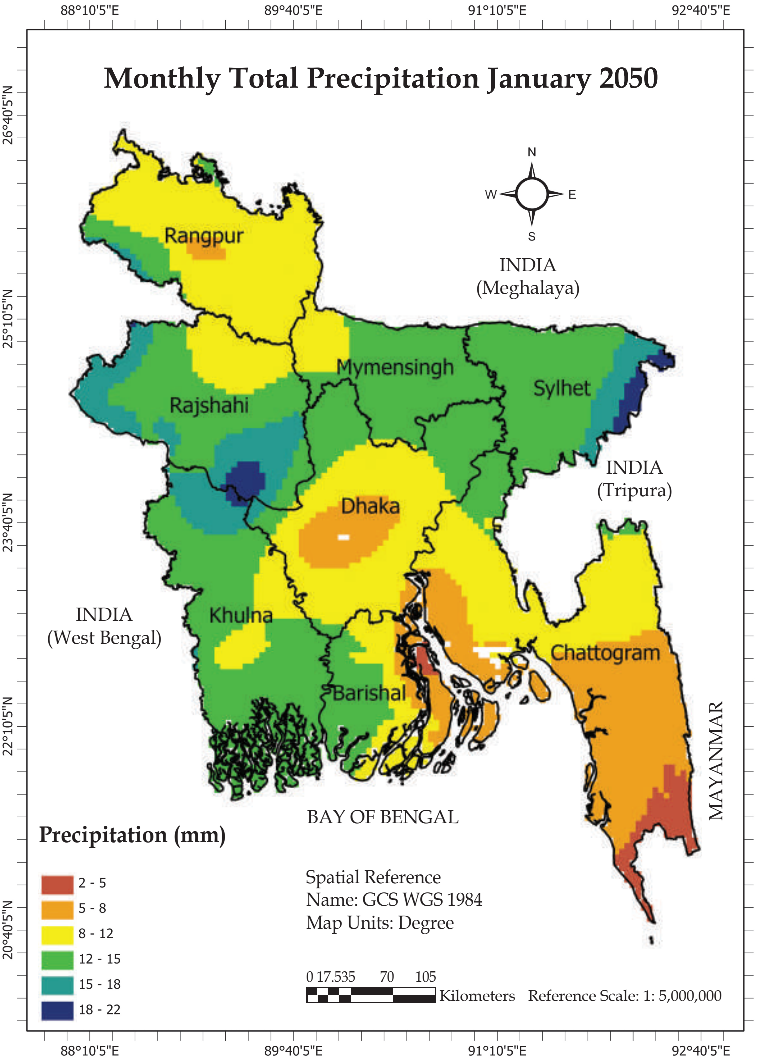


Figure 11. Average of total precipitation for January 2050 according to RCP 6.0

Figure 11 is describing the forecasted January month average precipitation of Bangladesh according to RCP 6.0 model. The precipitation condition of Bangladesh is showing almost the same as the RCP 2.6 and 4.5 models.

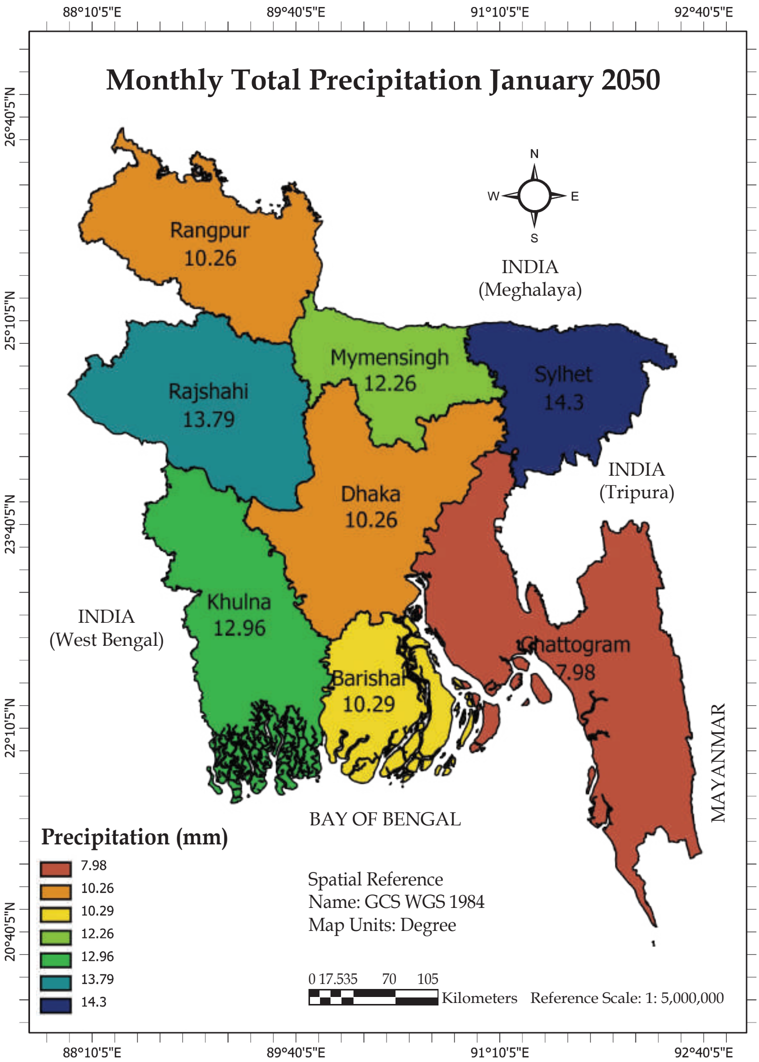


Figure 12. Division-wise average of total precipitation for January 2050 according to RCP 6.0

Figure 12 shows that the highest precipitation division in 2050 will be Sylhet (14.30 mm) followed by Rajshahi division (13.79 mm) and the lowest precipitated division will be Chattogram (7.98 mm).

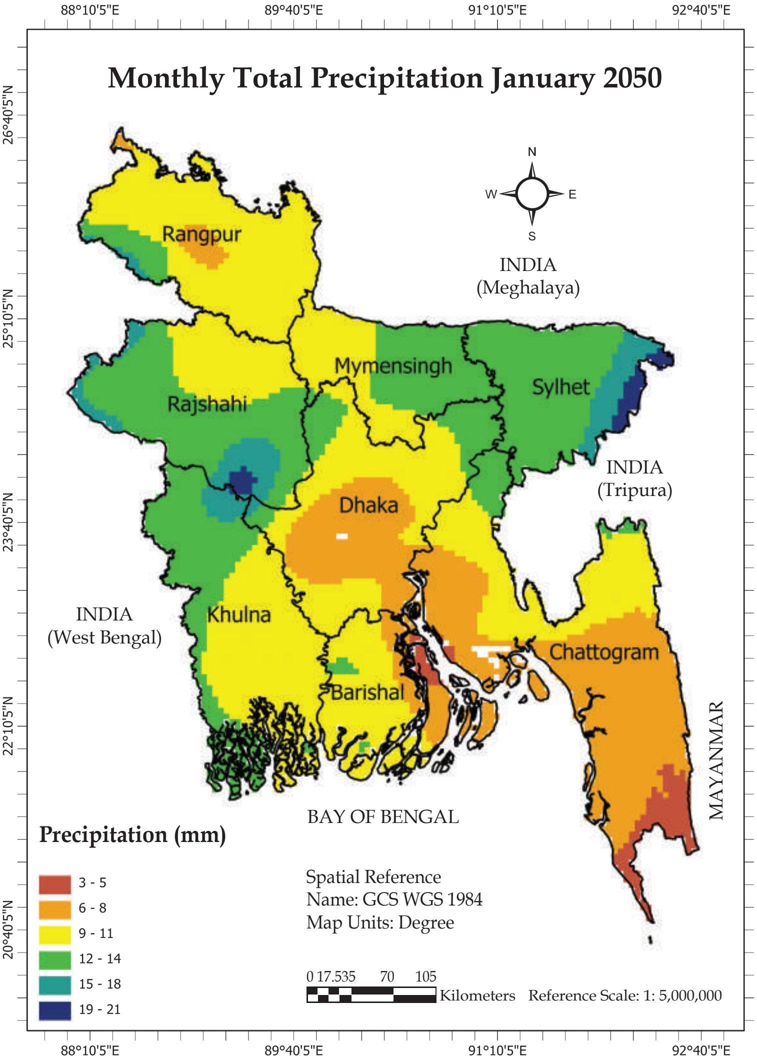


Figure 13. Average of total precipitation for January 2050 according to RCP 8.5

Figure 13 is explaining the forecasted (2050) January month average precipitation of Bangladesh by employing RCP 8.5 model. The precipitation condition of Bangladesh is showing almost similar as the RCP 2.6, 4.5, and 6.0 models with a little difference as the precipitation in the central southern part has been forecasted to be decreased in 2050.

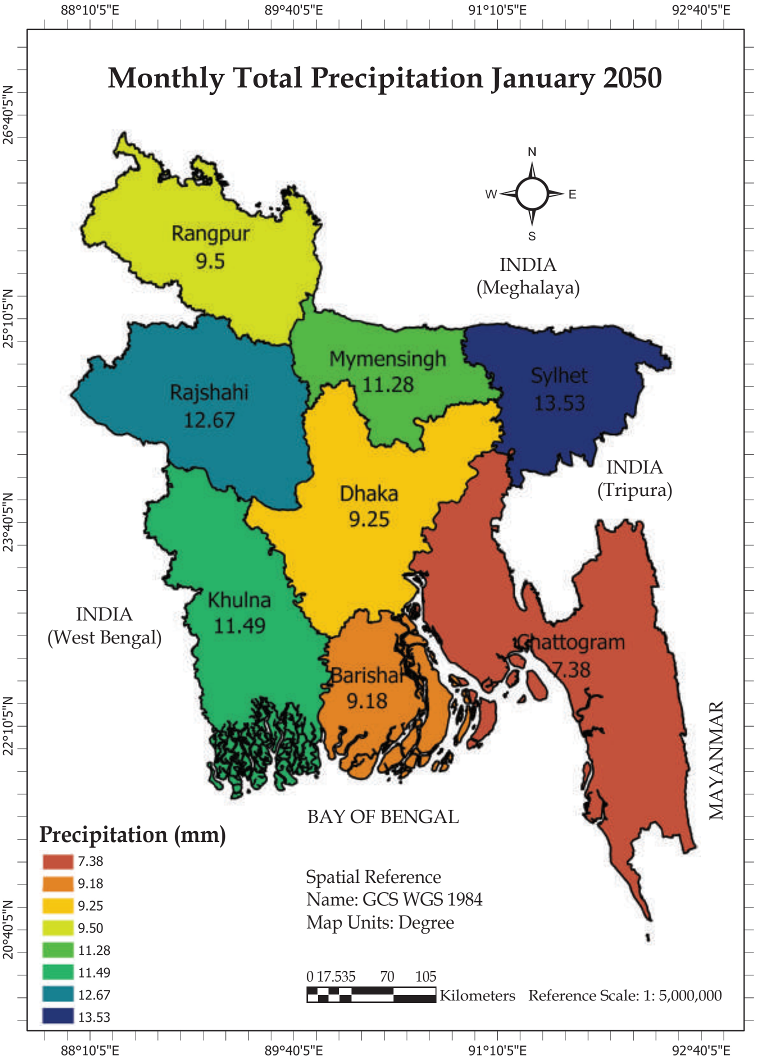


Figure 14. Division-wise average of total precipitation for January 2050 according to RCP 8.5

Figure 14 is showing that the highest precipitation division will be Sylhet (13.53mm) followed by Rajshahi (12.67 mm) and the lowest precipitated division will be the same as all others RCP model i.e., Chattogram (7.38 mm) in 2050.

Table 3. Summary of January month average total precipitation of 1970 to 2000, 2010 to 2018 and forecasted 2050 (By RCP model 2.6, 4.5, 6.0, and 8.5)

Division	Average Precipitation (mm) 1970 to 2000	Average Precipitation (mm) 2010 to 2018	Precipitation (mm) 2050 (RCP 2.6)	Precipitation (mm) 2050 (RCP 4.5)	Precipitation (mm) 2050 (RCP 6.0)	Precipitation (mm) 2050 (RCP 8.5)	Average of Precipitation (mm) 2050 (RCP 2.6, 4.5, 6.0 & 8.5)	Change of Precipitation (mm) 2050 to 2010-2018
Barishal	8.55	5.19	8.47	8.01	10.29	9.18	8.99	3.80
Chattogram	7.23	5.42	6.82	6.23	7.98	7.38	7.10	1.68
Dhaka	7.54	5.18	8.71	8.34	10.26	9.25	9.14	3.96
Khulna	11.65	6.43	10.71	10.33	12.96	11.49	11.37	4.94
Mymensingh	9.15	6.83	10.81	9.89	12.26	11.28	11.06	4.23
Rajshahi	12.29	8.01	12.27	11.08	13.79	12.67	12.45	4.44
Rangpur	9.80	6.80	9.60	8.13	10.26	9.50	9.37	2.57
Sylhet	11.78	8.76	12.27	11.56	14.30	13.53	12.92	4.16

In all the divisions of Bangladesh average total precipitation (average by RCP 2.6, 4.5, 6.0, and 8.5 models) of January month in 2050 will be increased in comparison to average total precipitation during 2010-2018 (Table 3).

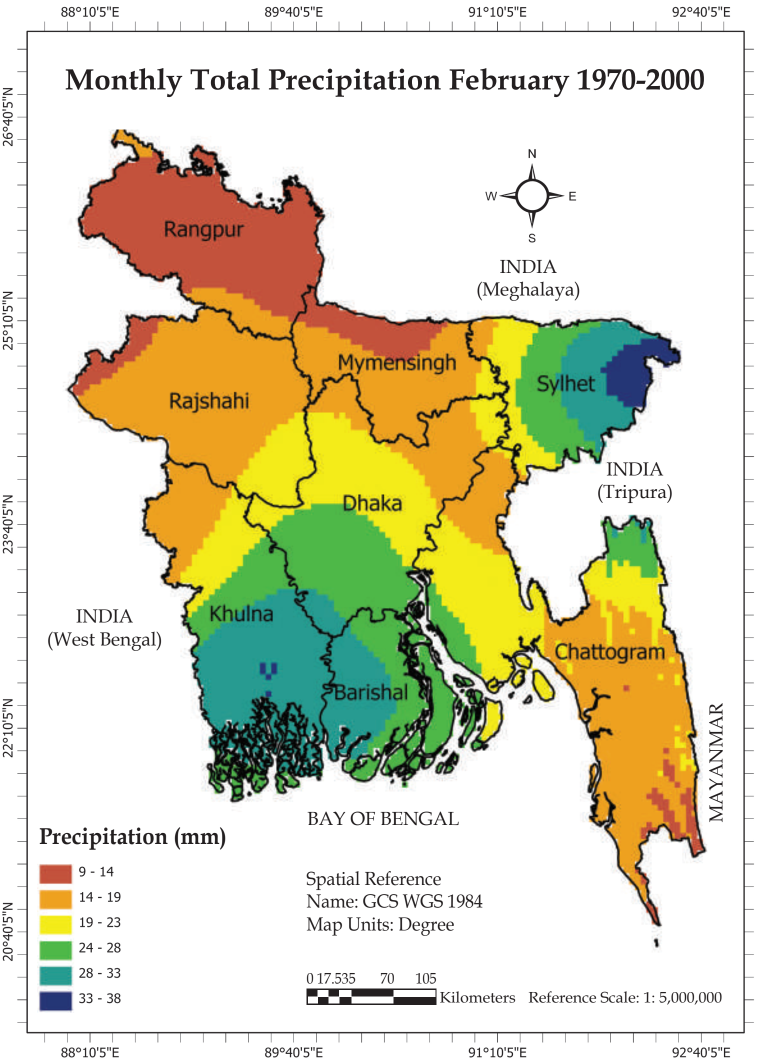


Figure 15. Average of total precipitation for February 1970-2000

Figure 15 shows the average precipitation scenario of February month during 1970-2000 in Bangladesh. The high precipitation areas were the north-eastern part of Bangladesh followed by the lower part of south-western Bangladesh. The central part (both north and south) of the country experienced moderate precipitation and the lowest precipitation observed at the north-western side of Bangladesh.

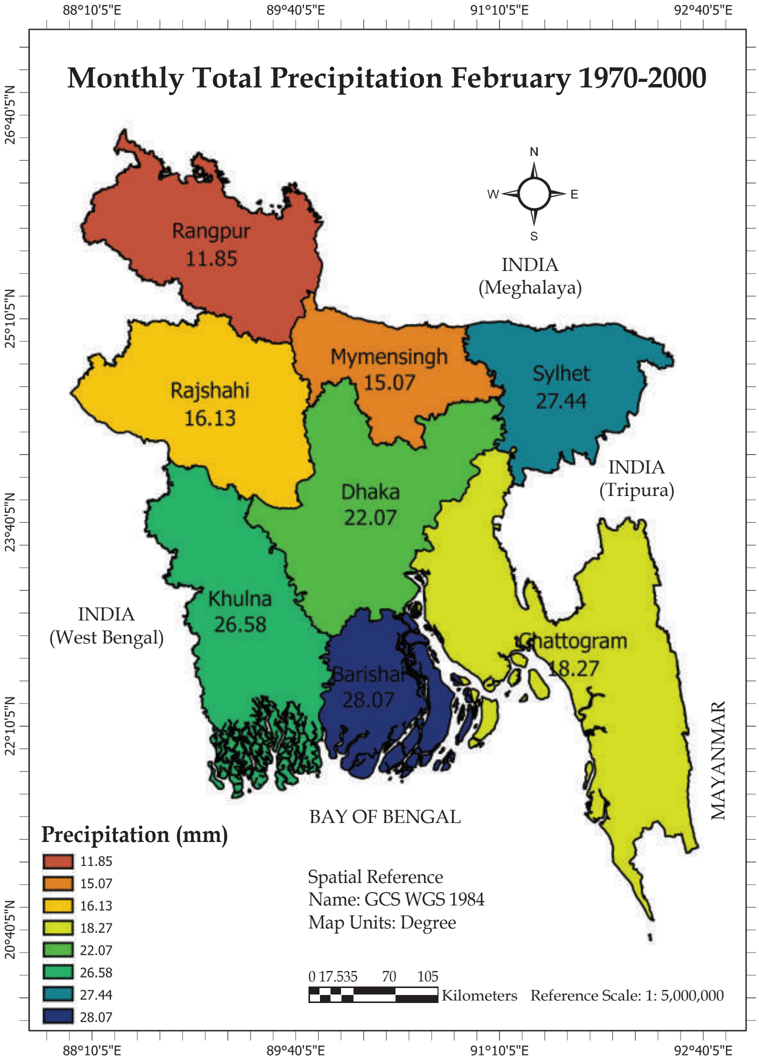


Figure 16. Division-wise average of total precipitation for February 1970-2000

Figure 16 The division-wise analyses show that February month average total precipitation during 1970-2000 was the highest in Barishal (28.07 mm), followed by Sylhet division (27.44 mm). The lowest precipitation observed in Rangpur division with an average of 11.85 mm.

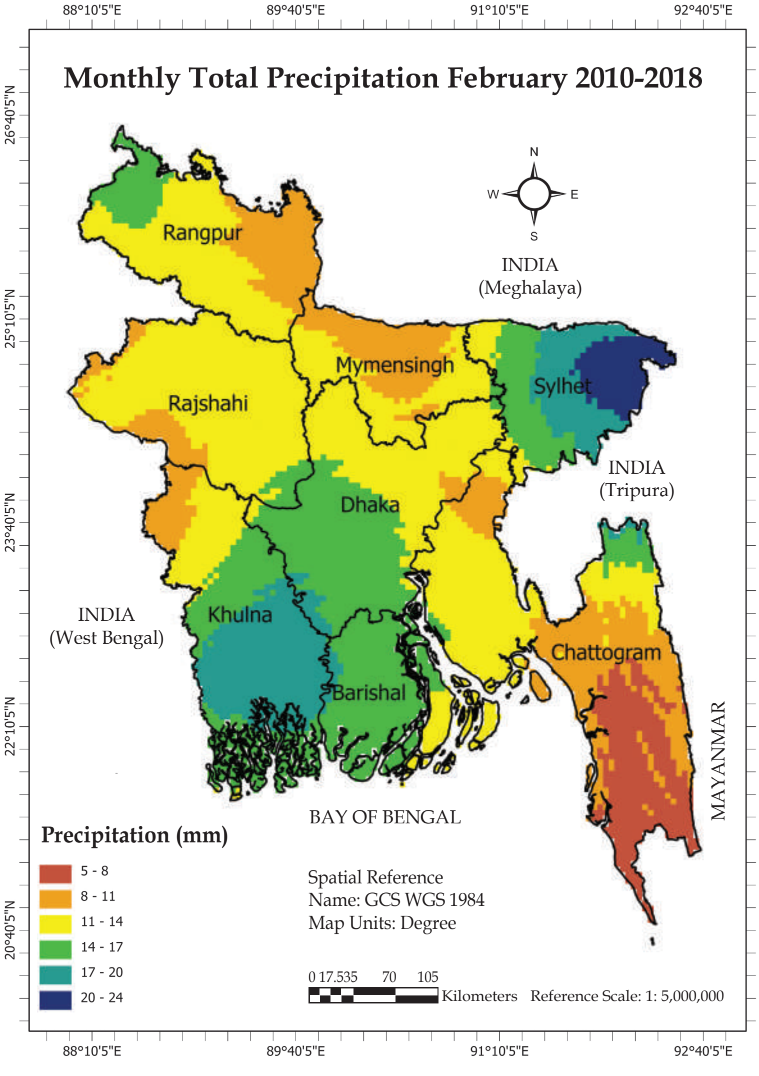


Figure 17. Average of total precipitation for February 2010-2018

Figure 17 is showing the average of total precipitation scenario of February month during 2010-2018 in Bangladesh, where the highest precipitation observed in the north-eastern part of Bangladesh, followed by the lower part of the south-western side. The central part was moderate and the south-eastern side was the lowest pricipitated area.

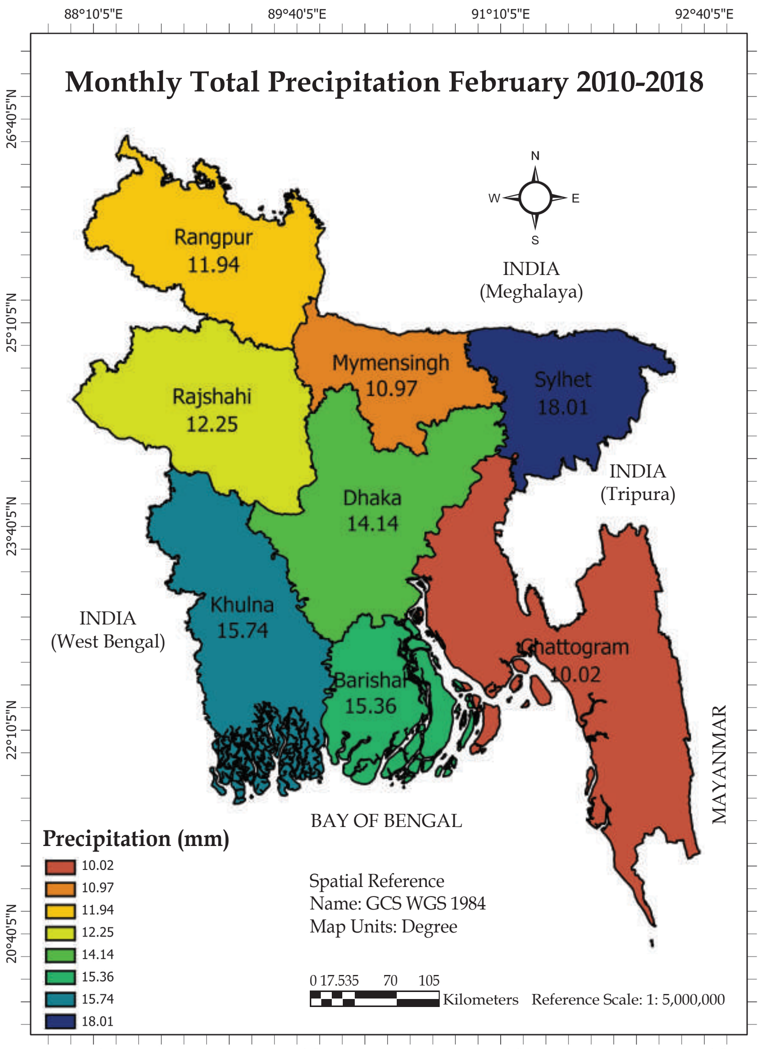


Figure 18. Division-wise average of total precipitation for February 2010-2018

Figure 18 is describing division-wise February month average total precipitation during 2010-2018 in Bangladesh, where Sylhet division had the highest precipitation (18.76 mm), followed by Khulna division (15.74 mm). The lowest precipitat division shifted from the chattogram division (1970-2000) to Chattogram division (10.02 mm).

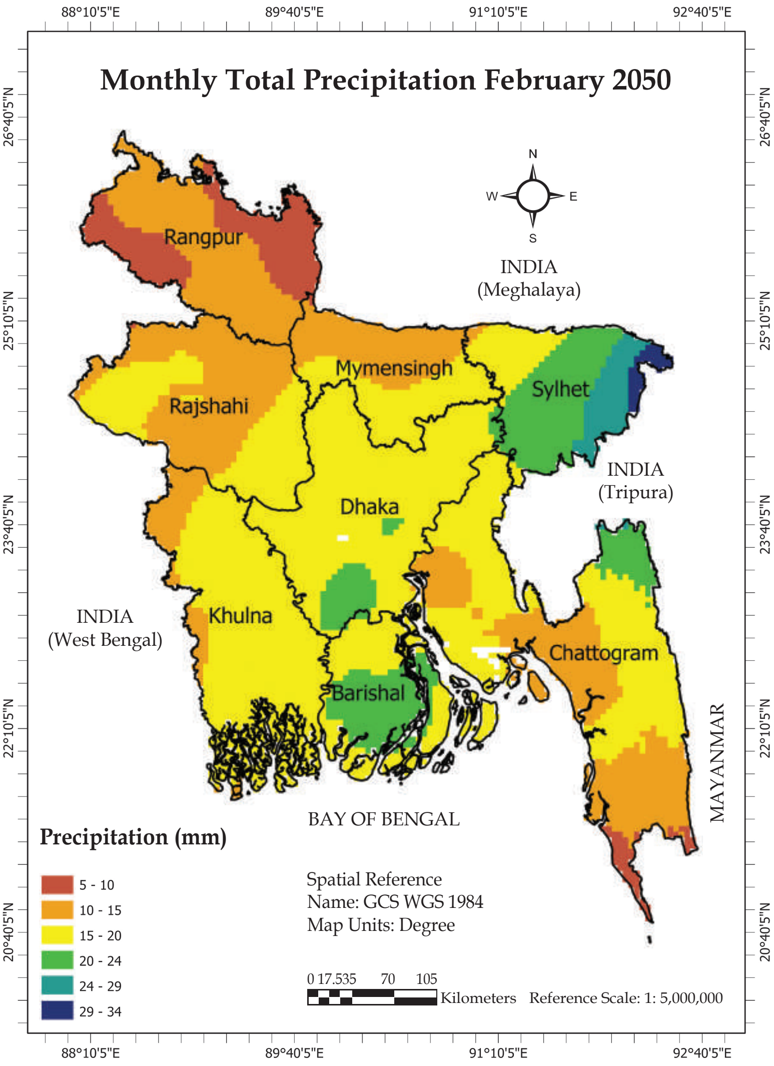


Figure 19. Average of total precipitation for February 2050 according to RCP 2.6

Figure 19 presents the forecasted February month average precipitation of Bangladesh using to RCP 2.6 model. The highest precipitated area will be the north-eastern part of the country, where the central part will experience moderate precipitation. The lowest precipitated area will be the north-western and also some parts of the south-eastern side of Bangladesh.

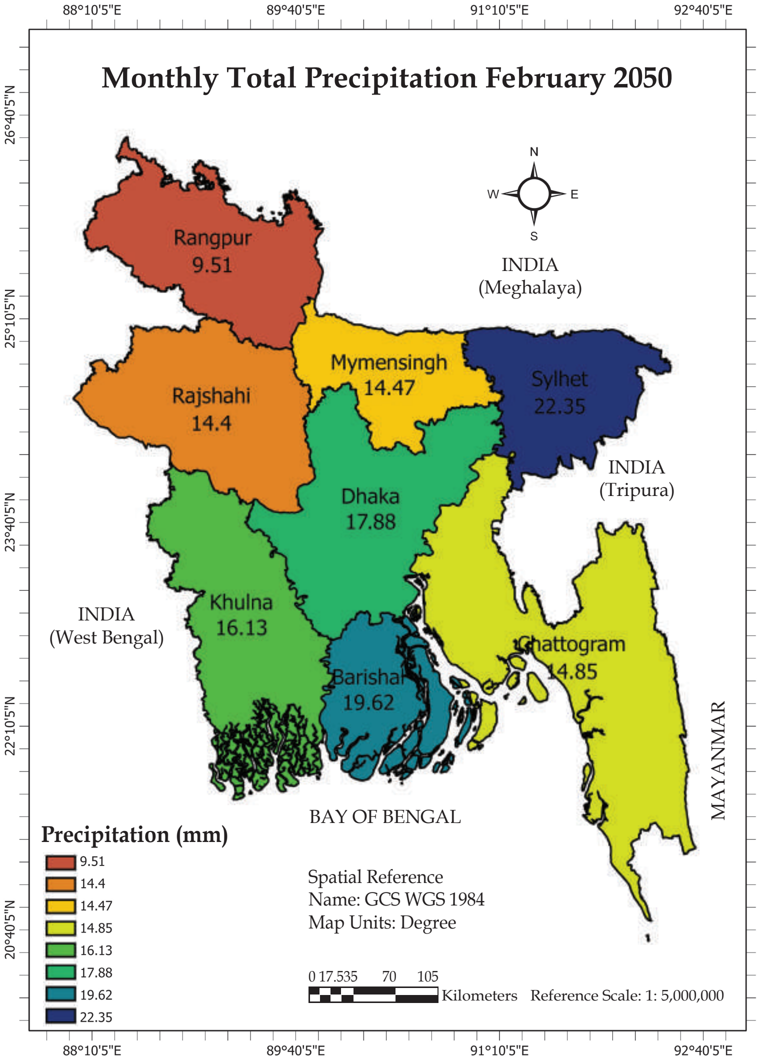


Figure 20. Division-wise average of total precipitation for February 2050 according to RCP 2.6

Figure 20 is showing that Sylhet will be the highest precipitated division (22.35 mm) and Rangpur will be the lowest precipitat division (9.51 mm) in 2050.

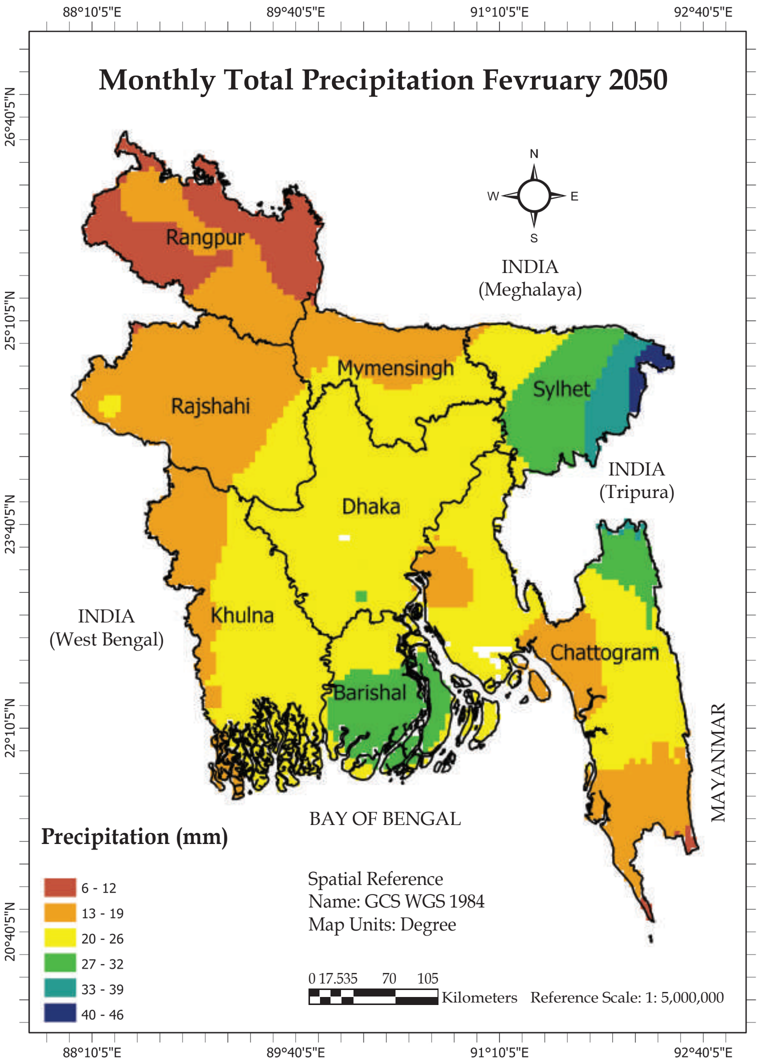


Figure 21. Average of total precipitation for Fevruary 2050 according to RCP 4.5

Figure 21 is describing the forecasted February month average precipitation of Bangladesh using RCP 4.5 model, where the precipitation condition of Bangladesh is showing almost same as the RCP 2.6 model.

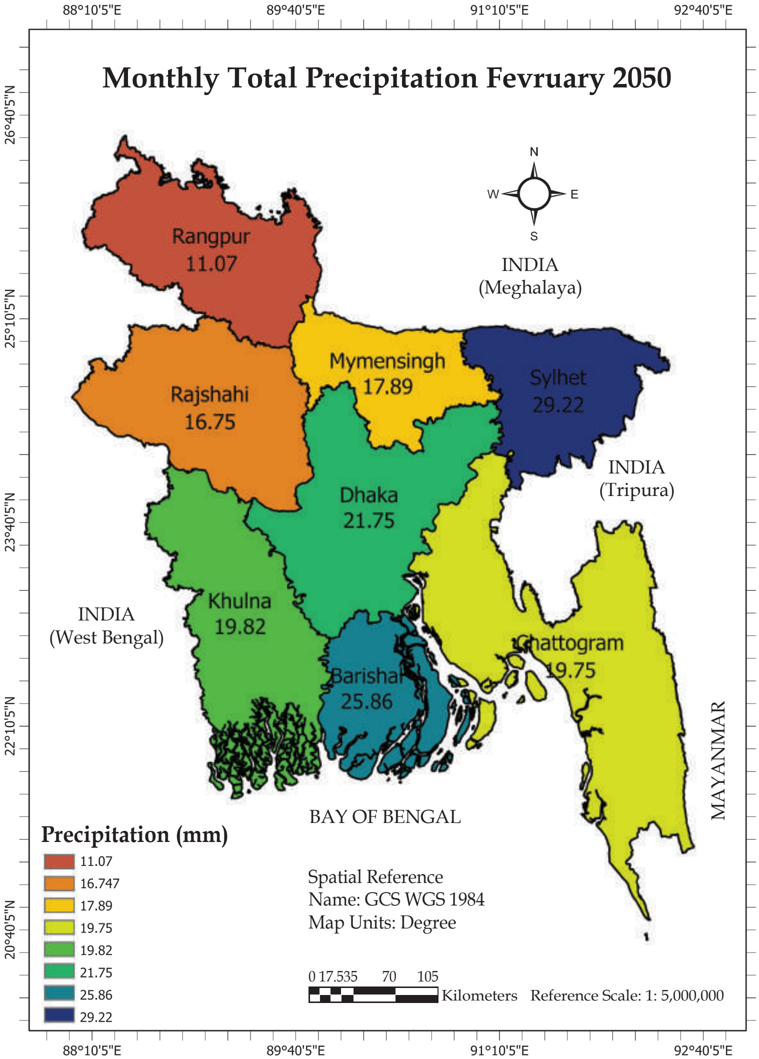


Figure 22. Division- wise average of total precipitation for Fevruary 2050 according to RCP 4.5

Figure 22 is showing that the highest precipitation division will be Sylhet (29.22 mm) followed by Barishal (25.86 mm) and the lowest precipitation division will be Rangpur (11.07 mm) in 2050.

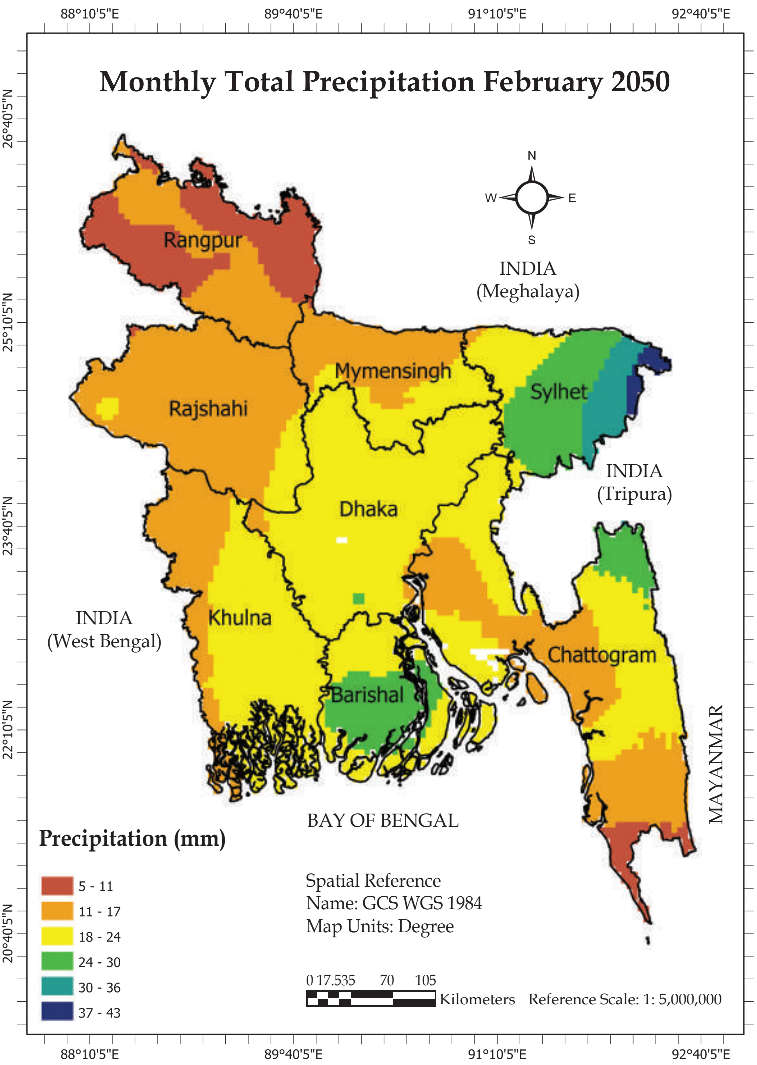


Figure 23. Average of total precipitation for February 2050 according to RCP 6.0

Figure 23 shows the forecasted February month average precipitation of Bangladesh according to RCP 6.0 model, where the precipitation condition of Bangladesh is showing almost same as the RCP 2.6 and 4.5 models

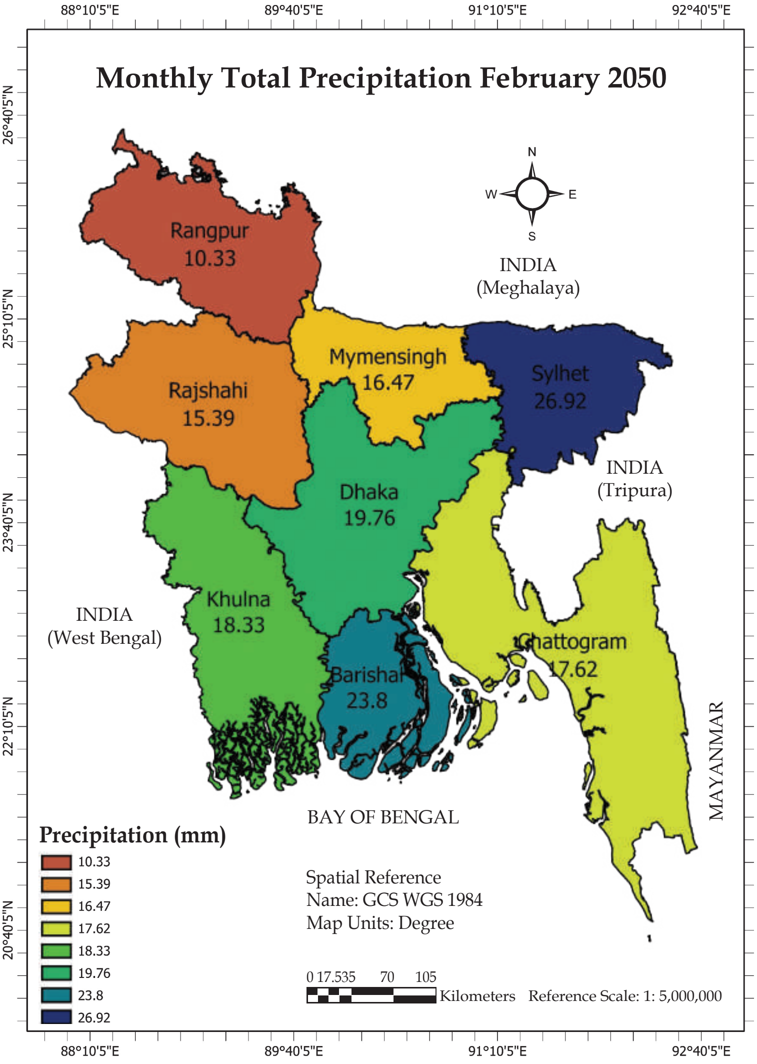


Figure 24. Division-wise average of total precipitation for February 2050 according to RCP 6.0

Figure 24 is showing that the highest precipitation division will be Sylhet (26.92 mm), followed by Barishal (23.8 mm) and the lowest precipitation division will be Rangpur (10.33 mm) in 2050.

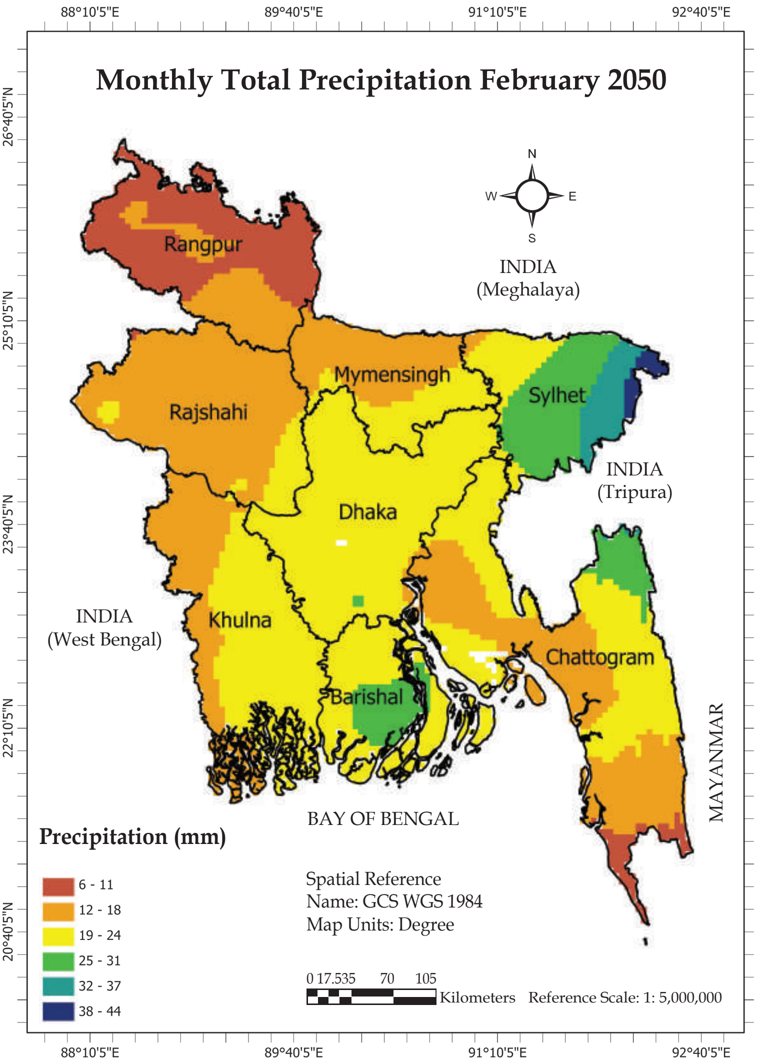


Figure 25. Average of total precipitation for February 2050 according to RCP 8.5

Figure 25 shows the forecasted February month average precipitation of Bangladesh according to RCP 8.5 model, where precipitation condition of Bangladesh is showing almost same as the RCP 2.6, 4.5, and 6.0 models.

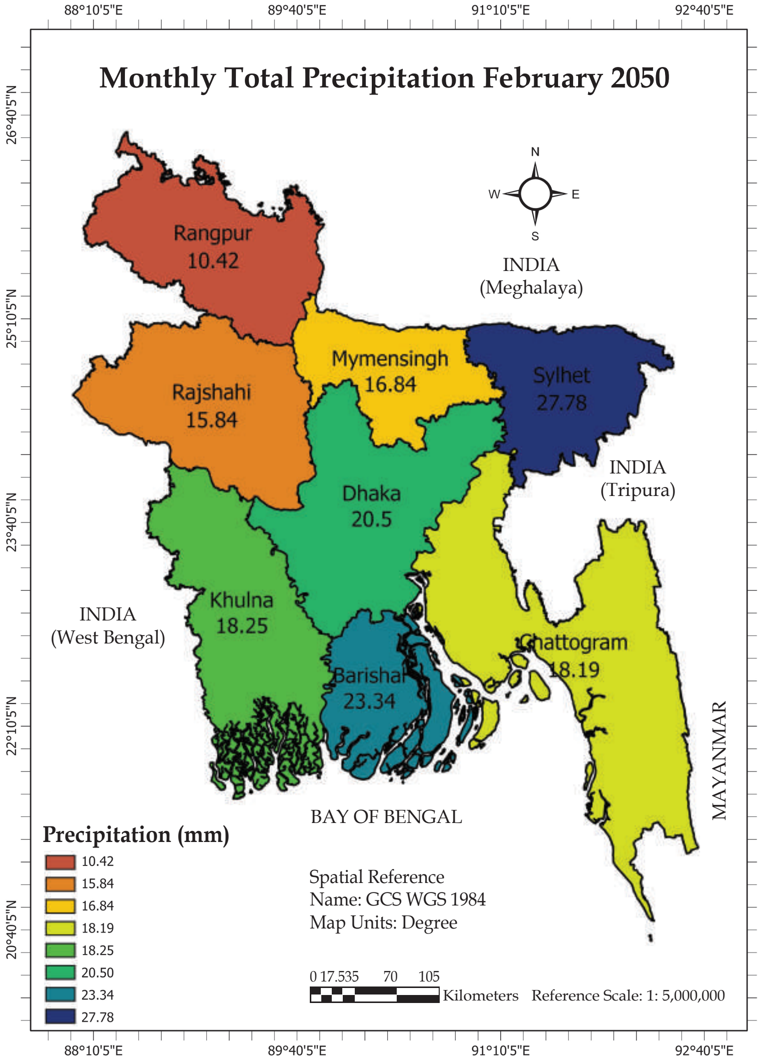


Figure 26. Division-wise average of total precipitation for February 2050 according to RCP 8.5

Figure 26 is showing that the highest precipitation division will be again Sylhet (27.38 mm) followed by Barishal (23.34 mm) in 2050 and the lowest precipitation division will be the same as all the other RCP models i.e. Rangpur (10.42 mm).

Table 4. Summary of average total precipitation of February 1970 to 2000, 2010 to 2018 and forecasted 2050 (By RCP model 2.6, 4.5, 6.0 and 8.5)

Division	Average Precipitation (mm) 1970 to 2000	Average Precipitation (mm) 2010 to 2018	Precipitation (mm) 2050 (RCP 2.6)	Precipitation (mm) 2050 (RCP 4.5)	Precipitation (mm) 2050 (RCP 6.0)	Precipitation (mm) 2050 (RCP 8.5)	Average of Precipitation (mm) 2050 (RCP 2.6, 4.5, 6.0 & 8.5)	Change of Precipitation (mm) 2050 to 2010-2018
Barishal	28.07	15.36	19.62	25.86	23.8	23.34	23.15	7.79
Chattogram	18.27	10.02	14.85	19.75	17.62	18.19	17.60	7.58
Dhaka	22.07	14.14	17.88	21.75	19.76	20.5	19.97	5.83
Khulna	26.58	15.74	16.13	19.82	18.33	18.25	18.13	2.39
Mymensingh	15.07	10.97	14.47	17.89	16.47	16.84	16.42	5.45
Rajshahi	16.13	12.25	14.40	16.75	15.39	15.84	15.59	3.34
Rangpur	11.85	11.94	9.51	11.07	10.33	10.42	10.33	-1.61
Sylhet	27.44	18.01	22.35	29.22	26.92	27.78	26.57	8.56

Table 4 presents that in all the divisions of Bangladesh, average total precipitation (Average by RCP 2.6, 4.5, 6.0, and 8.5 models) of February in 2050 will be increased in comparison to average total precipitation during 2010-2018.

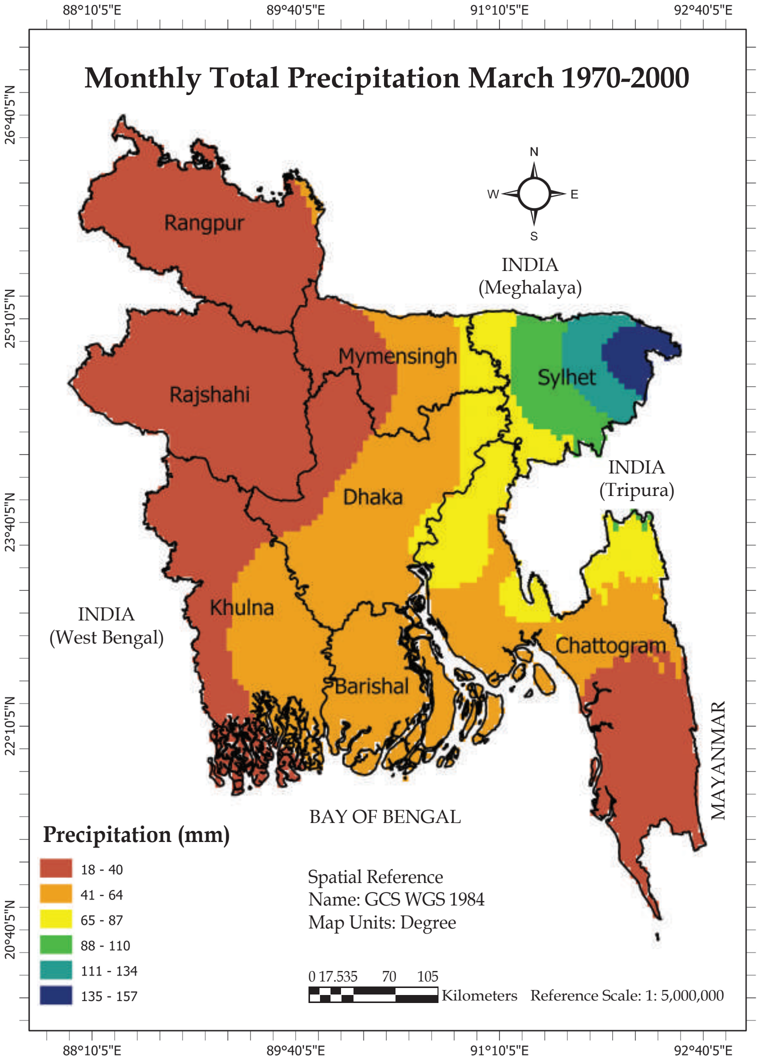


Figure 27. Average of total precipitation in March 1970-2000

Figure 27 shows the average precipitation during March 1970-2000 in Bangladesh. The highest precipitation was found in the north-eastern side of Bangladesh. The central part of Bangladesh (both north and south) had lower precipitation and the lowest precipitation was observed in the north-western part of Bangladesh followed by the south-eastern side.

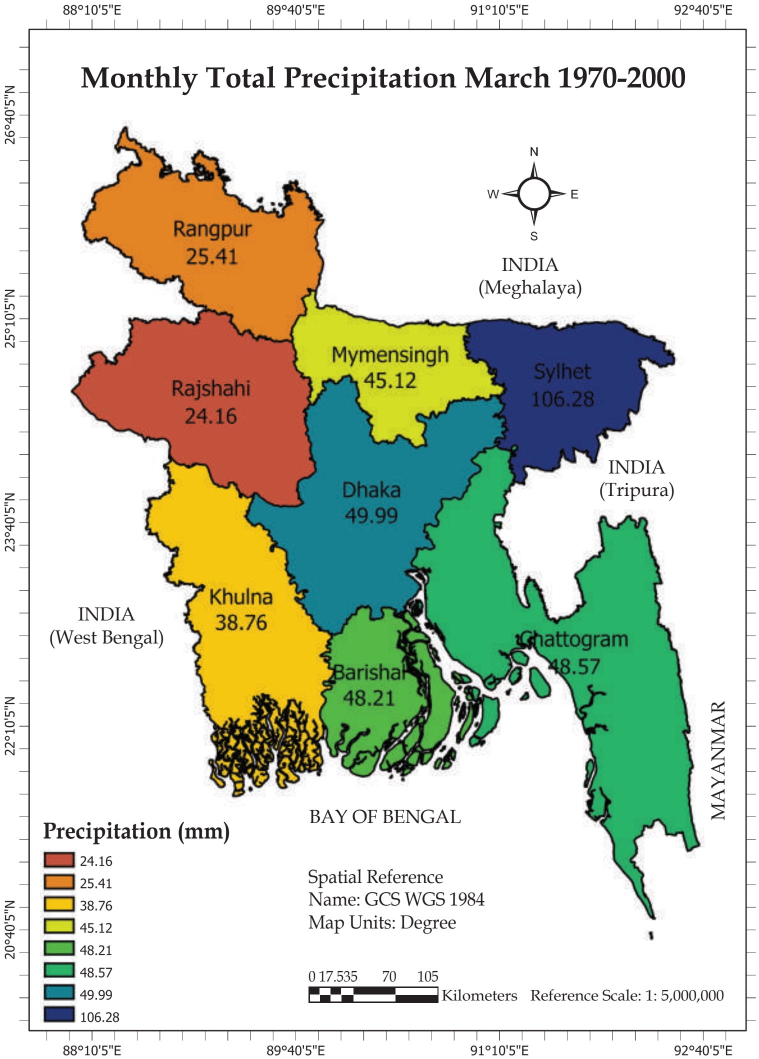


Figure 28. Division-wise average of total precipitation in March 1970-2000

Figure 28 is describing division wise March month average precipitation during 1970-2000 in Bangladesh. The results present that Sylhet division had the highest precipitation (106.28 mm) followed by Dhaka division (49.99 mm). The lowest precipitation was observed in Rajshahi division (24.16 mm).

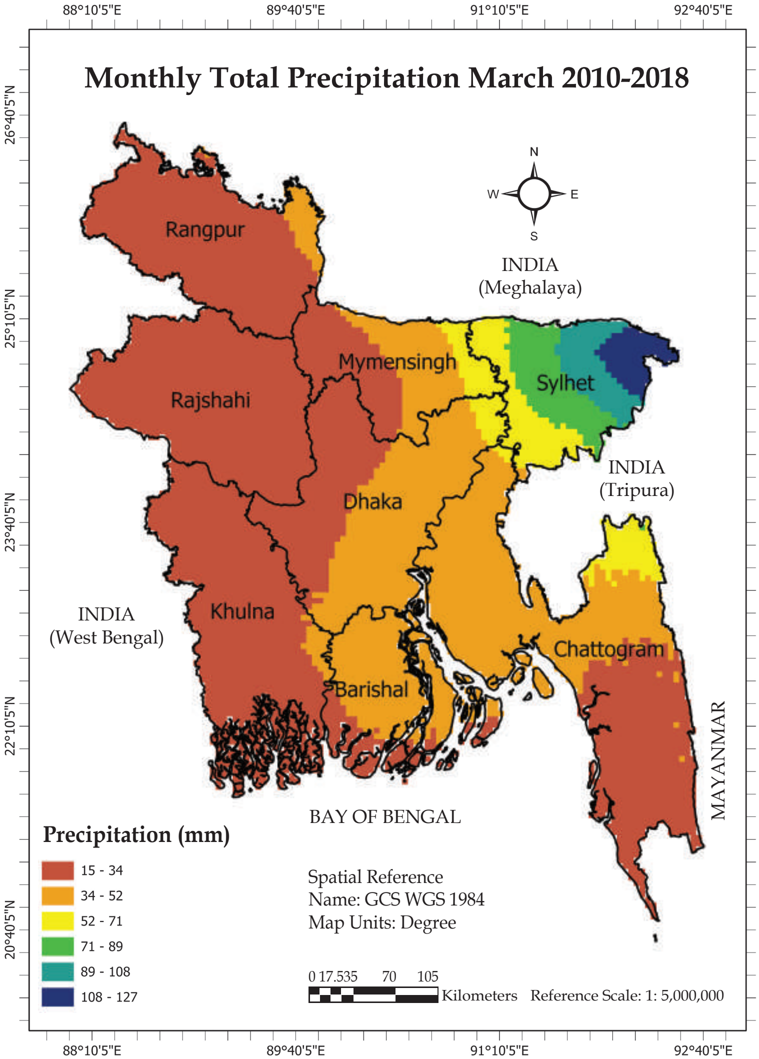


Figure 29. Average of total precipitation in March 2010-2018

Figure 29 is showing the average precipitation of March during 2010-2018 in Bangladesh. The highest precipitation observed in the north-eastern side of Bangladesh. The central part of Bangladesh was under low precipitation, whereas the lowest precipitation was in the north-western part of the country followed by the south-eastern side.

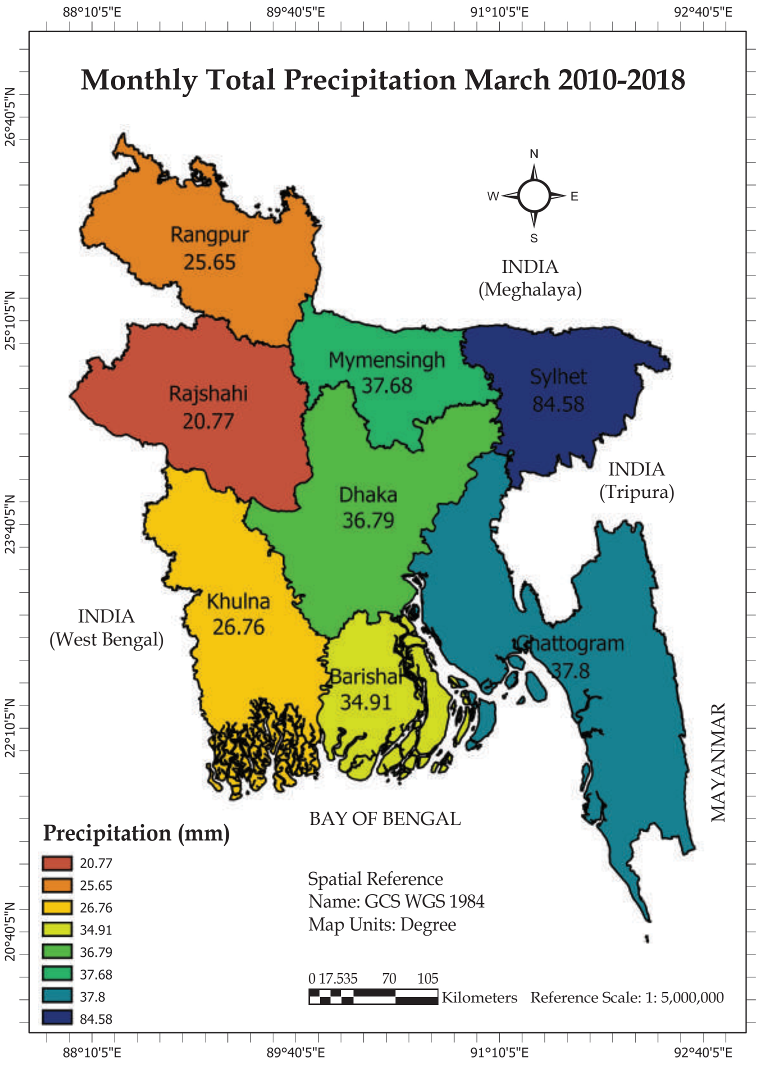


Figure 30. Division-wise average of total precipitation in March 2010-2018

Figure 30 is describing division-wise March month average precipitation during 2010-2018 in Bangladesh. In the concerned period Sylhet division had the highest precipitation (84.58 mm) and the lowest was in Rajshahi division (20.77 mm).

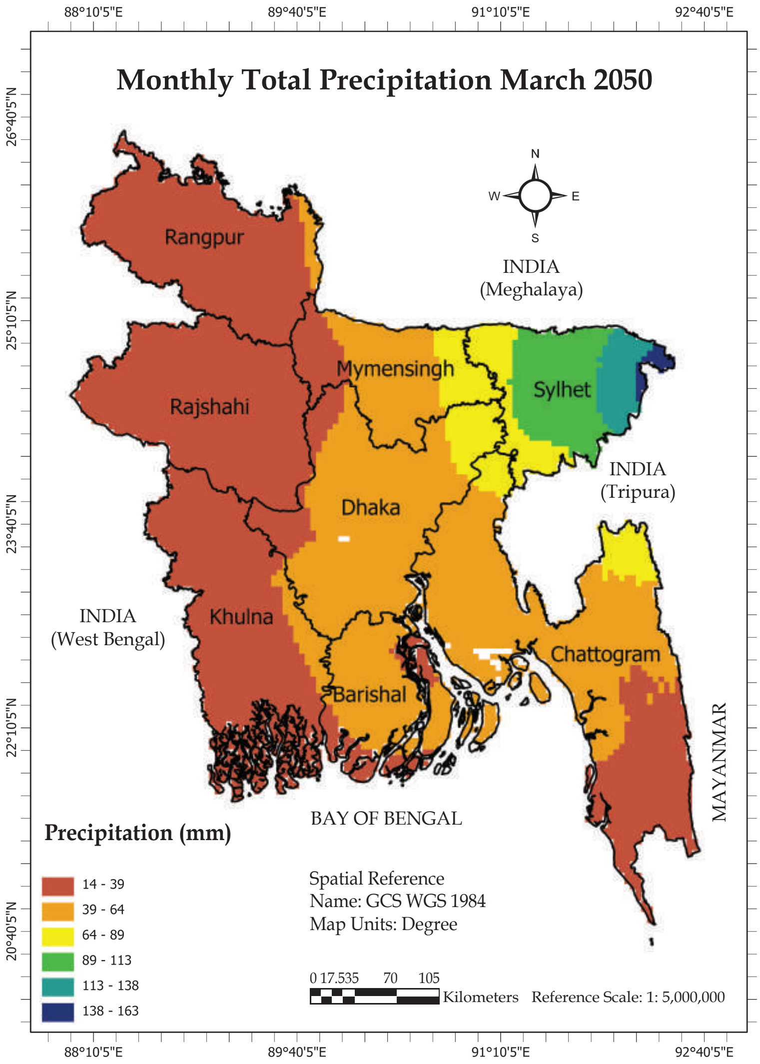


Figure 31. Average of total precipitation for March 2050 according to RCP 2.6

Figure 31 is shows the forecasts of average precipitation of Bangladesh in March according to RCP 2.6 model. The highest precipitation will be observed in the north-eastern part of Bangladesh. The central part will have moderate precipitation and the lowest precipitation will be in the north-western part of Bangladesh followed by the south-eastern side.

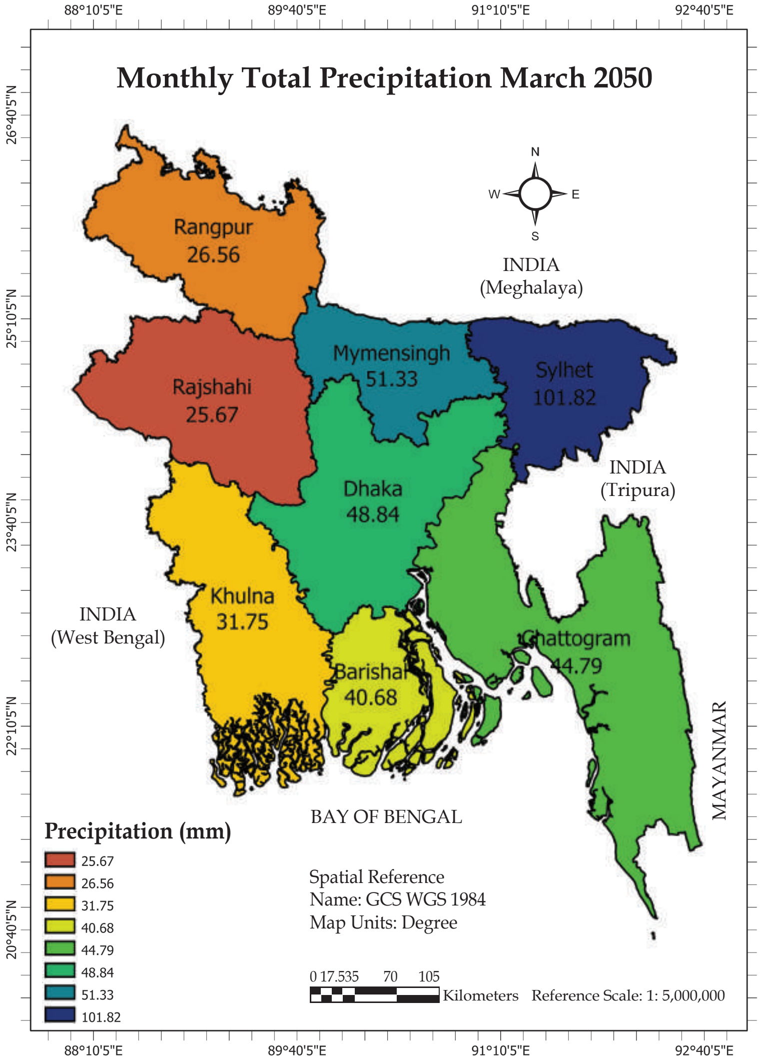


Figure 32. Division-wise average of total precipitation for March 2050 according to RCP 2.6

Figure 32 is showing that Sylhet will be the highest precipitation division (101.82 mm) and Rajshahi division will get the lowest precipitation (25.67 mm).

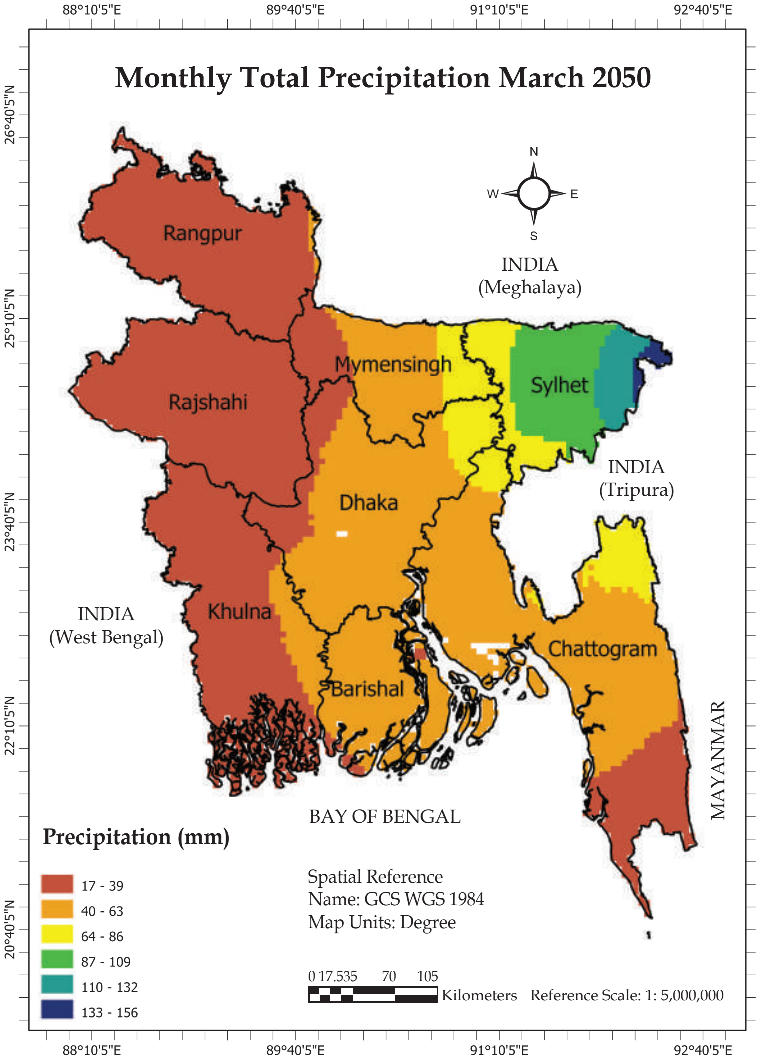


Figure 33. March month average of total precipitation for the year 2050 according to RCP 4.5

Figure 33 is describing the forecasted March month average precipitation of Bangladesh using RCP 4.5 model. The precipitation condition of Bangladesh has been shown as more or less similar the RCP 2.6 model.

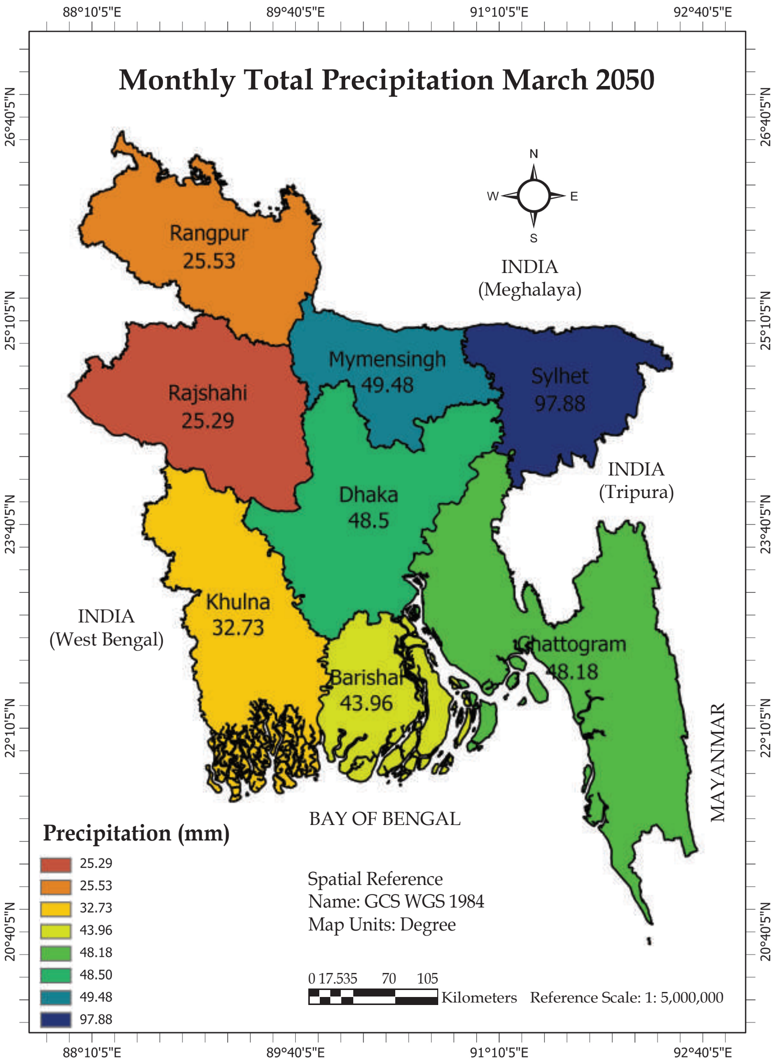


Figure 34. Division-wise March month average of total precipitation for the year 2050 according to RCP 4.5

Figure 34 shows that the highest precipitation division will be Sylhet (97.88 mm) and the lowest will be Rajshahi division (25.29 mm) by 2050.

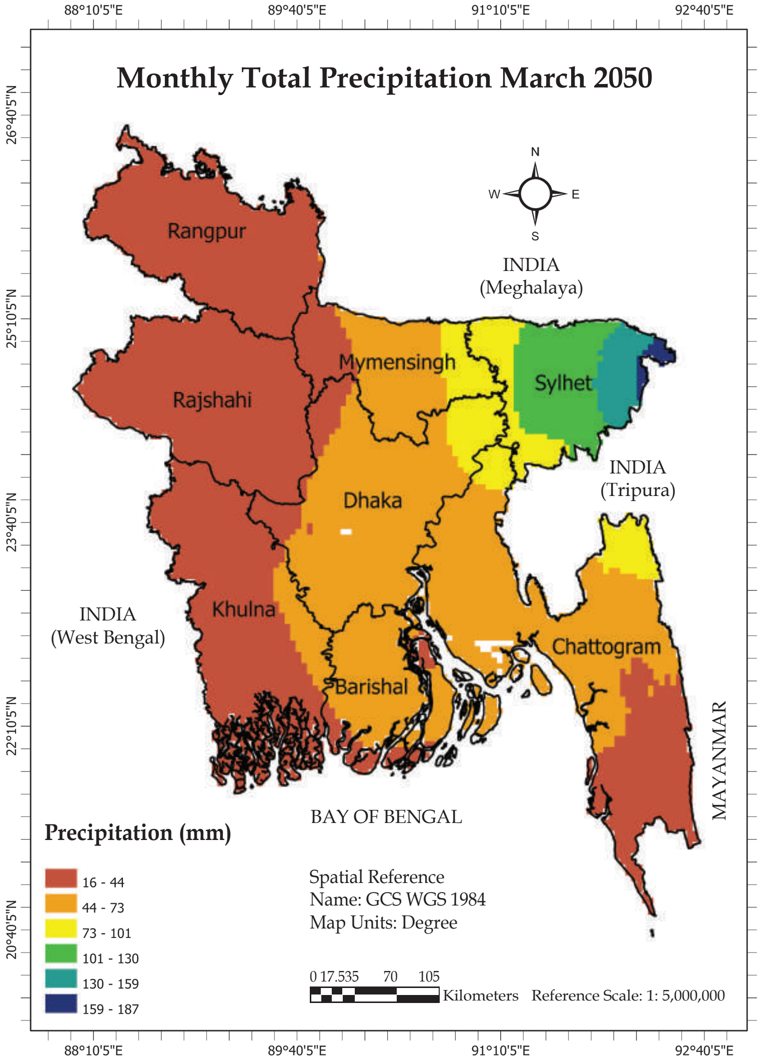


Figure 35. Average of total precipitation for March 2050 according to RCP 6.0

Figure 35 is describing the forecasted average precipitation of Bangladesh in March according to RCP 6.0 model. The precipitation condition of Bangladesh has been shown as almost similar to the RCP 2.6 and 4.5 models.

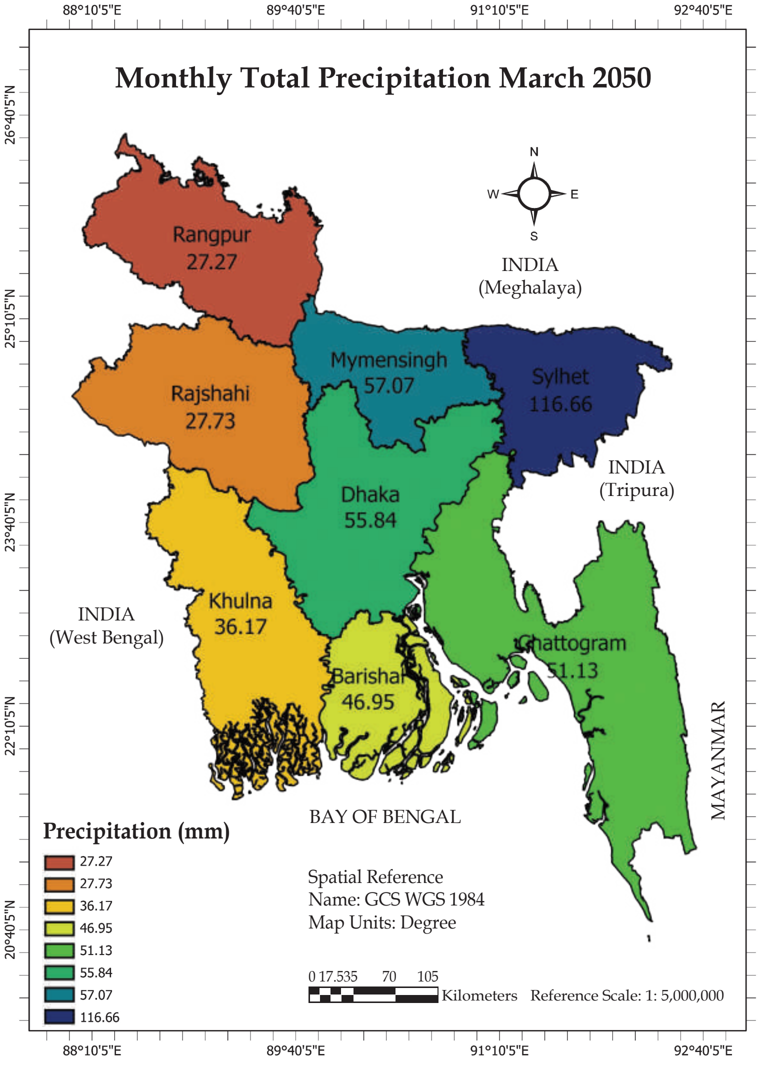


Figure 36. Division-wise average of total precipitation for March 2050 according to RCP 6.0

Figure 36 shows that the highest precipitated division will be Sylhet (116.66 mm) and the lowest precipitated division will be Rangpur (27.27 mm), followed by Rajshahi division (27.73 mm).

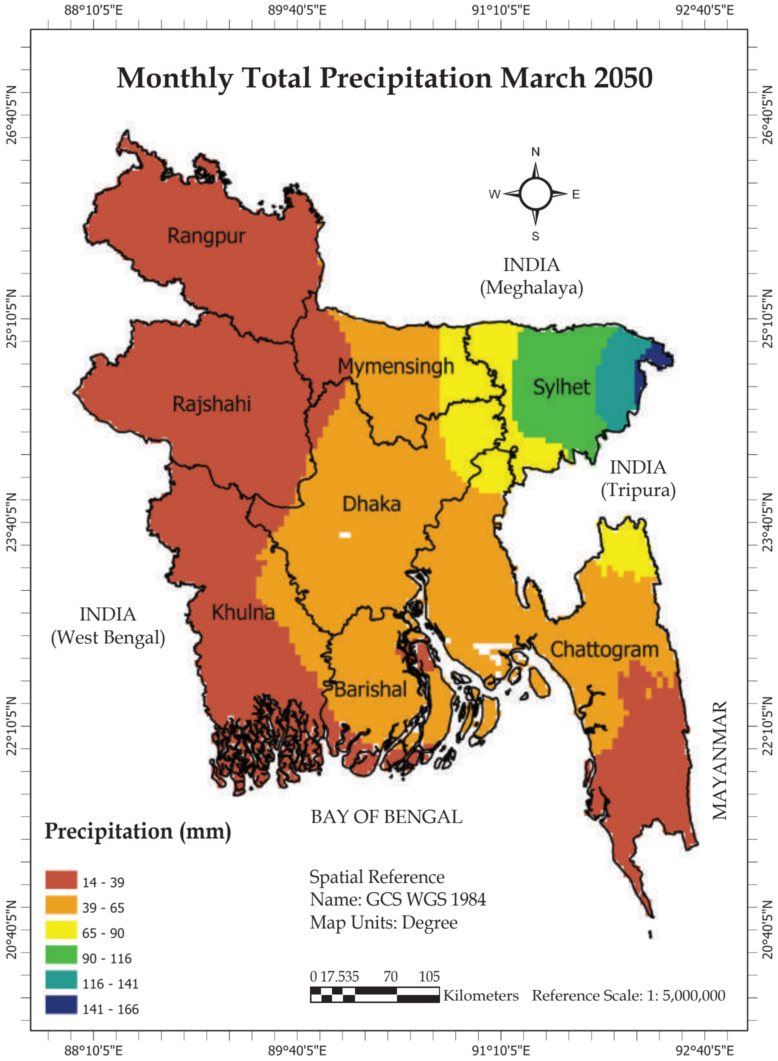


Figure 37. Average of total precipitation for March 2050 according to RCP 8

Figure 37 is explaining the forecasted average precipitation of Bangladesh in March according to RCP 8.5 model. The precipitation condition of Bangladesh has been shown as almost similar to the RCP 2.6, 4.5, and 6.0 models.

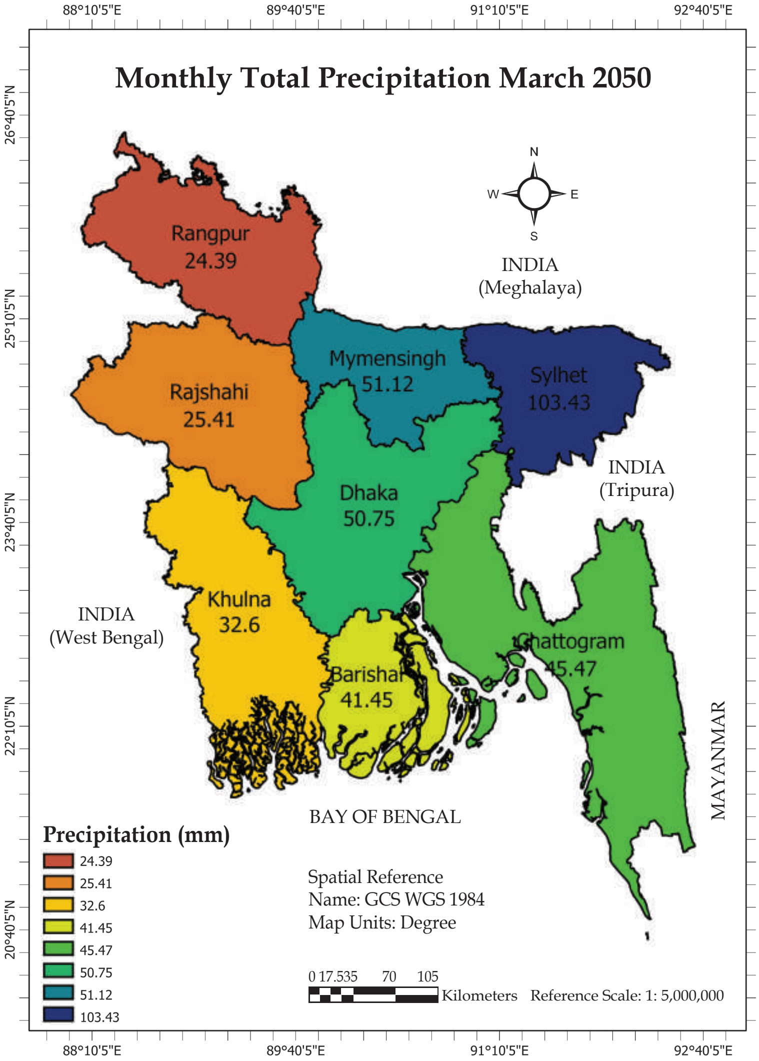


Figure 38. Division-wise average of total precipitation for March 2050 according to RCP 8.5

Figure 38 is showing that the highest precipitation division will be again Sylhet (103.43 mm) and the lowest will be the same as all other RCP models i.e., Rangpur division (24.39 mm) by 2050.

Table 3. Summary of January month average total precipitation of 1970 to 2000, 2010 to 2018 and forecasted 2050 (By RCP model 2.6, 4.5, 6.0, and 8.5)

Division	Average Precipitation (mm) 1970 to 2000	Average Precipitation (mm) 2010 to 2018	Precipitation (mm) 2050 (RCP 2.6)	Precipitation (mm) 2050 (RCP 4.5)	Precipitation (mm) 2050 (RCP 6.0)	Precipitation (mm) 2050 (RCP 8.5)	Average of Precipitation (mm) 2050 (RCP 2.6, 4.5, 6.0 and 8.5)	Change of Precipitation (mm) 2050 to 2010-2018
Rangpur	9.80	6.80	9.60	8.13	10.26	9.50	9.37	2.57
Rajshahi	12.29	8.01	12.27	11.08	13.79	12.67	12.45	4.44
Khulna	11.65	6.43	10.71	10.33	12.96	11.49	11.37	4.94
Mymensingh	9.15	6.83	10.81	9.89	12.26	11.28	11.06	4.23
Sylhet	11.78	8.76	12.27	11.56	14.30	13.53	12.91	4.15
Dhaka	7.54	5.18	8.71	8.34	10.26	9.25	9.14	3.96
Barishal	8.55	5.19	8.47	8.01	10.29	9.18	8.98	3.79
Chattogram	7.23	5.42	6.82	6.23	7.98	7.38	7.10	1.68

In all the divisions of Bangladesh average total precipitation (average by RCP 2.6, 4.5, 6.0, and 8.5 models) of January month in 2050 will be increased in comparison to average total precipitation during 2010-2018 (Table 3).

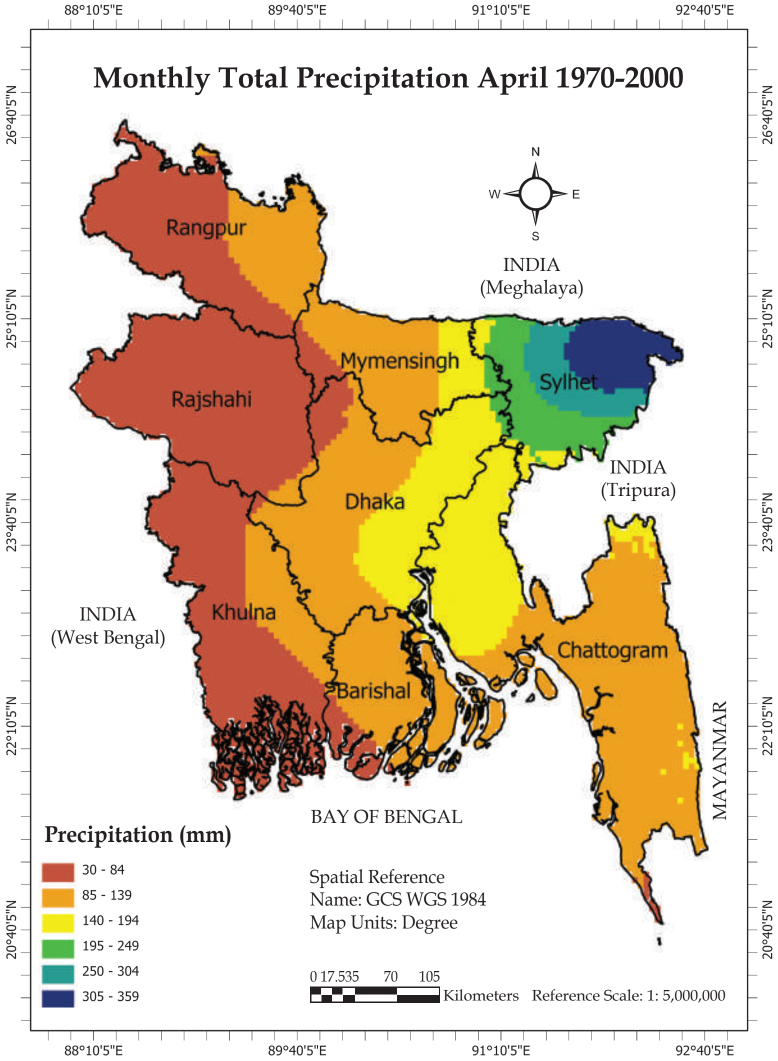


Figure 39. Average of total precipitation for April 1970-2000

Figure 39 shows the average precipitation for April in Bangladesh during 1970-2000. The highest precipitation has been observed in the north-eastern part of the country. The central part of Bangladesh experienced moderate to lower precipitation and the western side had the lowest precipitation during 1970-2000.

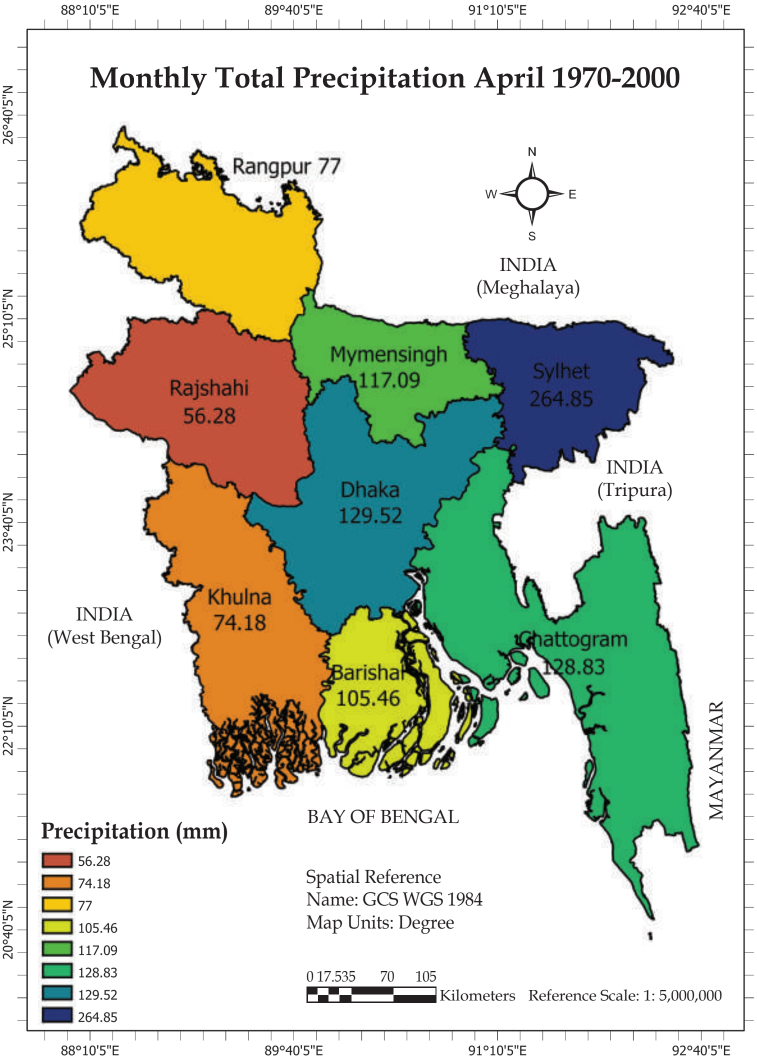


Figure 40. Division-wise average of total precipitation for April 1970-2000

The division-wise analyses of April month average total precipitation during 1970-2000 shows that Sylhet was the highest precipitation division (264.85 mm) and the lowest was Rajshahi with an average precipitation as 56.28 mm (Figure 40).

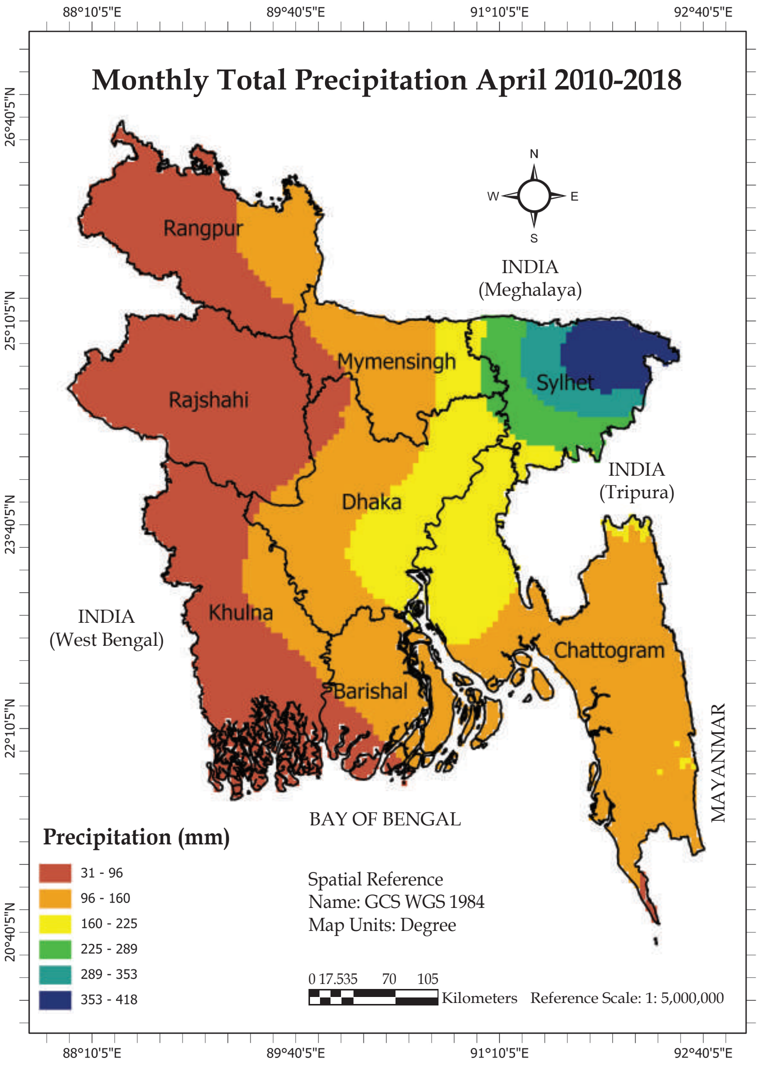


Figure 41. Average of total precipitation for April 2010-2018

Figure 41 is showing the average precipitation of April month during 2010-2018 in Bangladesh. The highest precipitation was observed at the north-eastern side of Bangladesh. Central and lower south-eastern part enjoyed moderate to lower precipitation and western side experienced the lowest precipitation.

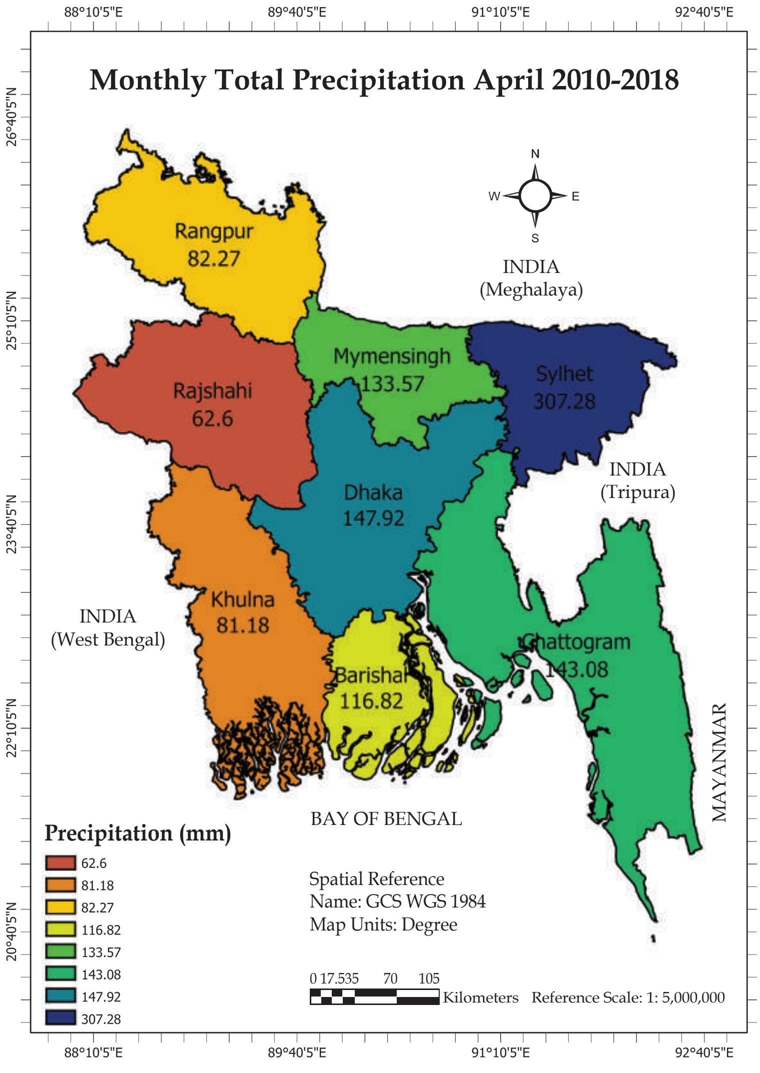


Figure 42. Division-wise average of total precipitation for April 2010-2018

A division-wise representation shows that Sylhet division had the highest precipitation (307.28 mm) and the lowest precipitation division was Rajshahi with an average of 62.6 mm. Mymensingh division will enjoy some more precipitation and a little reduction will be observed in Dhaka and Chattogram divisions (Figure 42).

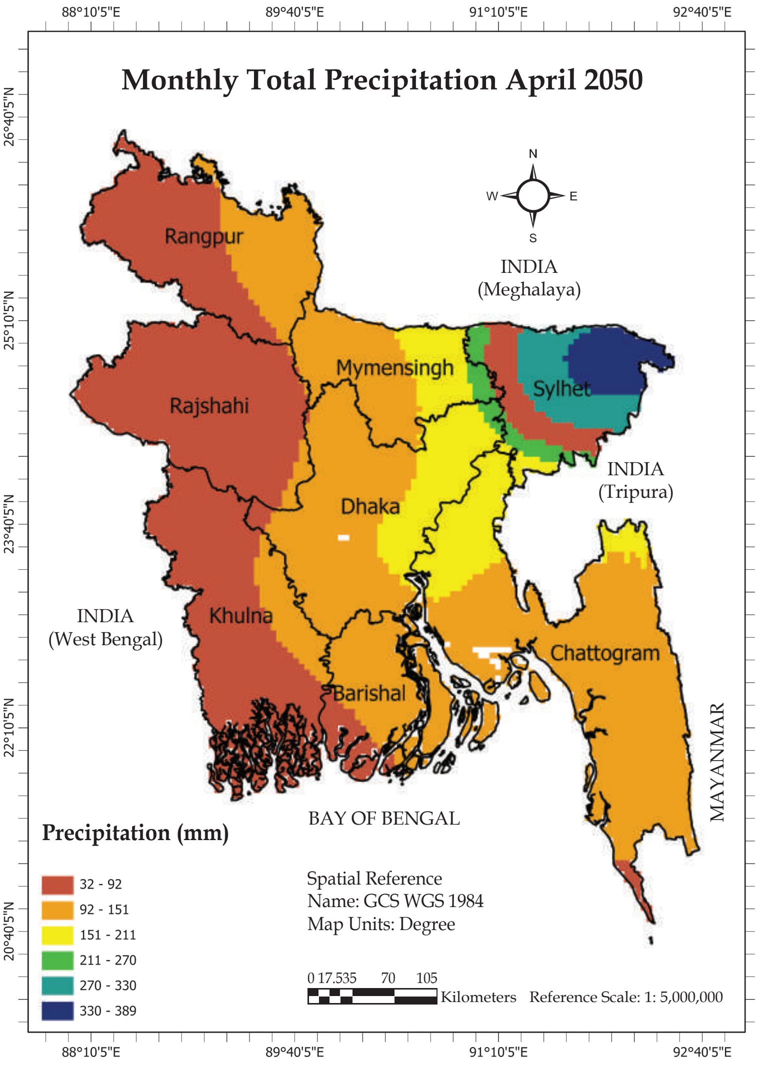


Figure 43. Average of total precipitation for April 2050 according to RCP 2.6

Figure 43 is showing the forecasted April month average precipitation in Bangladesh using RCP 2.6 model. The highest precipitated area in 2050 will be the north-eastern side of Bangladesh, central and lower south-eastern part will have a lower to moderate precipitation. The lowest precipitated area will be the western and south-western side of Bangladesh.

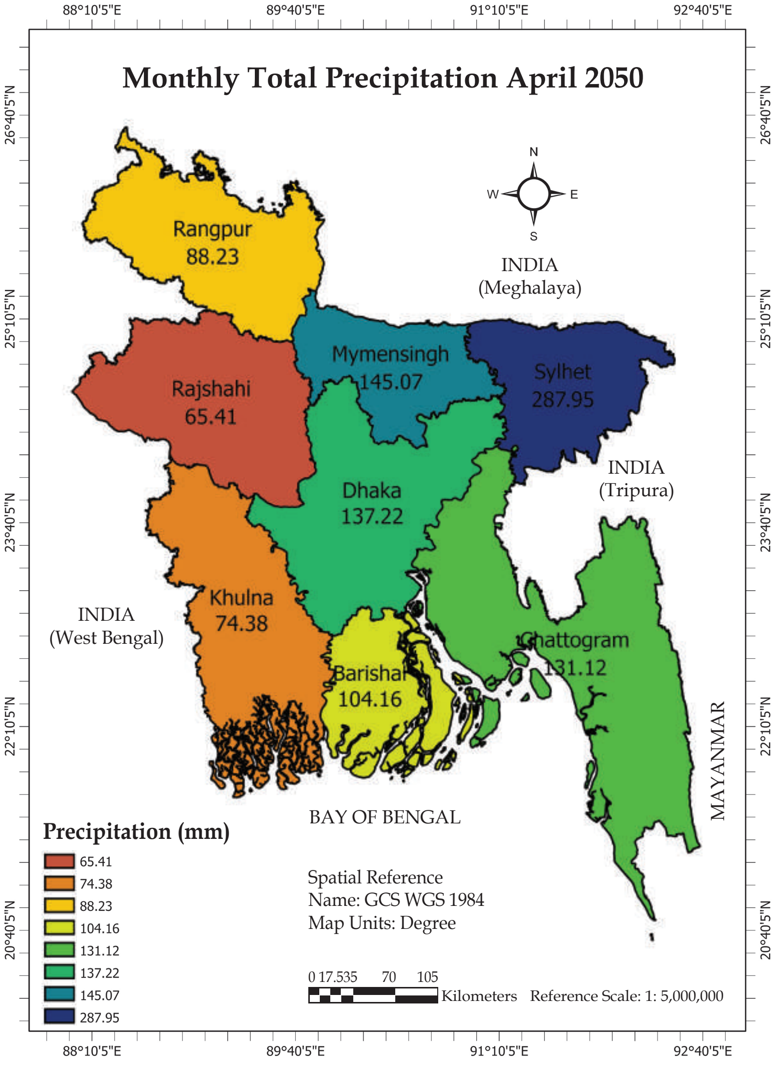


Figure 44. Division-wise average of total precipitation for April 2050 according to RCP 2.6

The division-wise April month forecasted average precipitation of Bangladesh according to RCP 2.6 model shows that Sylhet will be the highest precipitation division (287.95 mm) and Rajshahi will be the lowest precipitation division with an average of 65.41 mm (Figure 44).

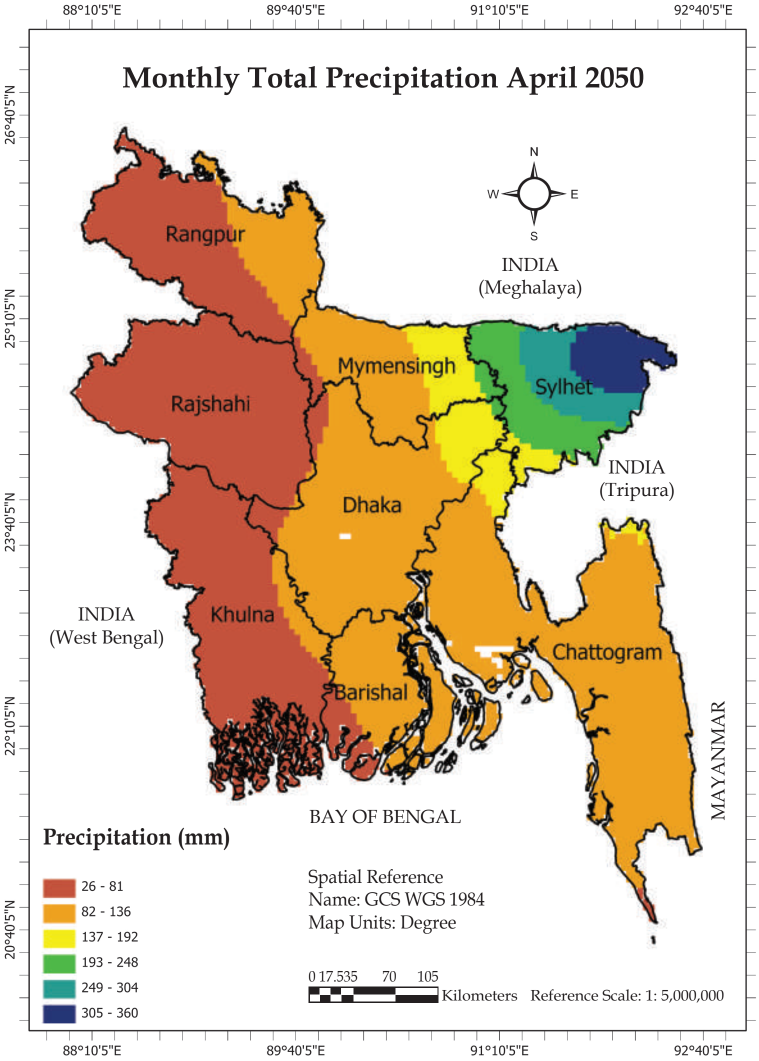


Figure 45. Average of total precipitation for the year 2050 according to RCP 4.5

Figure 45 shows the forecasted average precipitation of Bangladesh in April according to RCP 4.5 model. The highest precipitation will be in the north-eastern side of Bangladesh in 2050. The central and lower south-eastern part will have low precipitation and the lowest precipitation will be observed in the western and south-western side of Bangladesh.

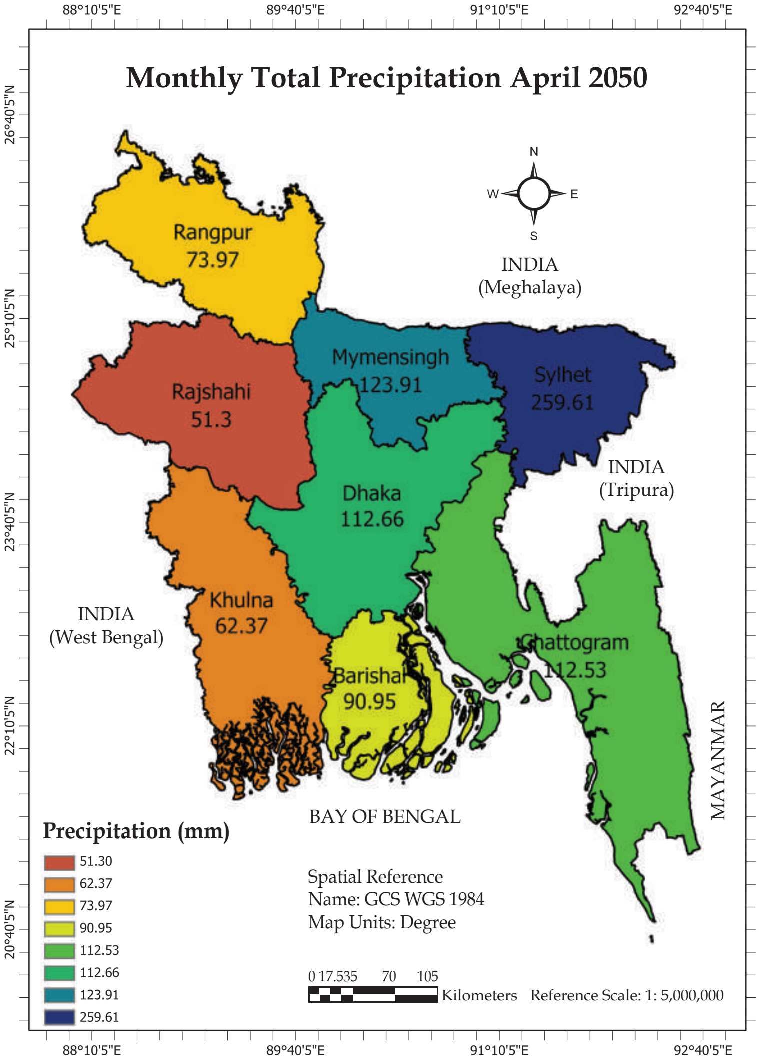


Figure 46. Division-wise average of total precipitation for the year 2050 according to RCP 4.5

The highest precipitation division will be Sylhet (259.61 mm) and lowest precipitation division will be Rajshahi (51.3 mm) in 2050 (Figure 46).

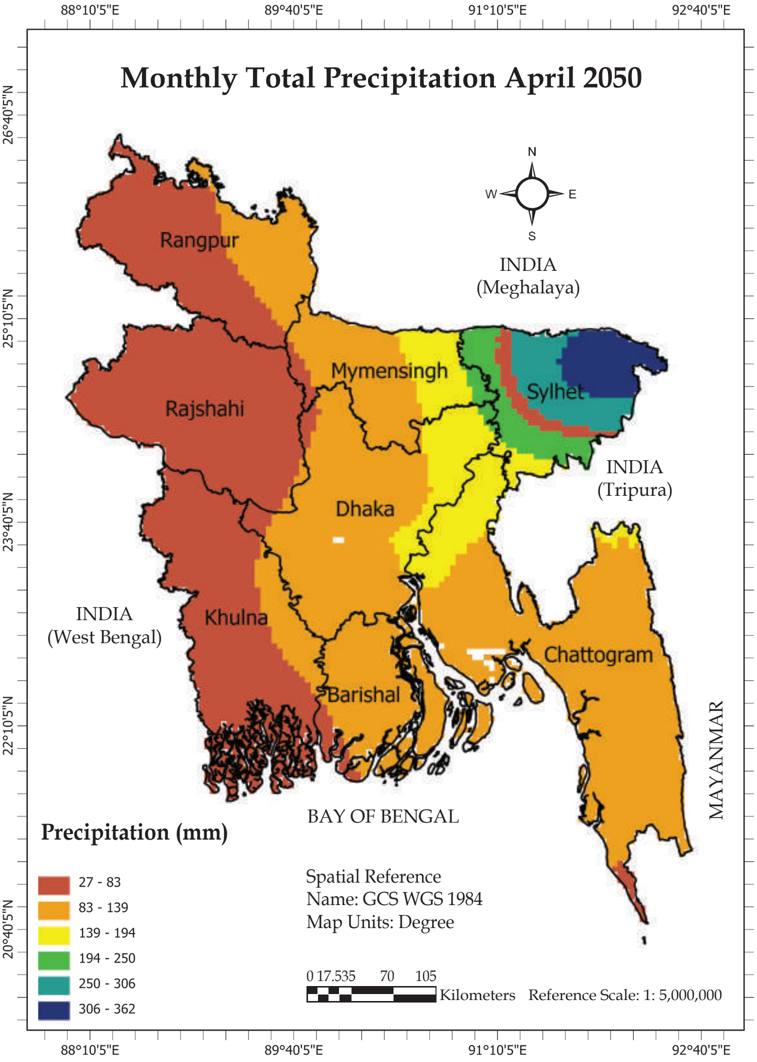


Figure 47. Average of total precipitation for April 2050 according to RCP 6.0

Figure 47 present the forecasted average precipitation of Bangladesh in April according to RCP 6.0 model. The precipitation condition of Bangladesh has been shown as almost similar to the RCP 2.6 model.

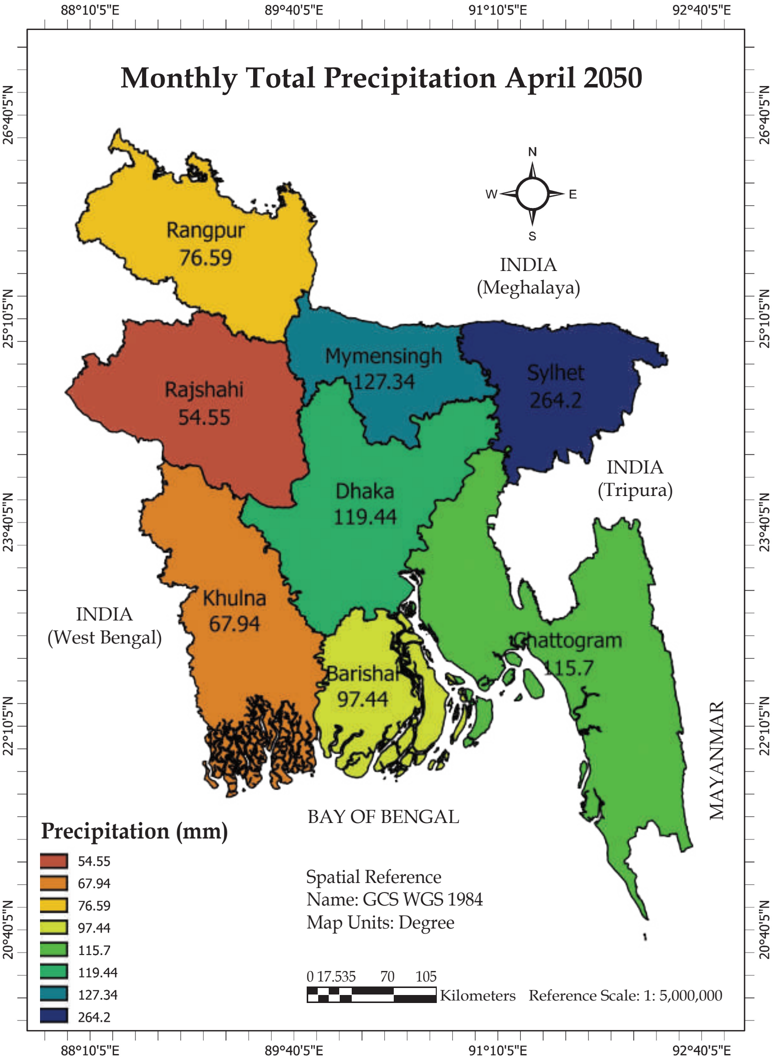


Figure 48. Division-wise average of total precipitation for April 2050 according to RCP 6.0

The highest precipitation division will be Sylhet (264.2 mm) and the lowest precipitated division will be Rajshahi (54.55 mm) in 2050 (Figure 48).

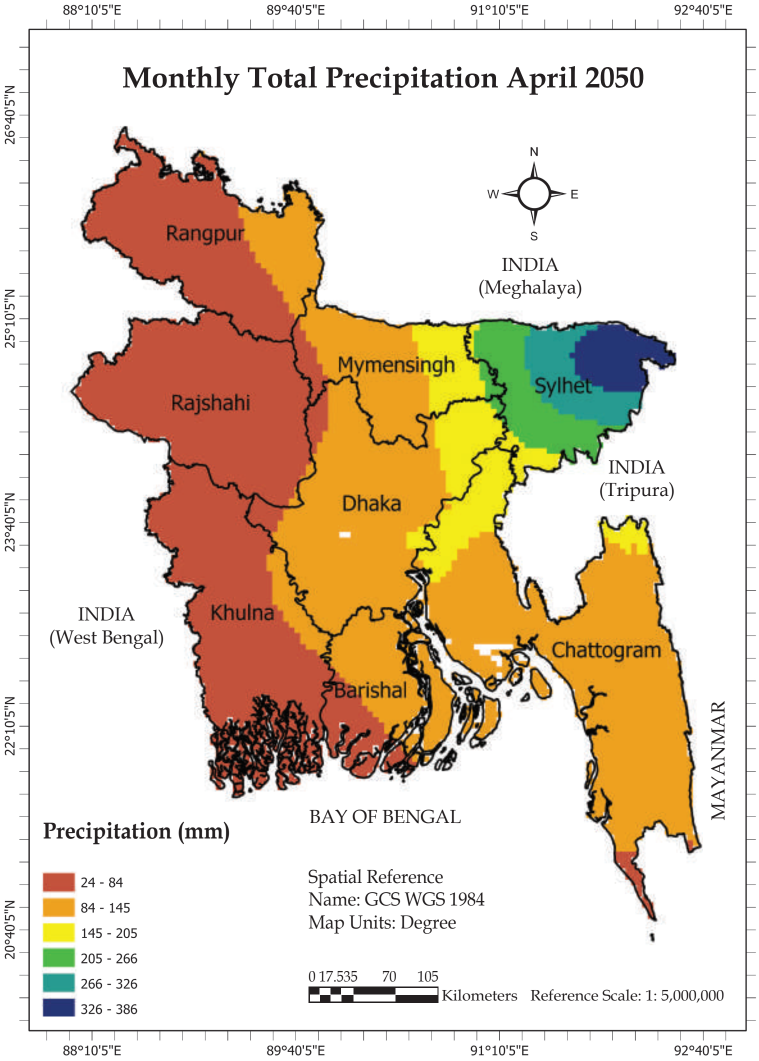


Figure 49. April month average of total precipitation for the year 2050 according to RCP 8.5

Figure 49 explains the forecasted April month average precipitation of Bangladesh according to RCP 8.5 model. The precipitation condition of Bangladesh has been shown as almost similar to the RCP 4.5 model.

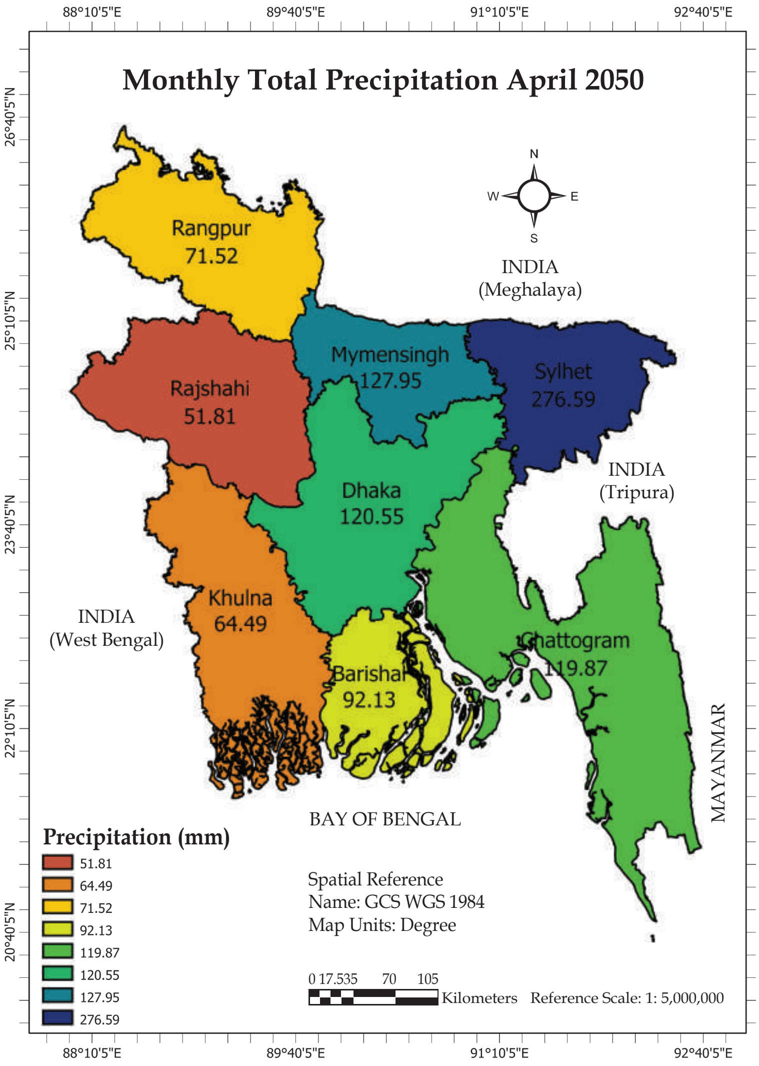


Figure 50. Division-wise April month average of total precipitation for the year 2050 according to RCP 8.5

Figure 50 is showing that the highest precipitation division will be Sylhet (276.59 mm) and the lowest precipitation division will be the same as all other RCP models i.e., Rajshahi (51.81 mm).

Table 6. Summary of April month average total precipitation of 1970 to 2000, 2010 to 2018 and forecasted 2050 (By RCP model 2.6, 4.5, 6.0 and 8.5)

Division	Average Precipitation (mm) 1970 to 2000	Average Precipitation (mm) 2010 to 2018	Precipitation (mm) 2050 (RCP 2.6)	Precipitation (mm) 2050 (RCP 4.5)	Precipitation (mm) 2050 (RCP 6.0)	Precipitation (mm) 2050 (RCP 8.5)	Average of Precipitation (mm) 2050 (RCP 2.6, 4.5, 6.0 and 8.5)	Change of Precipitation (mm) 2050 to 2010-2018
Barishal	105.46	116.82	104.16	90.95	97.44	92.13	96.17	-20.65
Chattogram	128.83	143.08	131.12	112.53	115.70	119.87	119.80	-23.28
Dhaka	129.52	147.92	137.22	112.66	119.44	120.55	122.47	-25.45
Khulna	74.18	81.18	74.38	62.37	67.94	64.49	67.29	-13.89
Mymensingh	117.09	133.57	145.07	123.91	127.34	127.95	131.07	-2.50
Rajshahi	56.28	62.60	65.41	51.30	54.55	51.81	55.77	-6.83
Rangpur	77.00	82.27	88.23	73.97	76.59	71.52	77.58	-4.69
Sylhet	264.85	307.28	287.95	259.61	264.20	276.59	272.09	-35.19

Table 6 shows that in all divisions of Bangladesh average total precipitation (average of RCP 2.6, 4.5, 6.0, and 8.5 models) of April in 2050 will be decreased in comparison to average total precipitation of 2010-2018 period.

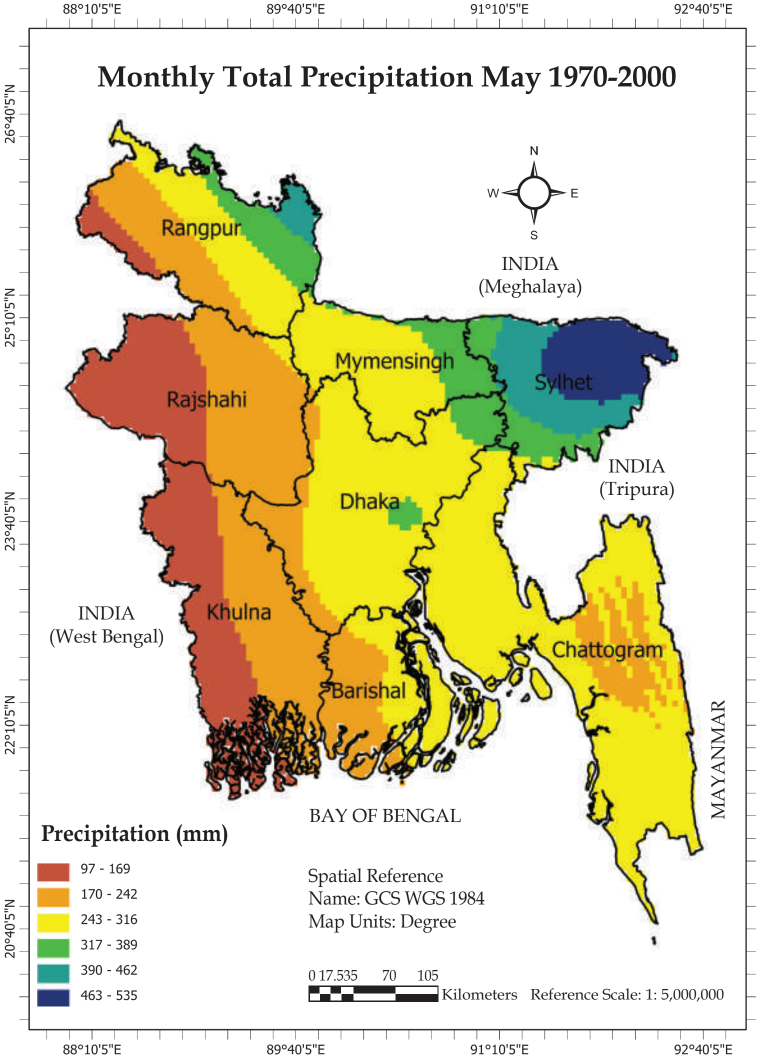


Figure 51. May month average of total precipitation from 1970-2000

Figure 51 shows the average precipitation scenario of May during 1970-2000 in Bangladesh. The highest precipitation was observed in the north-eastern part of Bangladesh. The central part had moderate to lower precipitation and the lowest was in the north-western and south-western side of the country.

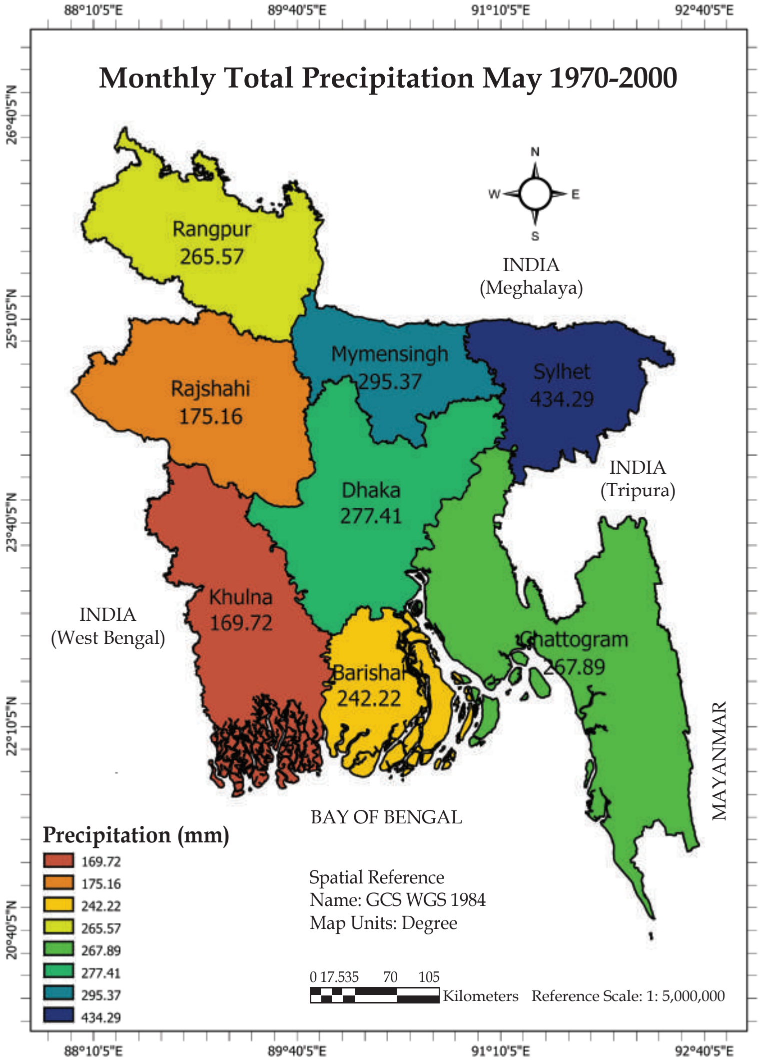


Figure 52. Division-wise May month average of total precipitation from 1970-2000

The division-wise average precipitation of May during 1970-2000 in Bangladesh shows that Sylhet division had the highest precipitation (434.29 mm) and the lowest was in Khulna division with an average of 169.72 mm (Figure 52).

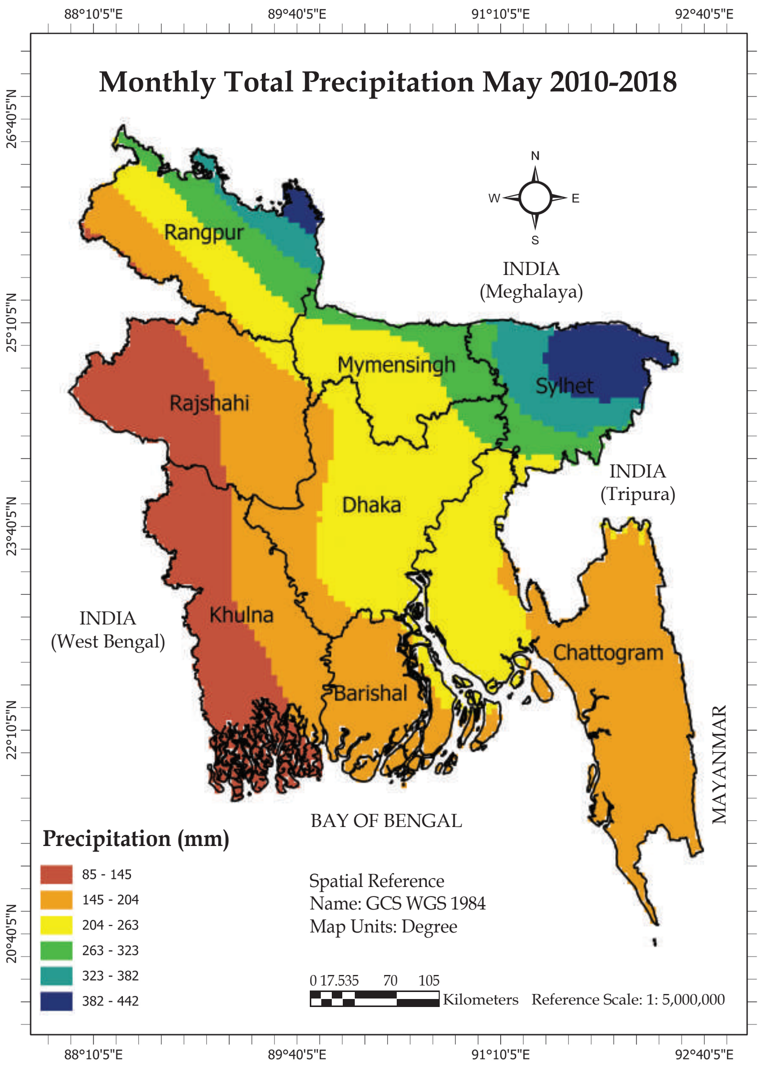


Figure 53. May month average of total precipitation from 2010-2018

Figure 53 is showing the average precipitation of May month during 2010-2018 in Bangladesh. The highest precipitation was observed in the north-eastern side of Bangladesh. The central part (covering both north and south) was under moderate to lower precipitation and lower south-eastern part had low and south-western and north-western side had the lowest precipitation.

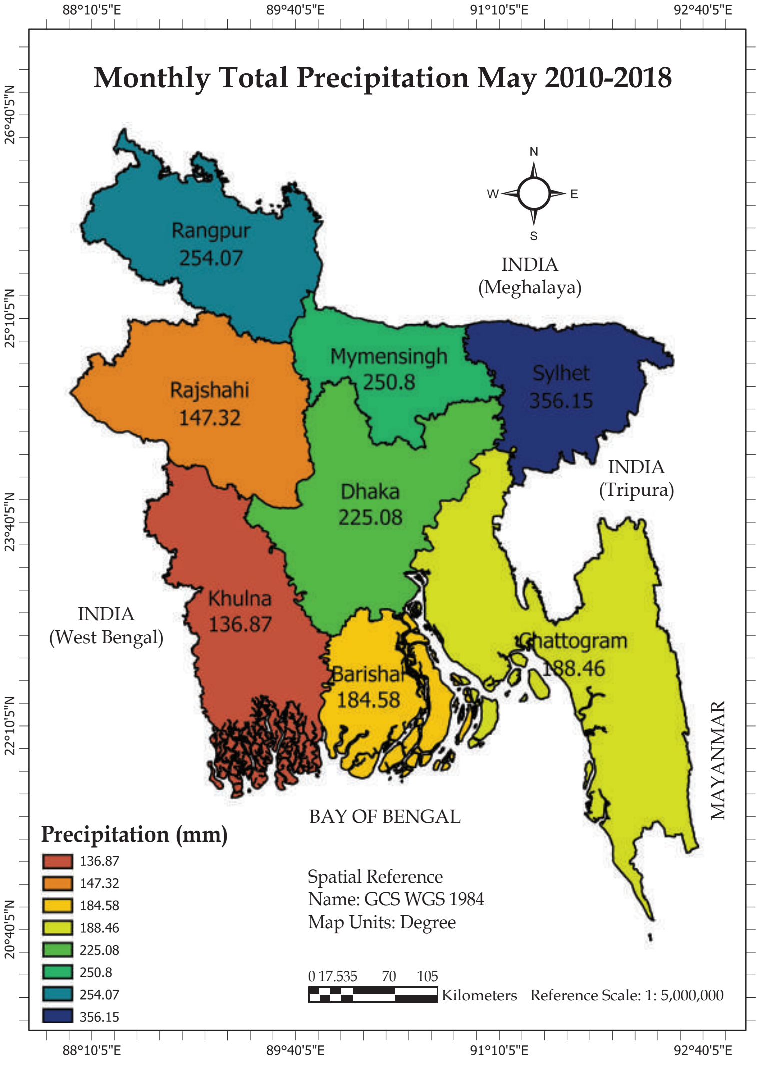


Figure 54. Division-wise May month average of total precipitation from 2010-2018

Figure 54 is describing division-wise May month average precipitation during 2010-2018 in Bangladesh. The Sylhet division had the highest precipitation (356.15 mm) and the lowest was in Khulna division (136.87 mm).

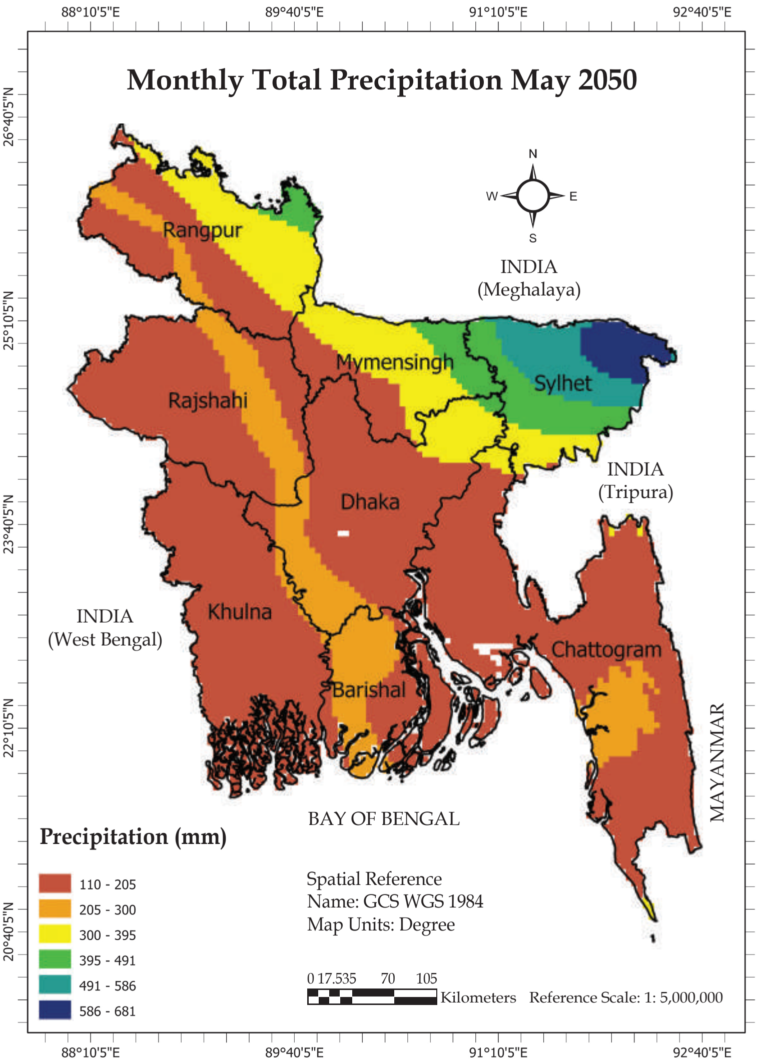


Figure 55. May month average of total precipitation for the year 2050 according to RCP 2.6

Figure 55 is describing the May month average forecasted precipitation of Bangladesh according to RCP 2.6 model. The highest precipitation will be observed in the north-eastern side of Bangladesh. The central, south-eastern, and western part of the country will have very low precipitation.

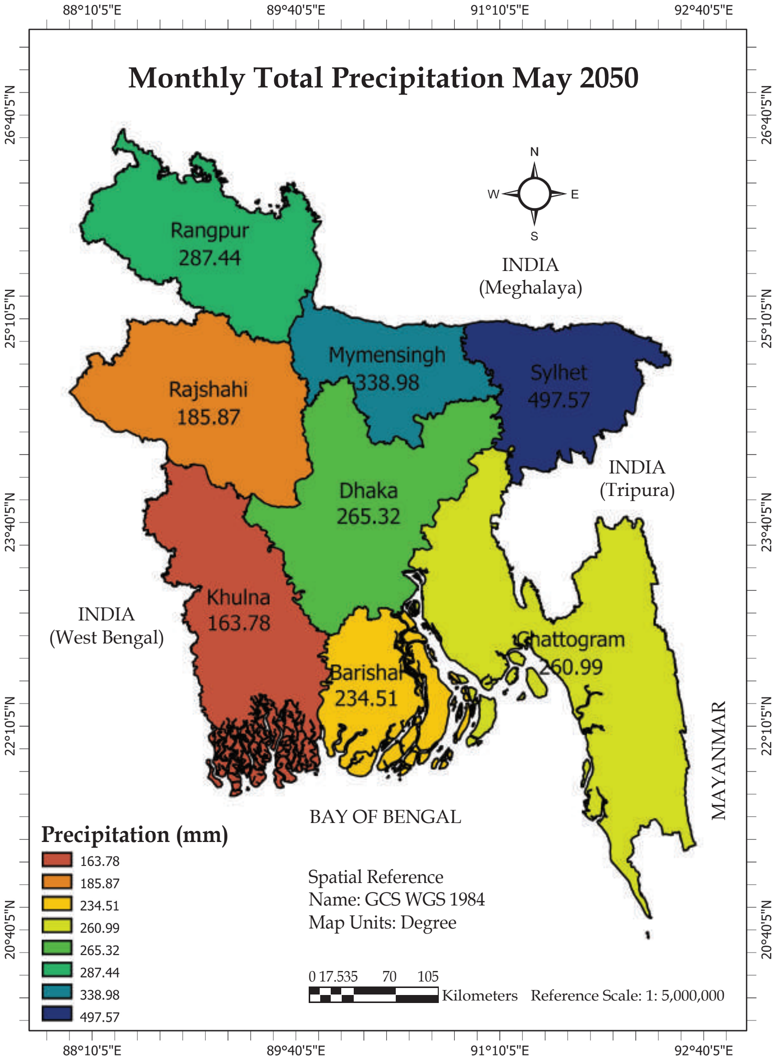


Figure 56. Division-wise May month average of total precipitation for the year 2050 according to RCP 2.6

Figure 56 is showing the division wise forecasted May month average precipitation of Bangladesh according to RCP 2.6 model. The results present that Sylhet will have the highest precipitation (497.57 mm) and Khulna division will have the lowest (163.78 mm) in 2050.

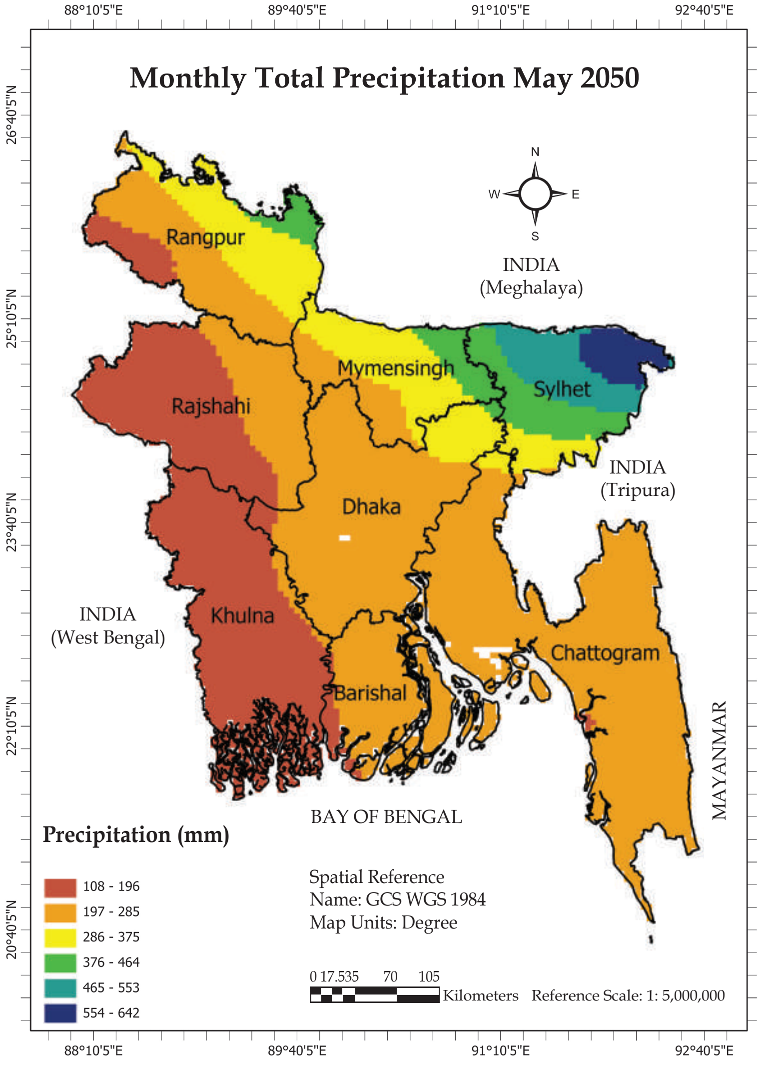


Figure 57. Average of total precipitation for May 2050 according to RCP 4.5

Figure 57 is describing the forecasted May month average precipitation of Bangladesh according to RCP 4.5 model. The highest precipitation will be observed in the north-eastern side of Bangladesh. The central part (covering both north and south) will have moderate to lower precipitation and lower south-eastern part will get low, and south-western and north-western side will have the lowest precipitation.

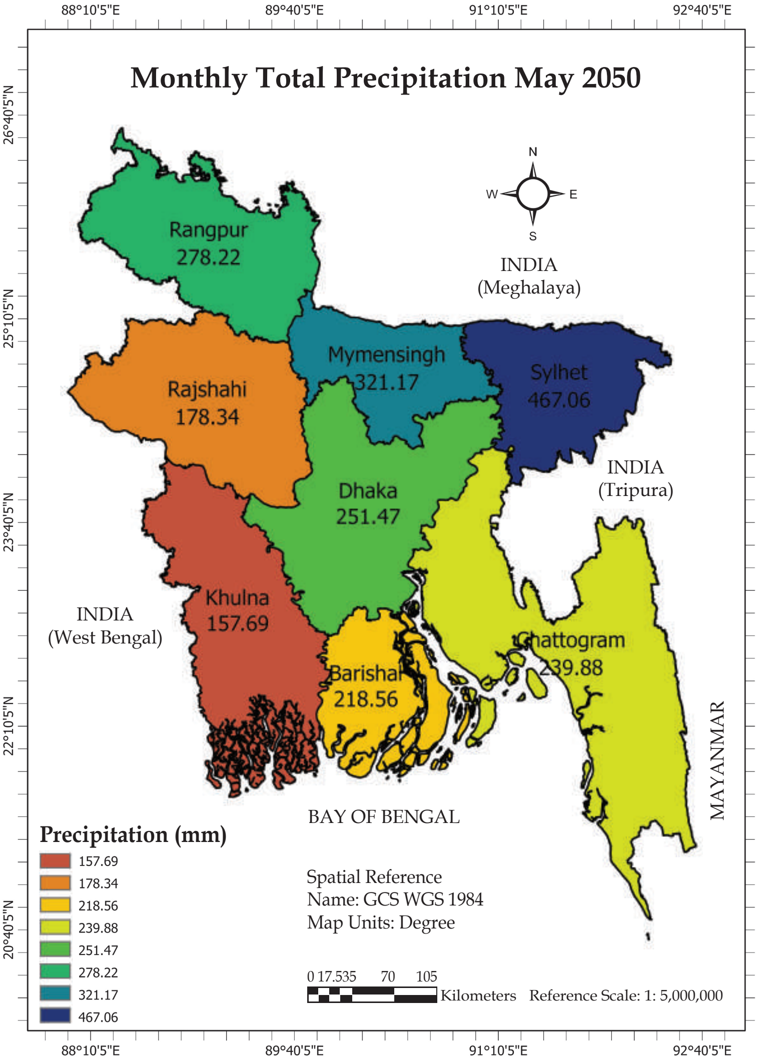


Figure 58. Division-wise average of total precipitation for May 2050 according to RCP 4.5

Figure 58 shows that Sylhet division will have the highest precipitation (467.06 mm) and the lowest will have in Khulna division (157.69 mm) in 2050.

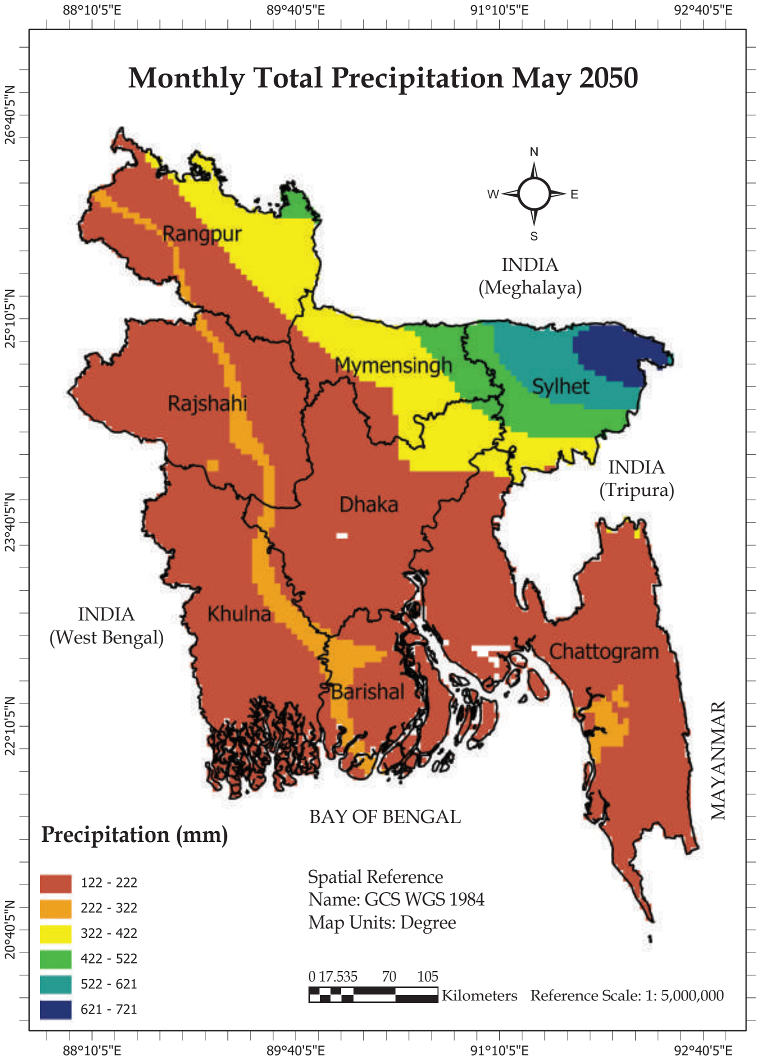


Figure 59. Average of total precipitation for May 2050 according to RCP 6.0

Figure 59 is describing the forecasted May month average precipitation of Bangladesh according to RCP 6.0 model. The forecasts show that precipitation condition of Bangladesh is showing almost similar as the RCP 2.6 model.

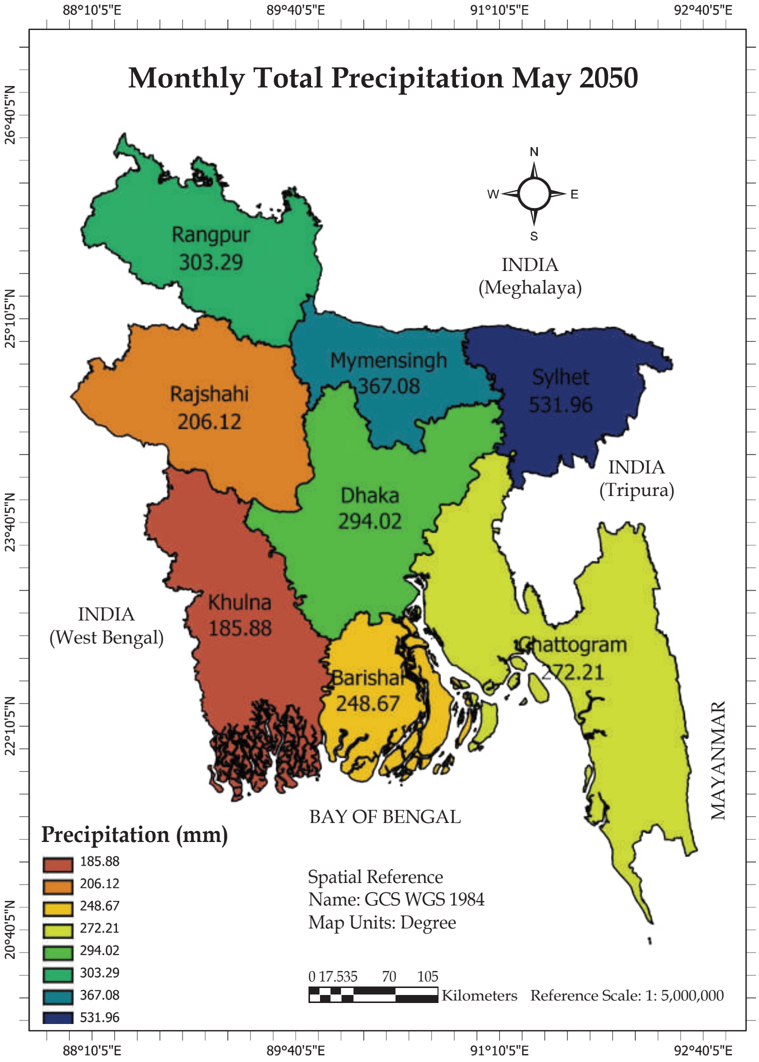


Figure 60. Division-wise average of total precipitation for May 2050 according to RCP 6.0

Figure 60 shows that the highest precipitation division will be Sylhet (531.96 mm) and the lowest will be Khulna division (185.88 mm) in 2050.

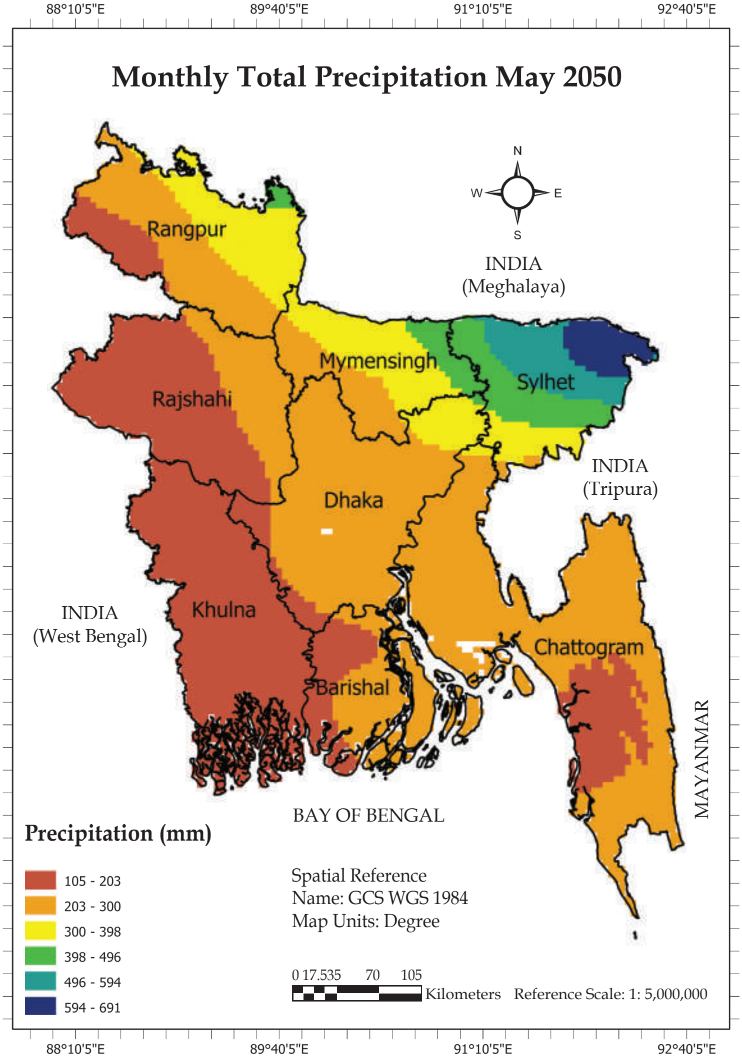


Figure 61. Average of total precipitation for May 2050 according to RCP 8.5

Figure 61 is explaining the forecasted May month average precipitation of Bangladesh according to RCP 8.5 model. The precipitation condition of Bangladesh is showing almost similar as the RCP 4.5 model.

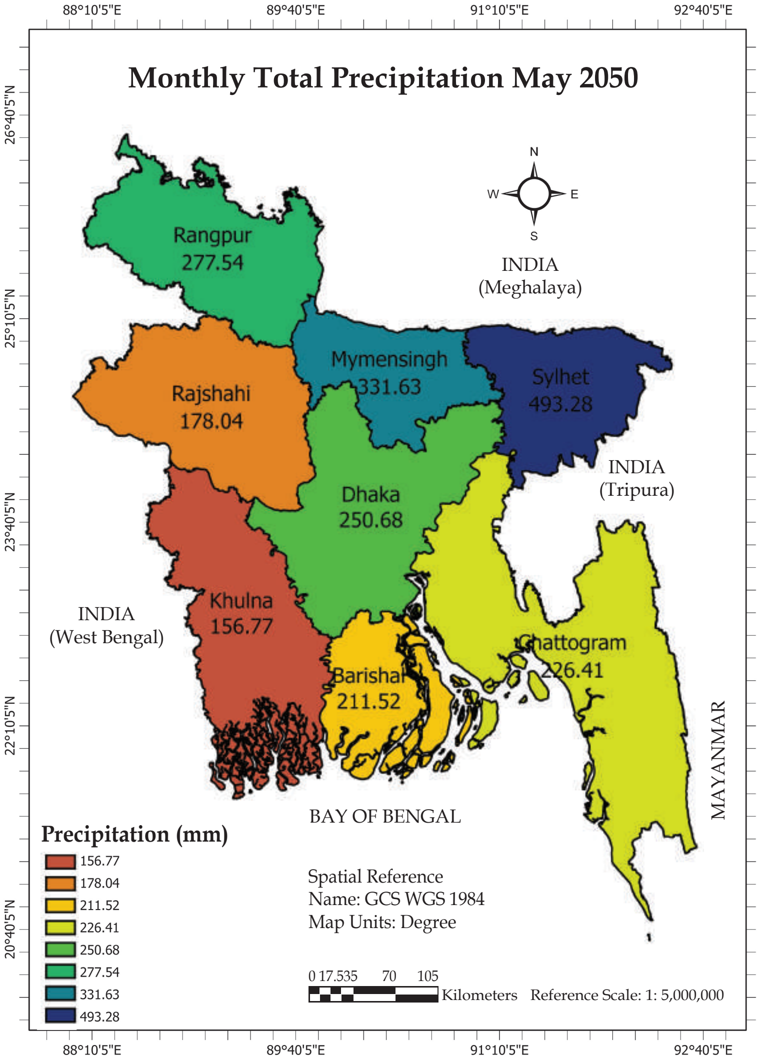


Figure 62. Division-wise average of total precipitation for May 2050 according to RCP 8.5

Figure 62 is showing that the highest precipitation division will be again Sylhet (493.28 mm) and the lowest precipitation division will be the same as all others RCP models i.e., Khulna (156.77 mm) in 2050.

Table 7. Summary of May month average total precipitation of 1970 to 2000, 2010 to 2018 and forecasted 2050 (By RCP 2.6, 4.5, 6.0 and 8.5 models

Division	Average Precipitation (mm) 1970 to 2000	Average Precipitation (mm) 2010 to 2018	Precipitation (mm) 2050 (RCP 2.6)	Precipitation (mm) 2050 (RCP 4.5)	Precipitation (mm) 2050 (RCP 6.0)	Precipitation (mm) 2050 (RCP 8.5)	Average of Precipitation (mm) 2050 (RCP 2.6, 4.5, 6.0 and 8.5)	Change of Precipitation (mm) 2050 to 2010-2018
Barishal	242.22	184.58	234.51	218.56	248.67	211.52	228.31	43.73
Chattogram	267.89	188.46	260.99	239.88	272.21	226.41	249.87	61.41
Dhaka	277.41	225.08	265.32	251.47	294.02	250.68	265.37	40.29
Khulna	169.72	136.87	163.78	157.69	185.88	156.77	166.03	29.16
Mymensingh	295.37	250.8	338.98	321.17	367.08	331.63	339.71	88.91
Rajshahi	175.16	147.32	185.87	178.34	206.12	178.04	187.09	39.77
Rangpur	265.57	254.07	287.44	278.22	303.29	277.54	286.62	32.55
Sylhet	434.29	356.15	497.57	467.06	531.96	493.28	497.47	141.32

From the Table 7, it is found that in all divisions of Bangladesh average total precipitation (average by RCP 2.6, 4.5, 6.0, and 8.5 models) of May month in 2050 will be increased in comparison to average total precipitation during 2010-2018.

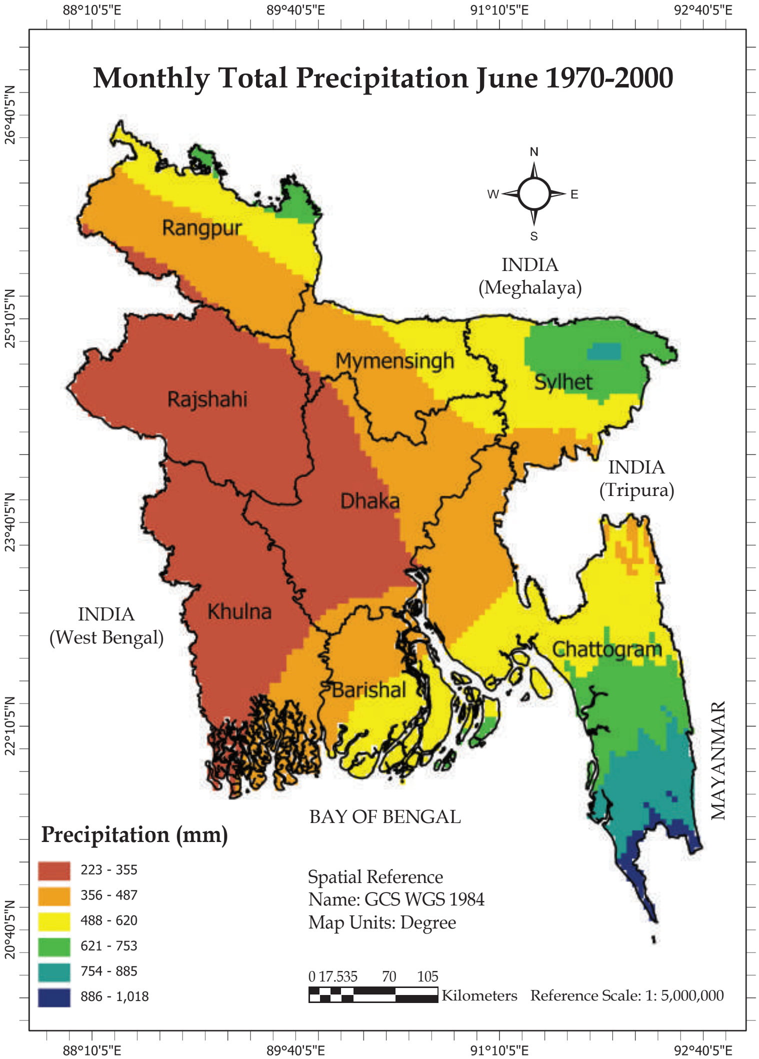


Figure 63. Average of total precipitation for June 1970-2000

Figure 63 shows the average precipitation for June month during 1970-2000 in Bangladesh. The highest precipitation was found in the south-eastern part of the country, followed by the lower north-eastern part. The central part of Bangladesh (both north and south) had lower to the moderate precipitation and the western side had the lowest precipitation.

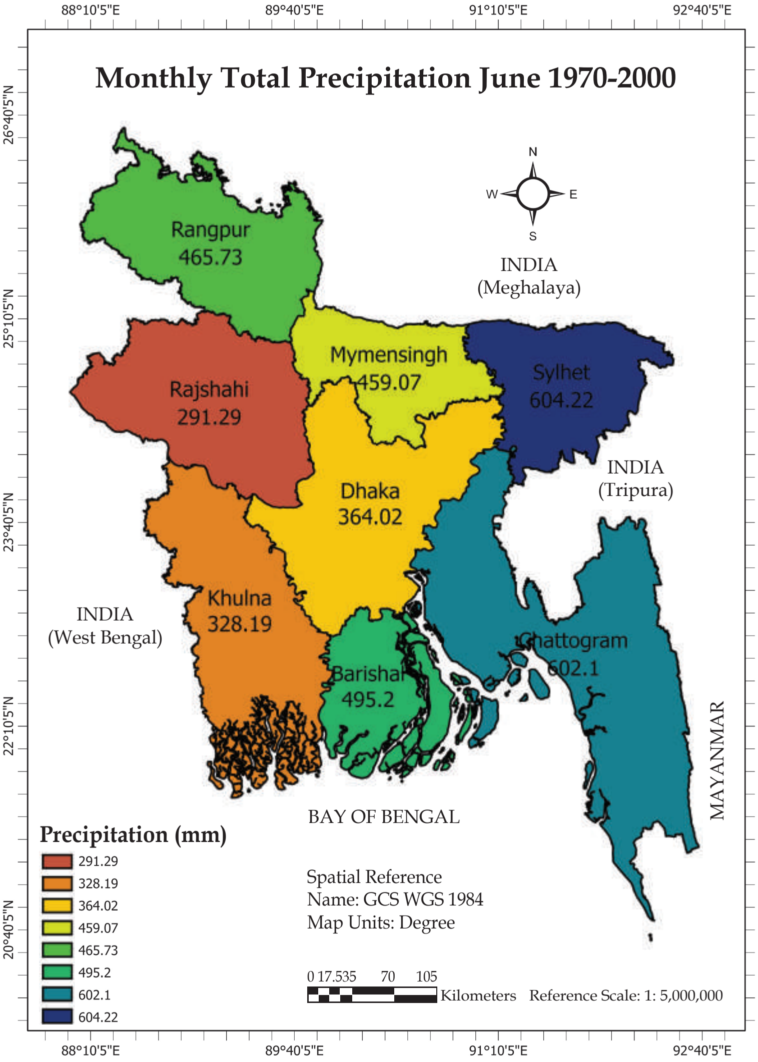


Figure 64. Division-wise average of total precipitation for June 1970-2000

Figure 64 presents the division-wise June month average precipitation during 1970-2000 in Bangladesh. The findings show that Sylhet division had the highest precipitation (604.22 mm) followed by Chattogram division (602.1 mm). The lowest precipitation was observed in Rajshahi division (291.29 mm).

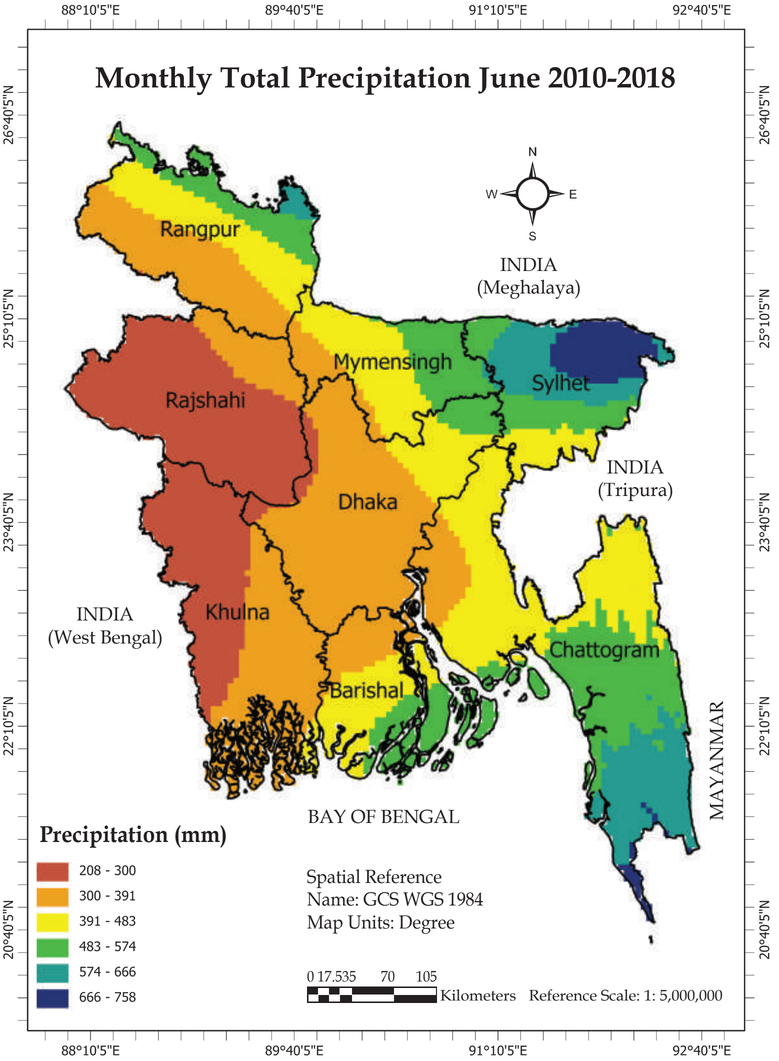


Figure 65. Average of total Precipitation for June 2010-2018

Figure 65 is showing the average precipitation for June month during 2010-2018 in Bangladesh, where the highest precipitated area was north-eastern part of the country followed by the lower part of the south-eastern side. The central part was lower to the moderate and the western side was the lowest precipitated areas.

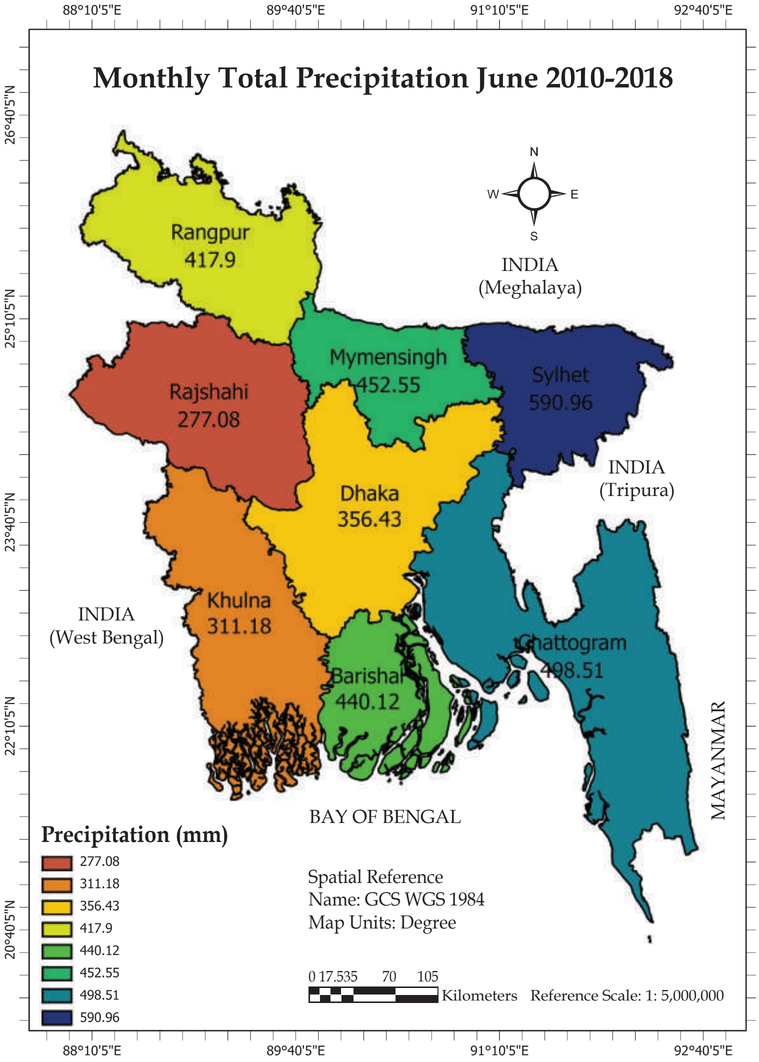


Figure 66. Division-wise average of total Precipitation for June 2010-2018

Figure 66 presents that Sylhet division had the highest precipitation (590.96 mm) and the lowest was in Rajshahi division (277.08 mm).

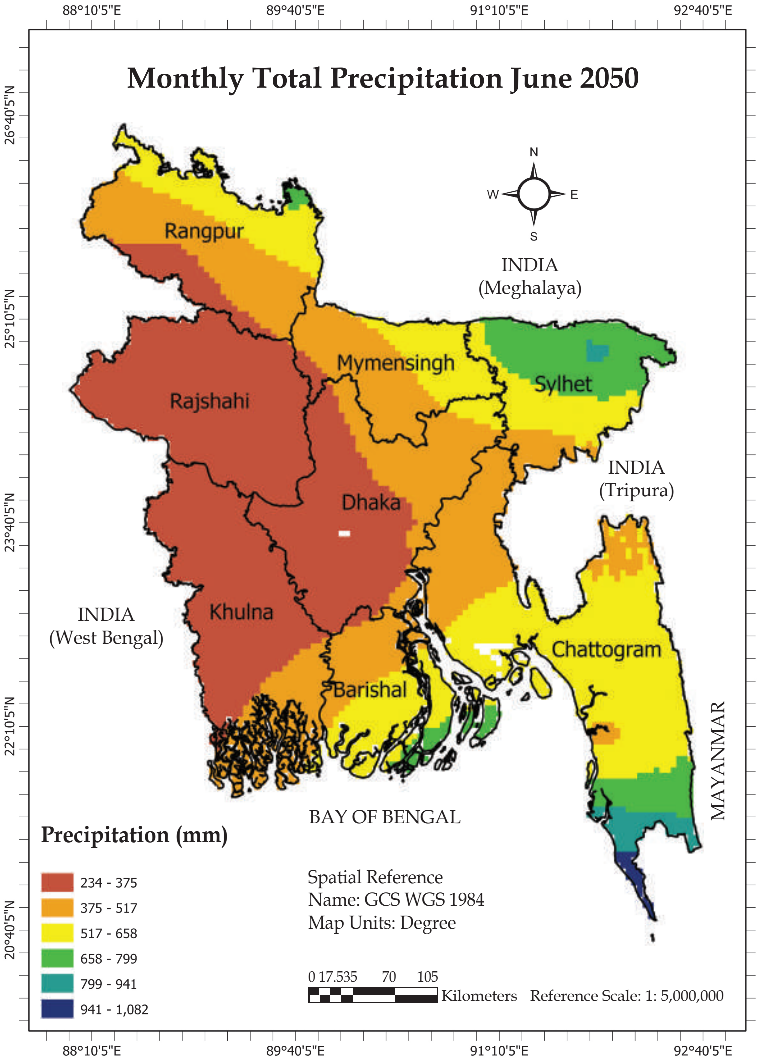


Figure 67. June Month average of total Precipitation for the year 2050 according to RCP 2.6

Figure 67 describes the forecasted June month average precipitation of Bangladesh according to RCP 2.6 model. The highest precipitation will be at the lower part of the south-western side and at some part of the north-eastern side of Bangladesh, the central part will be under lower to the moderate precipitation and the lowest precipitation will be onserved at the western side of Bangladesh.

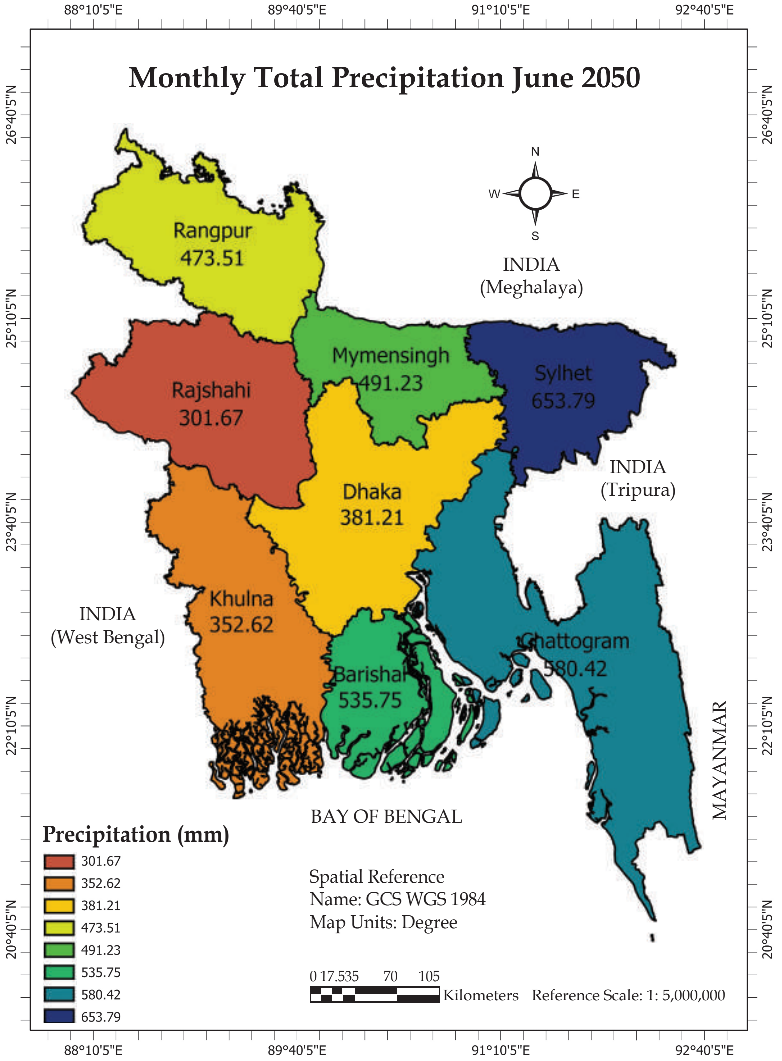


Figure 68. Division-wise June Month average of total Precipitation for the year 2050 according to RCP 2.6

Figure 68 is showing the division-wise June month average precipitation of Bangladesh according to RCP 2.6 model. Sylhet division will be the highest precipitation division (653.79 mm) and Rajshahi division will have the lowest precipitation (301.67 mm) in 2050.

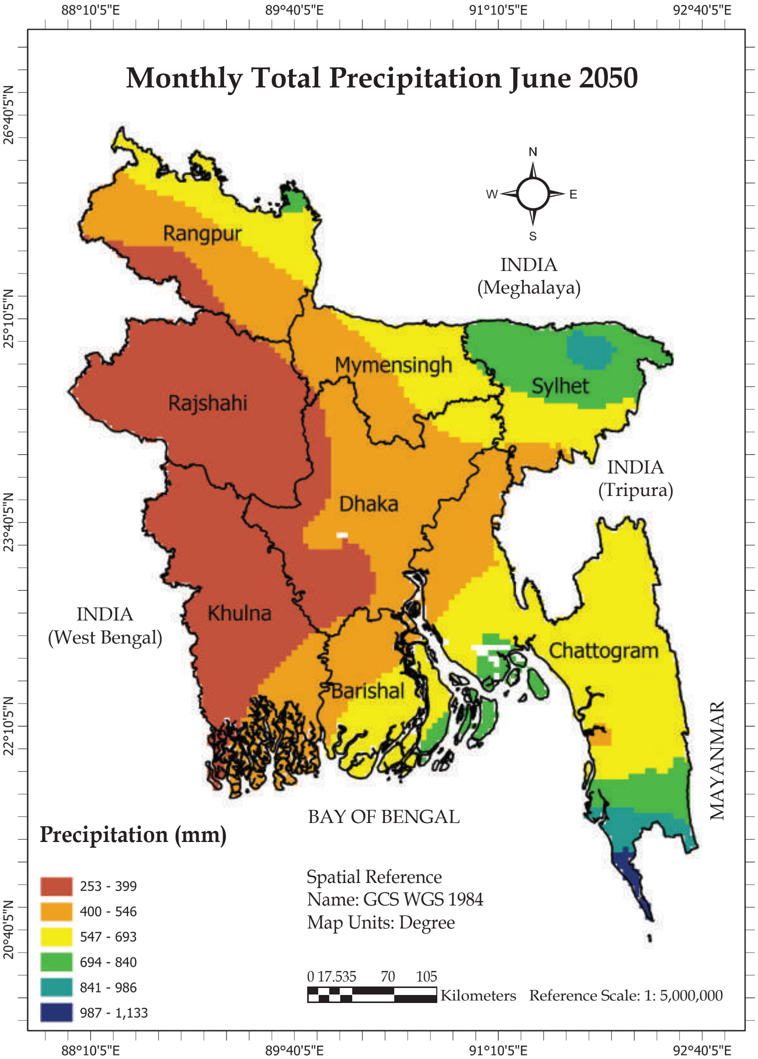


Figure 69. Average of total Precipitation for June 2050 according to RCP 4.5

Figure 69 is expressing the forecasted June month average precipitation of Bangladesh according to RCP 4.5 model. The precipitation condition of Bangladesh has been shown as more or less similar to the RCP 2.6 model.

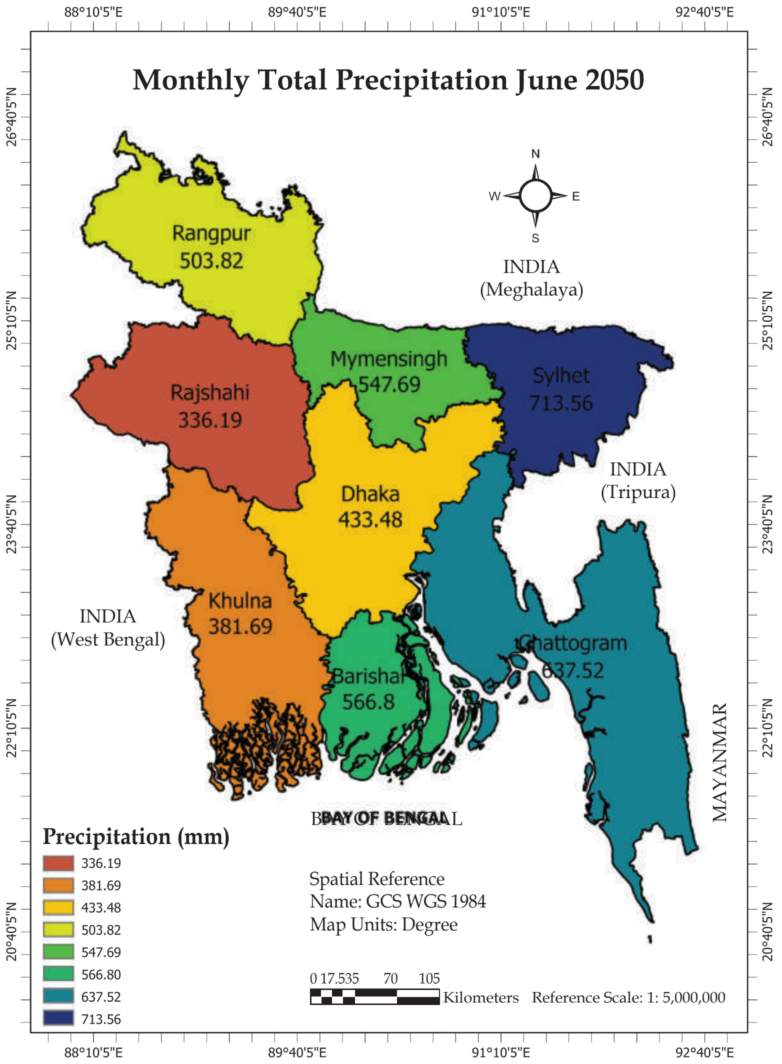


Figure 70. Division-wise average of total Precipitation for June 2050 according to RCP 4.5

Figure 70 shows that the highest precipitation division will be Sylhet (713.56 mm) and the lowest will be Rajshahi division (336.19 mm).

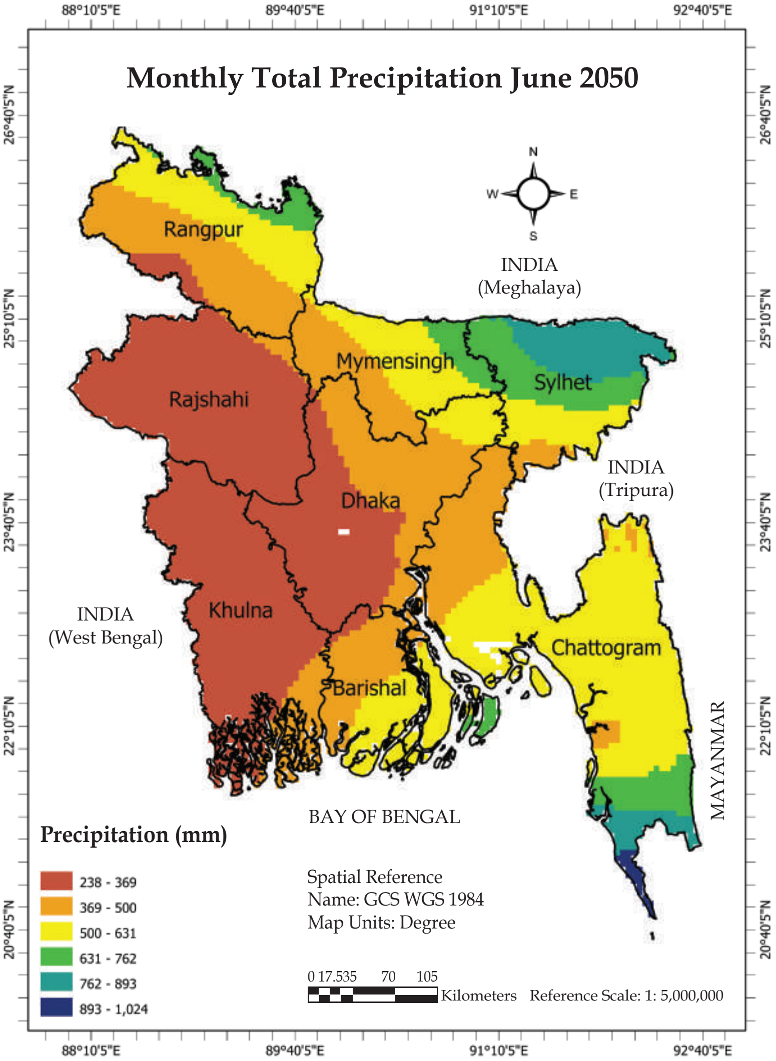


Figure 71. Average of total precipitation for June 2050 according to RCP 6.0

Figure 71 is describing the forecasted June month average precipitation of Bangladesh according to RCP 6.0 model. The precipitation condition of Bangladesh has been shown almost similar as the other RCP models' forecasts.

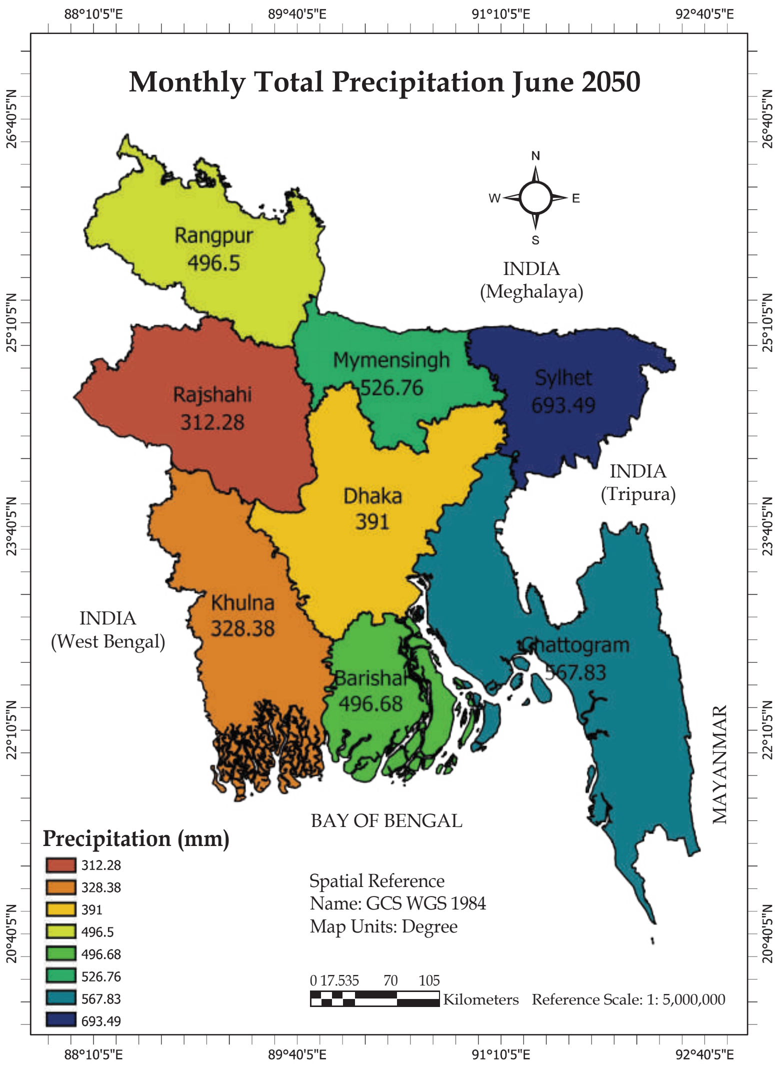


Figure 72. Division-wise average of total Precipitation for June 2050 according to RCP 6.0

Figure 72 shows that the highest precipitation division will be Sylhet (693.49 mm) and the lowest will be Rajshahi division (312.28 mm) in 2050.

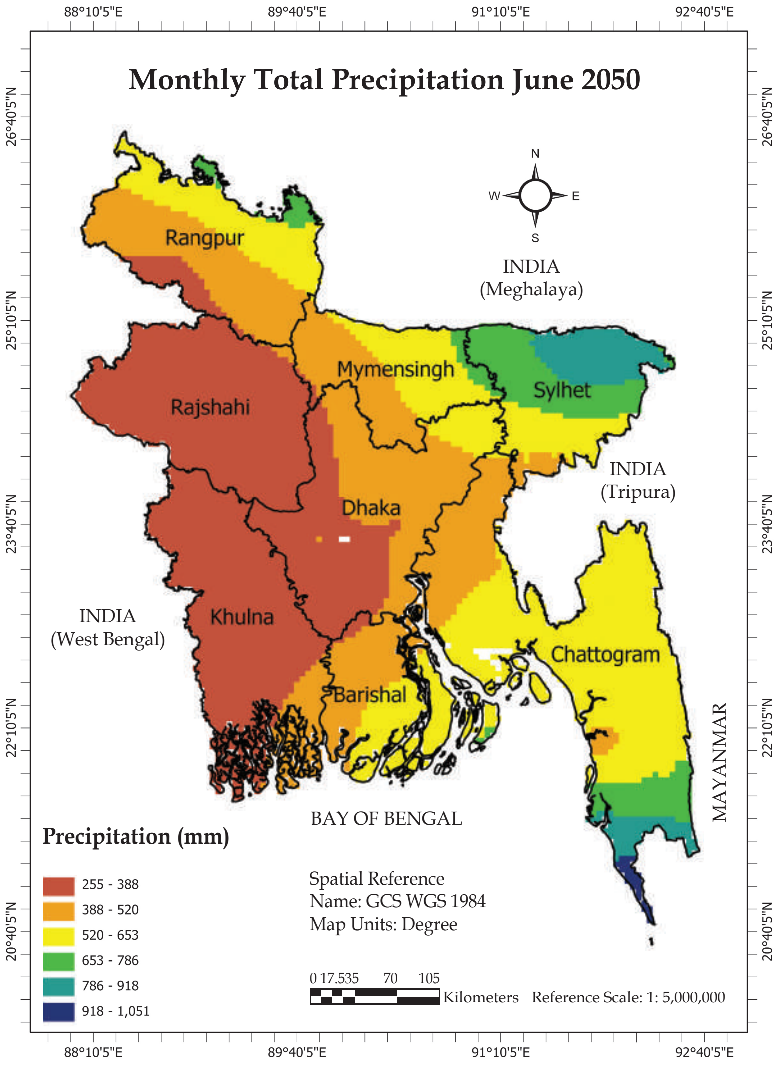


Figure 73. Average of total precipitation for June 2050 according to RCP 8.5

Figure 73 is explaining the forecasted June month average precipitation of Bangladesh according to RCP 8.5 model. The precipitation condition of Bangladesh has been shown almost similar as the RCP 2.6, 4.5, and 6.0 models' forecasts.

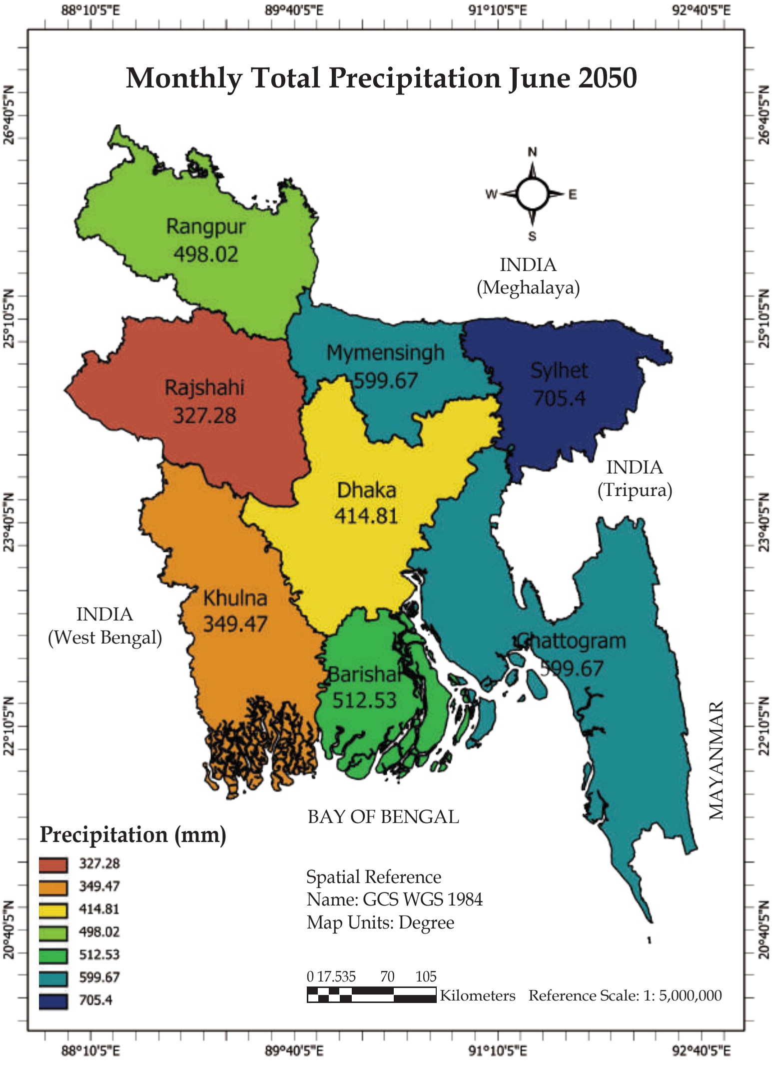


Figure 74. Division-wise average of total Precipitation for June 2050 according to RCP 8

Figure 74 is showing that the highest precipitation division will be Sylhet (705.4 mm) followed by Chattogram (599.67). The lowest precipitation division will be Rajshahi (327.28 mm) in 2050.

Table 8. Summary of June month average total precipitation of 1970 to 2000, 2010 to 2018 and forecasted 2050 (By RCP model 2.6, 4.5, 6.0 and 8.5)

Division	Average Precipitation (mm) 1970 to 2000	Average Precipitation (mm) 2010 to 2018	Precipitation (mm) 2050 (RCP 2.6)	Precipitation (mm) 2050 (RCP 4.5)	Precipitation (mm) 2050 (RCP 6.0)	Precipitation (mm) 2050 (RCP 8.5)	Average of Precipitation (mm) 2050 (RCP 2.6, 4.5, 6.0 and 8.5)	Change of Precipitation (mm) 2050 to 2010-2018
Barishal	495.20	440.12	535.75	566.80	496.68	512.53	527.94	87.82
Chattogram	602.10	498.51	580.42	637.52	567.83	599.67	596.36	97.85
Dhaka	364.02	356.43	381.21	433.48	391.00	414.81	405.12	48.69
Khulna	328.19	311.18	352.62	381.69	328.38	349.47	353.04	41.86
Mymensingh	459.07	452.55	491.23	547.69	526.76	599.67	541.34	88.79
Rajshahi	291.29	277.08	301.67	336.19	312.28	327.28	319.35	42.27
Rangpur	465.73	417.90	473.51	503.82	496.50	498.02	492.96	75.06
Sylhet	604.22	590.96	653.79	713.56	693.49	705.40	691.56	100.60

In all divisions of Bangladesh average total precipitation (average by RCP 2.6, 4.5, 6.0, and 8.5 models) of June month in 2050 will be increased in comparison to the average precipitation during 2010-2018 (Table 8). Spatial pattern of Precipitaton of Bangladesh will be more or less same as current situation. In almost all area in Bangladesh precipition will be increased. Though western side precipition will go up but amount not be high like eastern side. In eastern side Sylhet division average precipition in June will be increased about 100 mm than average of 2010-2018 and in Chattogram division, precipitation rise up amount will be near about Sylhet division while in western side Rajshahi division increased amout about will be 42.27 mm about and in Khulna division it will be near about 41.86 mm.

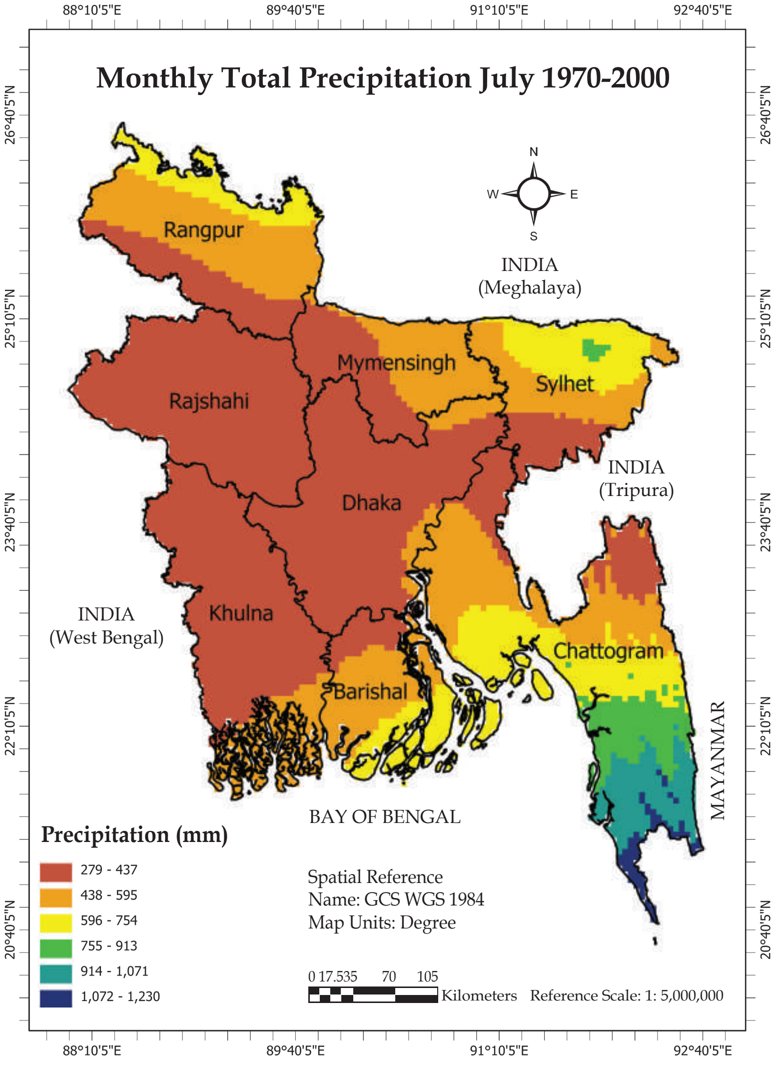


Figure 75. July month average of total precipitation from 1970-2000

Figure represents the historic precipitation scenario of the crucial rainy season month 'July' in Bangladesh covering the period 1970-2000. A country level analysis showed that the highest precipitation in July month was in the south-eastern part of Bangladesh (Figure 75).

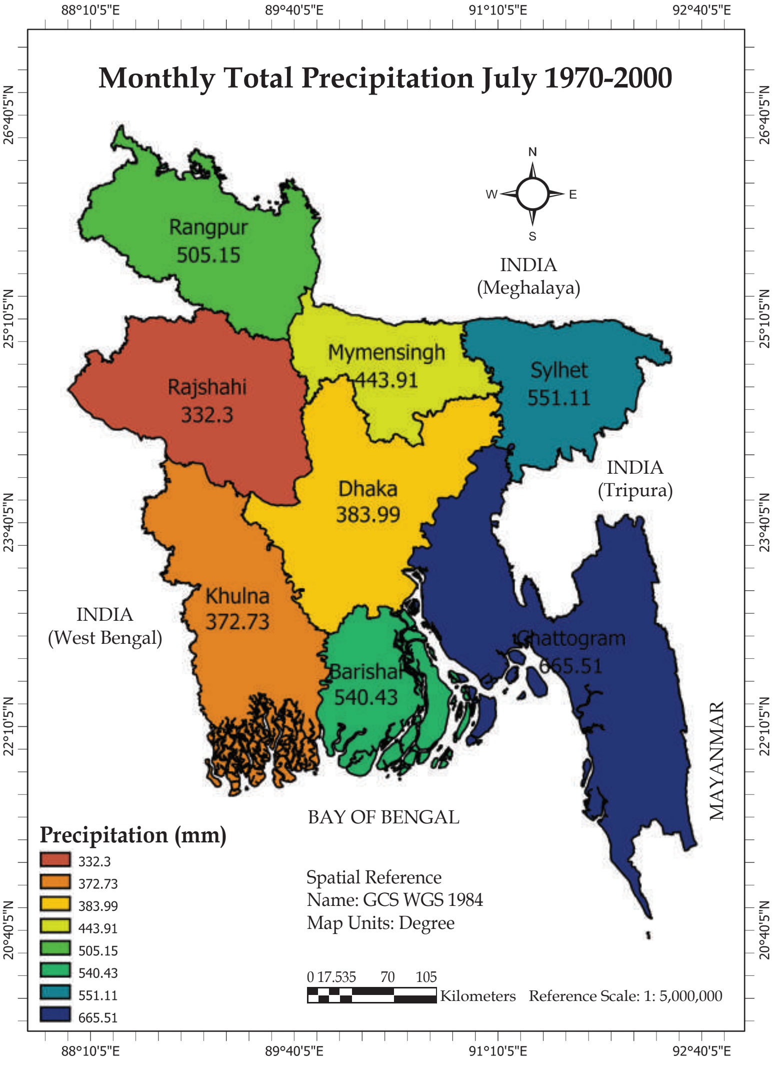


Figure 76. Division wise July month average of total precipitation from 1970-2000

Moreover, the areas adjacent to the Indian border showed relatively higher precipitation. A division-wise analysis showed that Chattogram division was found to have the highest precipitated division viz. 665.51 mm followed by Sylhet division (551.11 mm), and Barishal division (540.43 mm). The lowest precipitation was observed in Rajshahi division (332.3 mm), which is known as the drought prone region of the country (Figure 76).

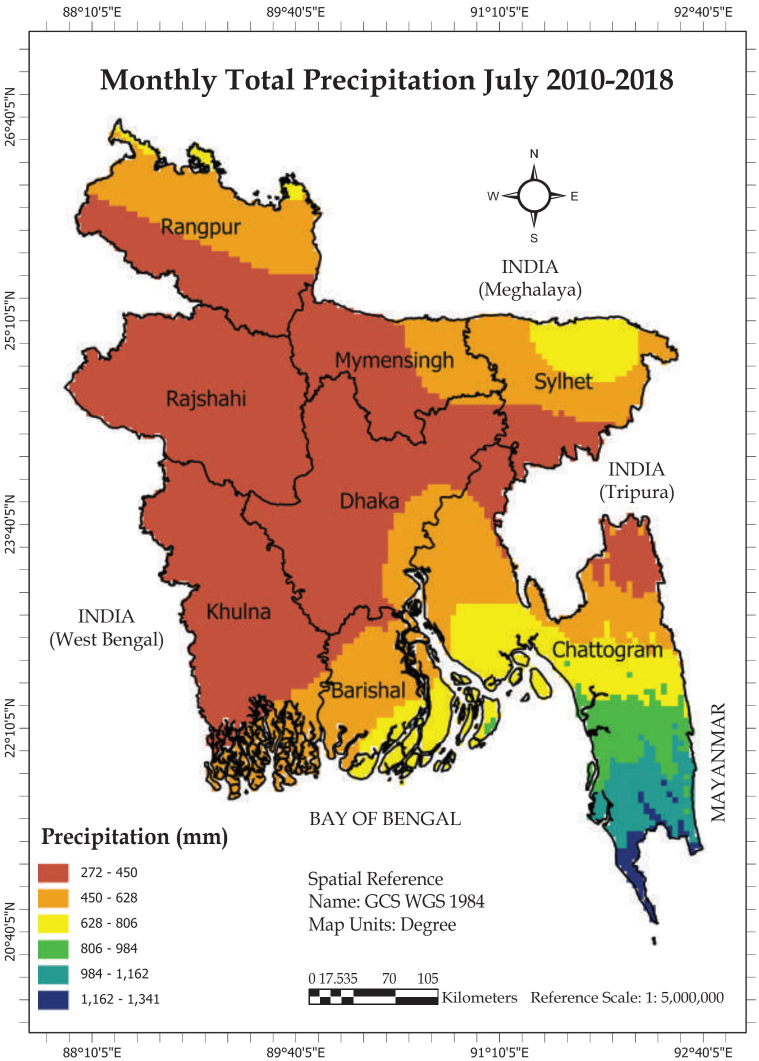


Figure 77. July month average of total precipitation from 2010-2018

The average precipitation 'July month during 2010-2018 in Bangladesh has been presented in Figure 77. The southeastern side of Bangladesh had high precipitation but most of the areas of Bangladesh were under low precipitation.

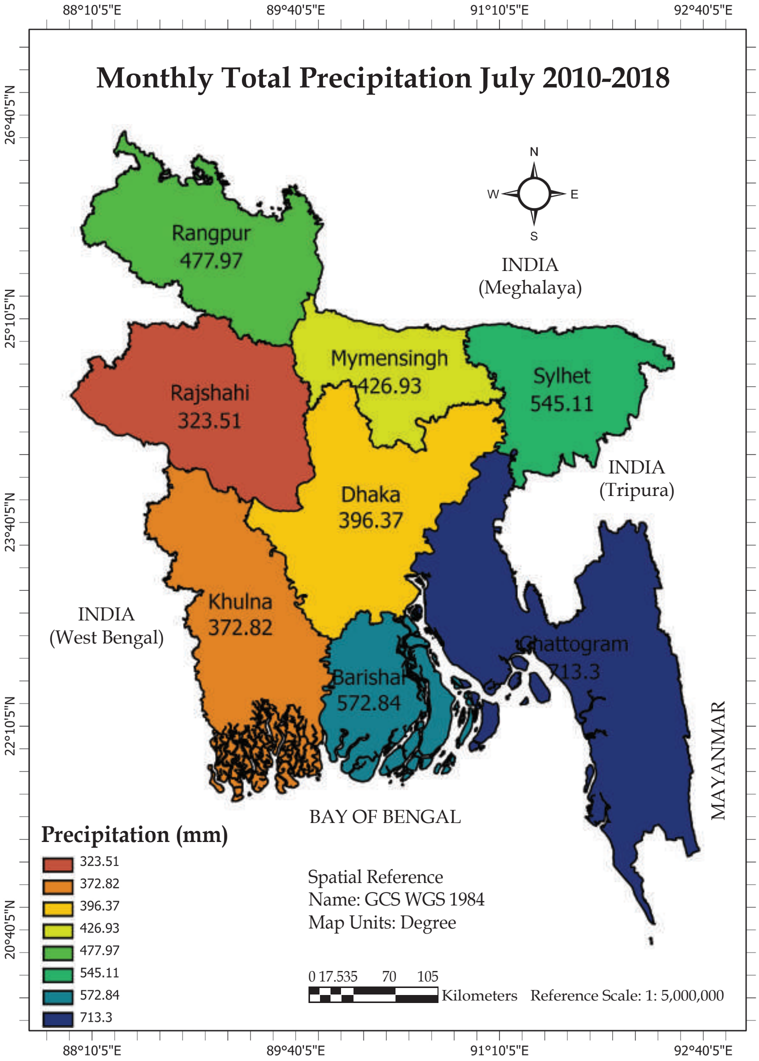


Figure 78. Division wise July month average of total precipitation from 2010-2018

Whereas a division-wise representation is in (Figure 78). The whole country analysis indicates that the highest precipitation was in the south-eastern part of the country. The division-wise analyses show that Chattogram is the highest precipitation division (713.3 mm) followed by Barishal (572.84 mm). This analysis is slightly differing with the 1970-2000 periods, where the second highest precipitation showed in Sylhet division.

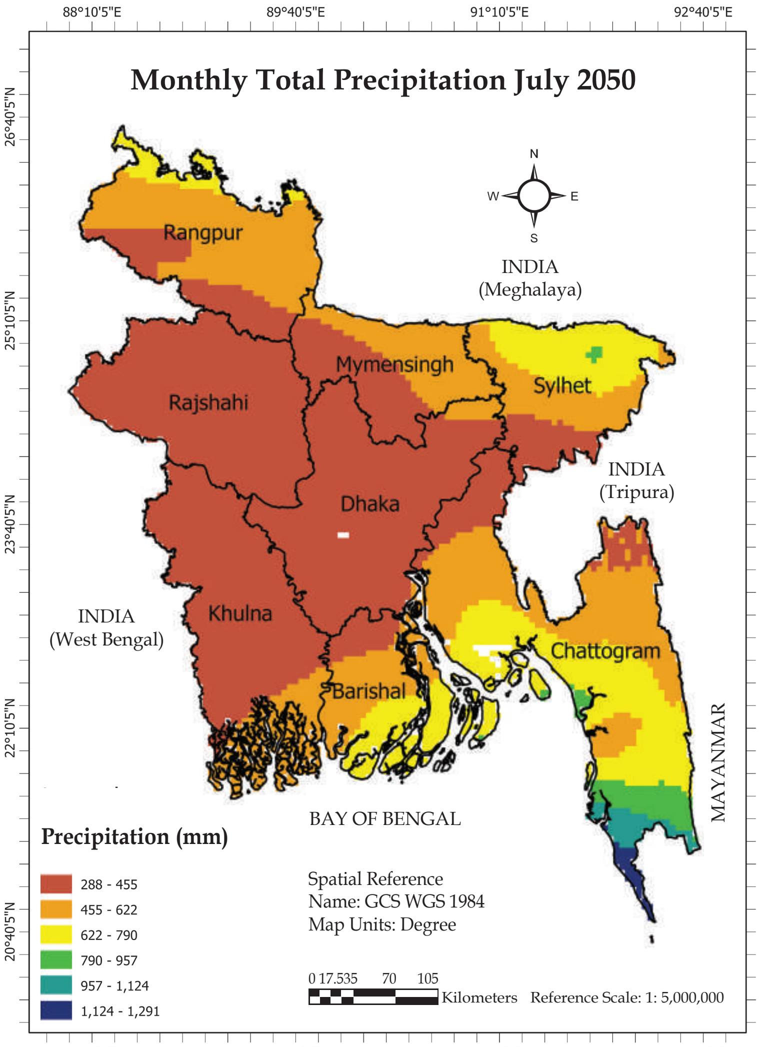


Figure 79. July month average of total precipitation for the year 2050 according to RCP 2.6

A forecasted scenario of average precipitation of July month using RCP 2.6 model has been presented in figure 41. The whole country analysis shows that the highest precipitated area will be the south-eastern side of Bangladesh. Besides, the majority of the area of Bangladesh will experience a 288 to 455mm precipitation in July month (Figure 79).

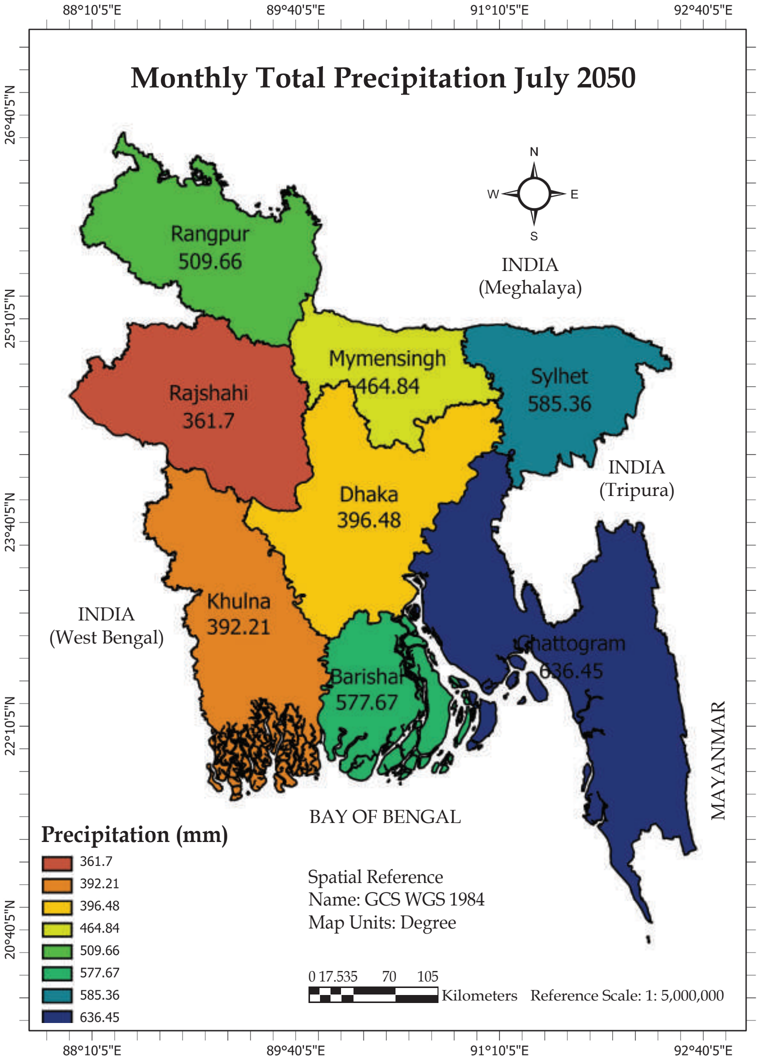


Figure 80. Division wise July month average of total precipitation for the year 2050 according to RCP 2.6

The division specific analyses deliver that Chattogram and Sylhet will be the highest precipitate division i.e., 636.45 and 585.36 mm respectively, where Rajshahi will be the lowest precipitated division with 361.7 mm in July month average (Figure 80).

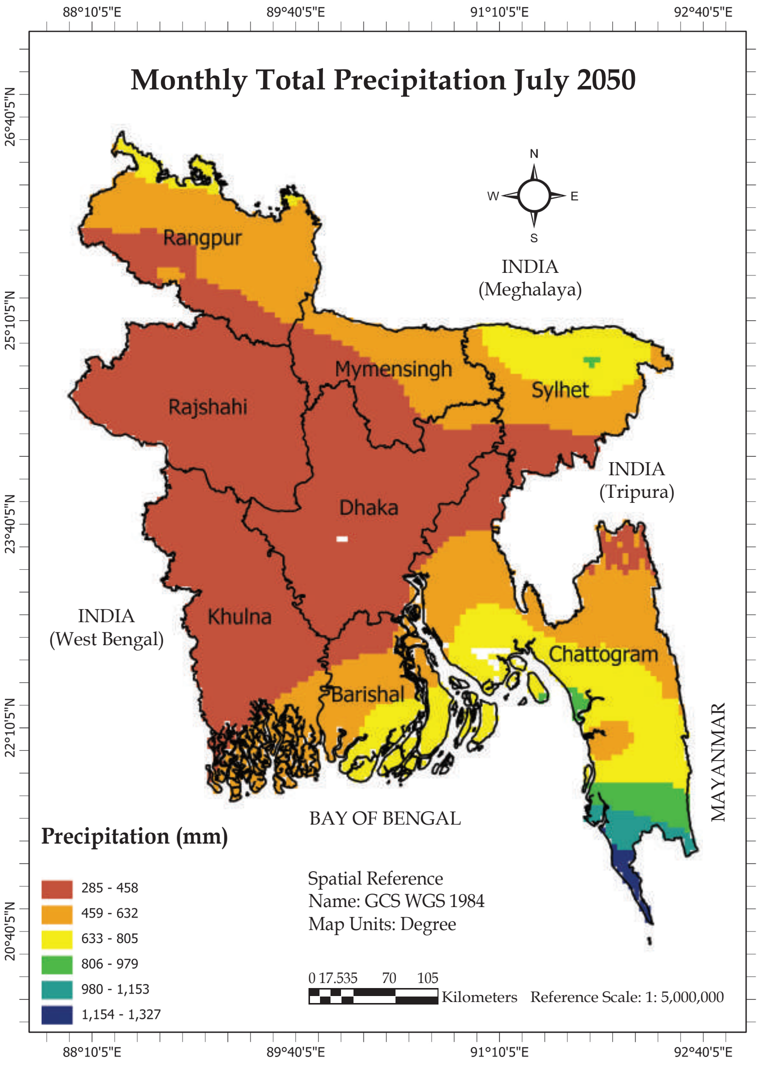


Figure 81. July month average of total precipitation for the year 2050 according to RCP 4.5

Figure 81 also shows the forecasted scenario of average precipitation in Bangladesh for July month, but it used RCP 4.5 model this time. The analyses ge3nerate almost similar results with RCP 2.6 model. Most of the area of Bangladesh will be under 285-458 mm precipitation in July month.

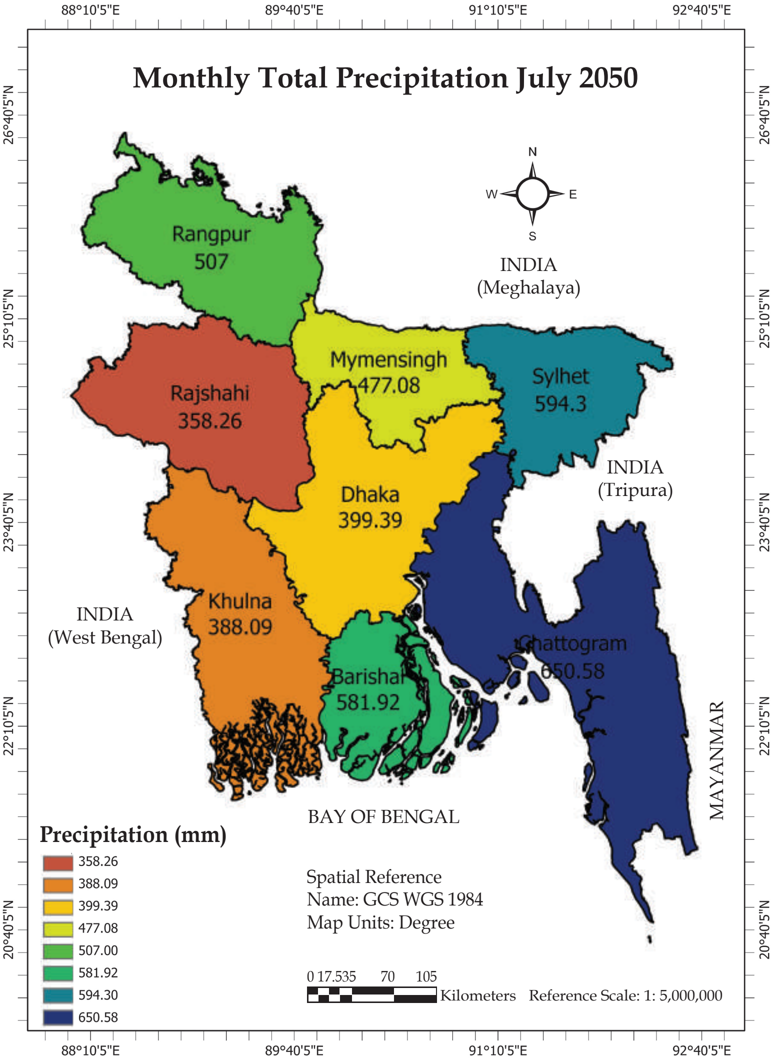


Figure 82. Division wise July month average of total precipitation for the year 2050 according to RCP 4.5

The highest precipitation division will be Chittagong (650.58 mm) followed by Sylhet division (594.3 mm) and lowest precipitation division will in Rajshahi division with an average of 358.26 mm in July month (Figure 82).

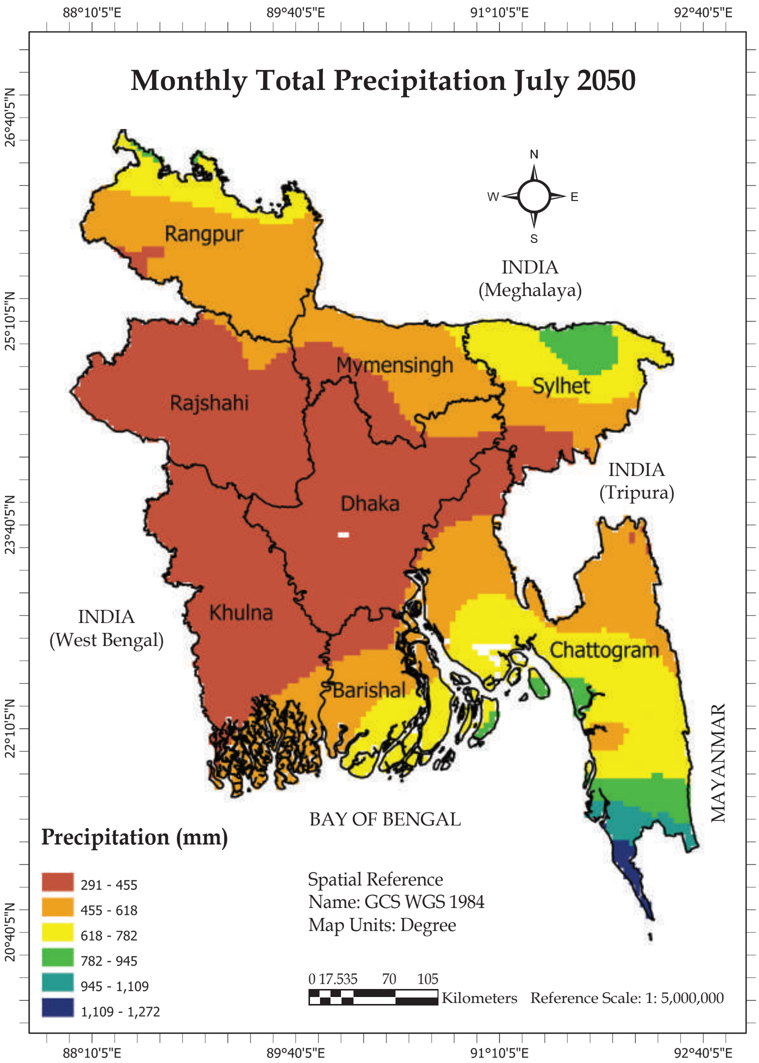


Figure 83. July month average of total precipitation for the year 2050 according to RCP 6.0

Describes the forecasted July month average precipitation of Bangladesh according to RCP model 6.0. The analysis shows almost same precipitation condition of Bangladesh as RCP 2.6 and 4.5 models, only difference is that the average precipitation will be little higher compare to the other two models analyses (Figure 83).

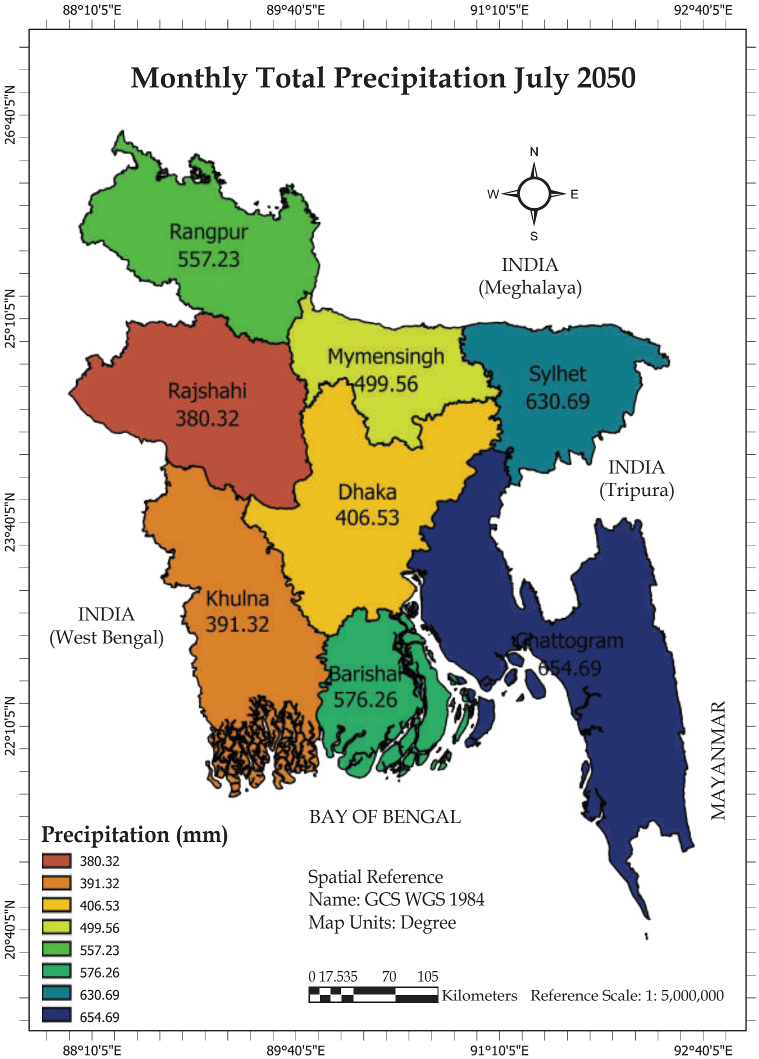


Figure 84. Division wise July month average of total precipitation for the year 2050 according to RCP 6.0

The division specific analyses generate the same results as before. The highest precipitation in the July month will be in Chattogram (654.69 mm) followed by Sylhet division (630.69 mm) and the lowest precipitation will be in Rajshahi division as 380.32 mm (Figure 84).

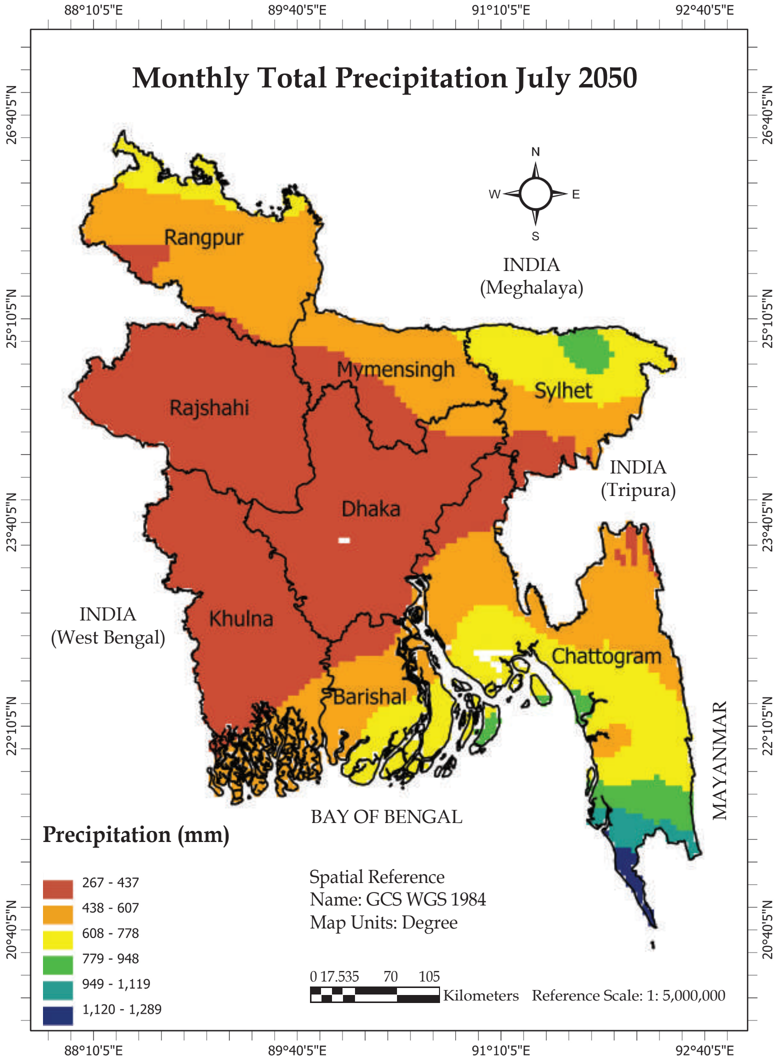


Figure 85. July month average of total precipitation for the year 2050 according to RCP 8.5

The forecasting with RCP 8.5 model also generates similar results with RCP 2.6, 4.5, and 6.0 models. (Figure 85) that explains the forecasted July month average precipitation of Bangladesh.

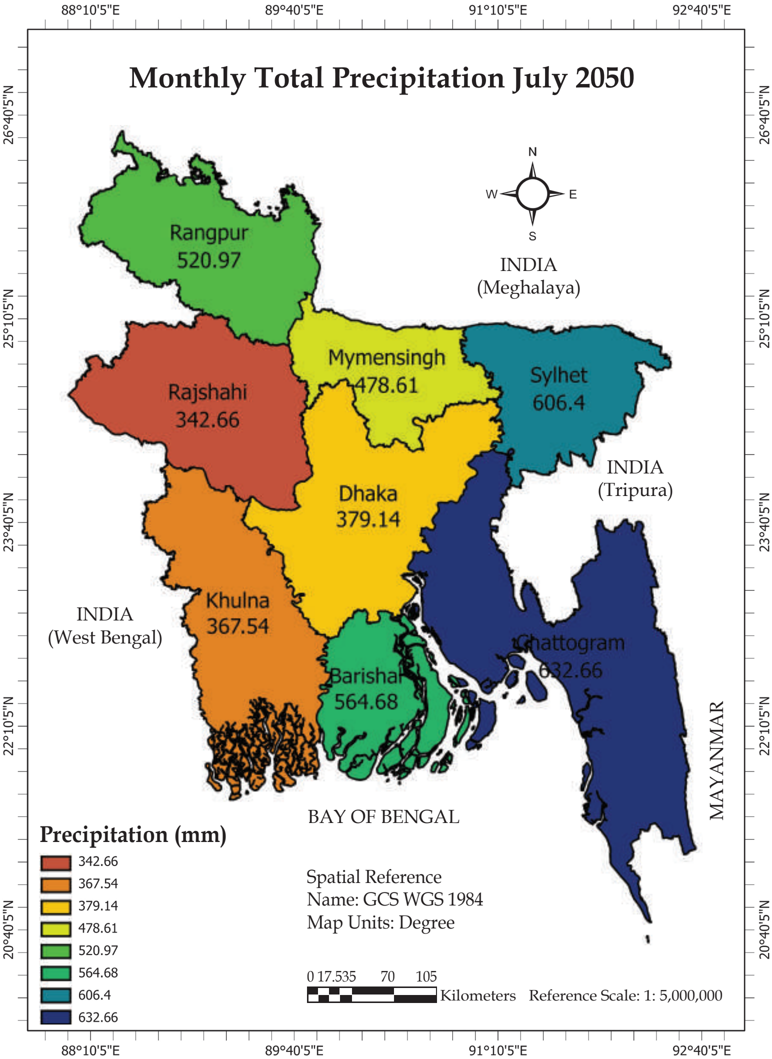


Figure 86. Division wise July month average of total precipitation for the year 2050 according to RCP 8.5

Figure 86 is showing the highest precipitation division will be again Chattogram (632.66 mm) followed by Sylhet division (606.4 mm) and the lowest precipitation division will be the same as all others RCP model i.e., Rajshahi division (342.66 mm).

Table 9: *Summary of July month average total precipitation of 1970 to 2000, 2010 to 2018 and forecasted 2050 (By RCP model 2.6, 4.5, 6.0 and 8.5)*

Division	Average Precipitation (mm) 1970 to 2000	Average Precipitation (mm) 2010 to 2018	Precipitation (mm) 2050 (RCP 2.6)	Precipitation (mm)2050 (RCP 4.5)	Precipitation (mm) 2050 (RCP 6.0)	Precipitation (mm) 2050 (RCP 8.5)	Average of Precipitation (mm) 2050 (RCP 2.6, 4.5, 6.0 and 8.5)	Change of Precipitation (mm) 2050 to 2010 2018 -
Barishal	450.43	572.84	577.67	581.92	576.26	564.68	575.13	2.29
Chattogram	665.51	713.30	636.45	650.58	654.69	632.66	643.60	-69.70
Dhaka	383.99	396.37	396.48	399.39	406.53	397.14	399.89	3.51
Khulna	372.73	372.82	392.21	388.09	391.32	367.54	384.79	11.97
Mymensingh	443.91	426.93	464.84	477.08	499.56	478.61	480.02	53.09
Rajshahi	332.3	323.51	361.70	385.26	380.32	342.66	367.49	43.98
Rangpur	505.15	477.97	509.66	507.00	557.23	520.97	523.72	45.75
Sylhet	551.11	545.11	585.36	594.30	630.69	606.40	604.19	59.08

From the Table 9, it is found that in all divisions of Bangladesh average total precipitation (average by RCP 2.6, 4.5, 6.0, and 8.5 models) of July month in 2050 will be increased in comparison to average total precipitation during 2010-2018, only exception is Chattogram division, where precipitation will be decreased by about 69 mm. The precipitation of July month will rise the highest in Sylhet and Mymensingh divisions with an amount of about 59 mm and 53 mm, respectively.

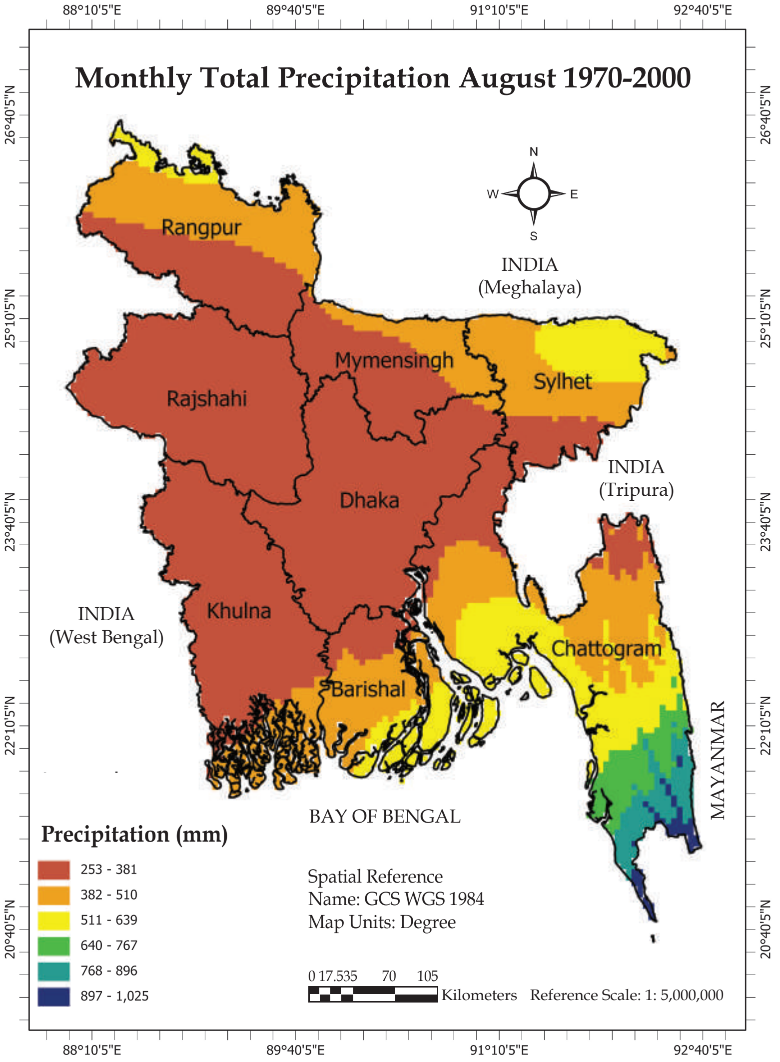


Figure 87. August month average of total precipitation from 1970-2000

Figure 87 shows the precipitation scenario of month 'August' in Bangladesh during 1970-2000. A country level analysis showed that the highest precipitation in August month was in the south-eastern part of Bangladesh.

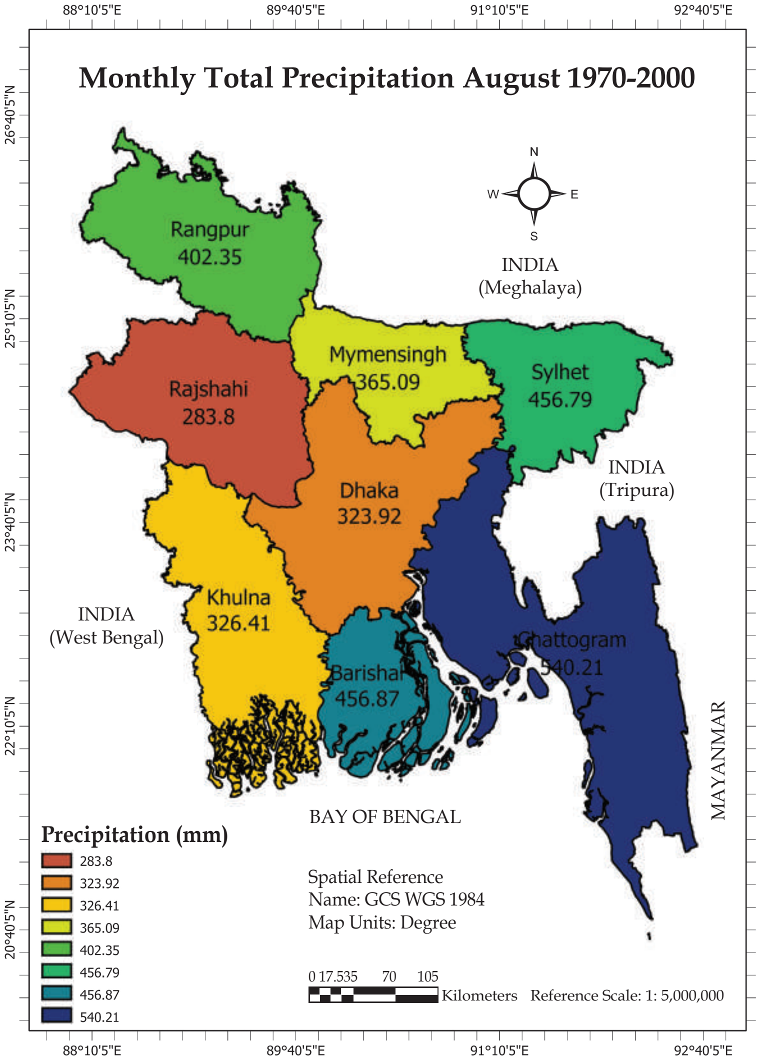


Figure 88. Division wise August month average of total precipitation from 1970-2000

North-east and south part of the country was under moderate precipitation and rest of the country was under lower precipitation. A division-wise analyses shows that in August month average total precipitation was highest in Chattogram division (540.21 mm) and lowest precipitated division was Rajshahi where average precipitation was 283.8 mm (Figure 88).

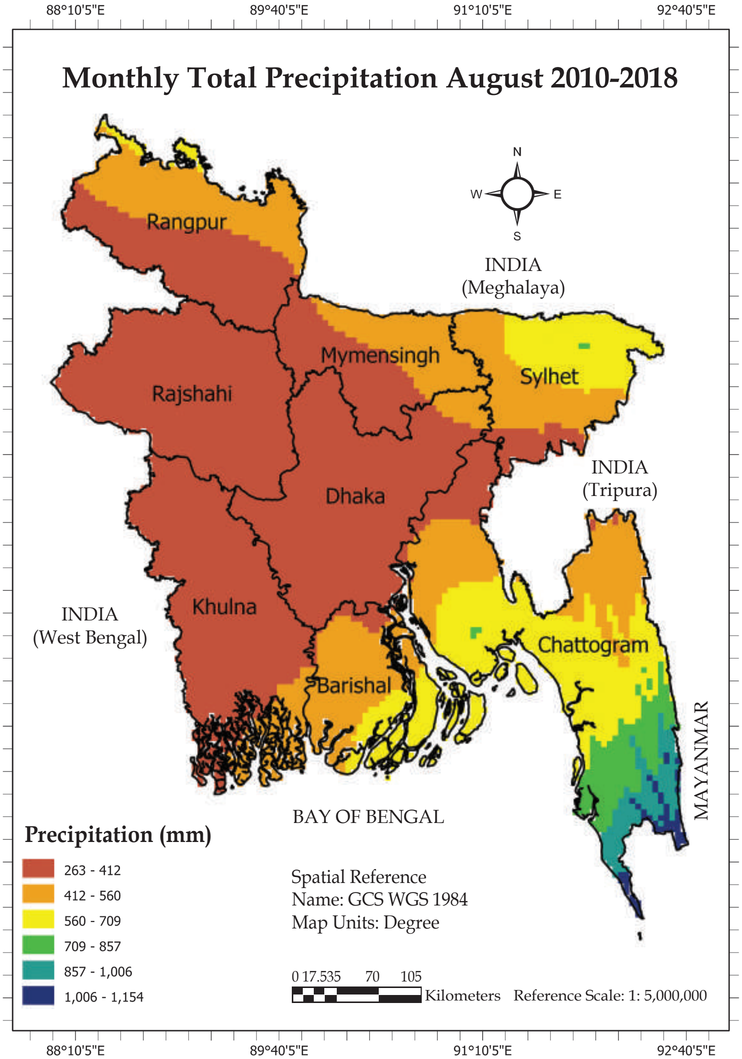


Figure 89. August month average of total precipitation from 2010-2018

Figure 89 is showing the average total precipitation for August month during 2010-2018 in Bangladesh, where the highest precipitate area was the lower southeast part of Bangladesh. North-east and south part of Bangladesh was under the moderate precipitation and rest of the country was under lower precipitation.

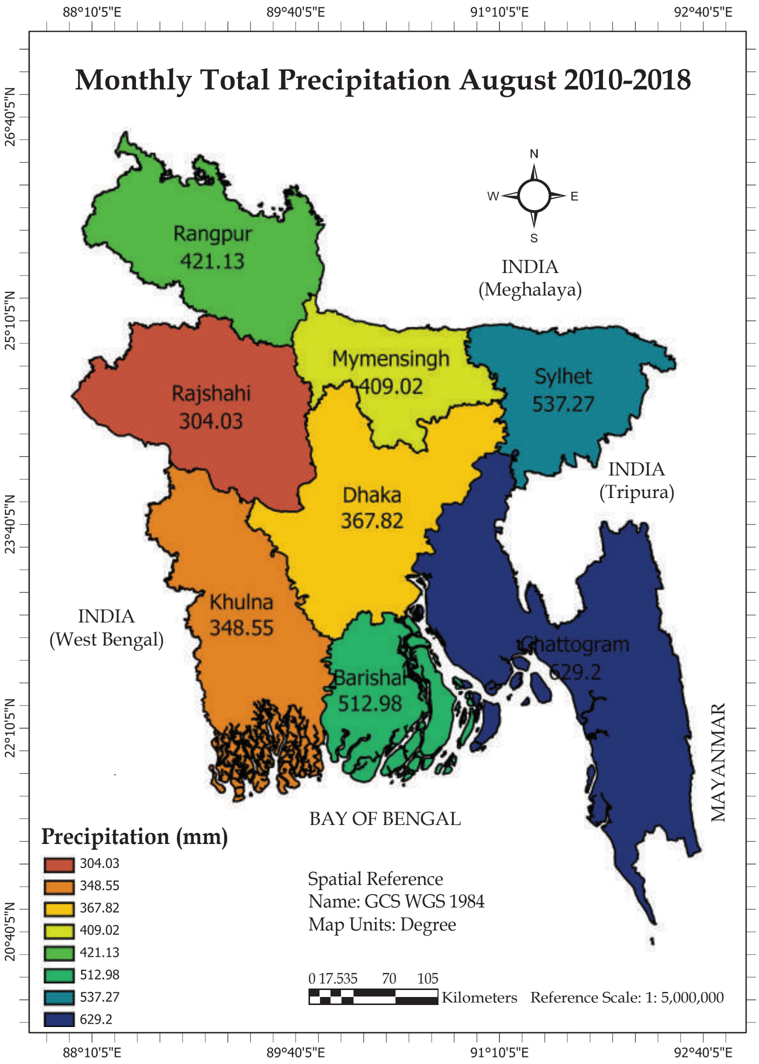


Figure 90. Division wise August month average of total precipitation from 2010-2018

Figure 90 is describing division wise average total precipitation of August month during 2010-2018 where the Chattogram division was the highest precipitation (629.2 mm) and Rajshahi was the lowest (304.03 mm) precipitated division.

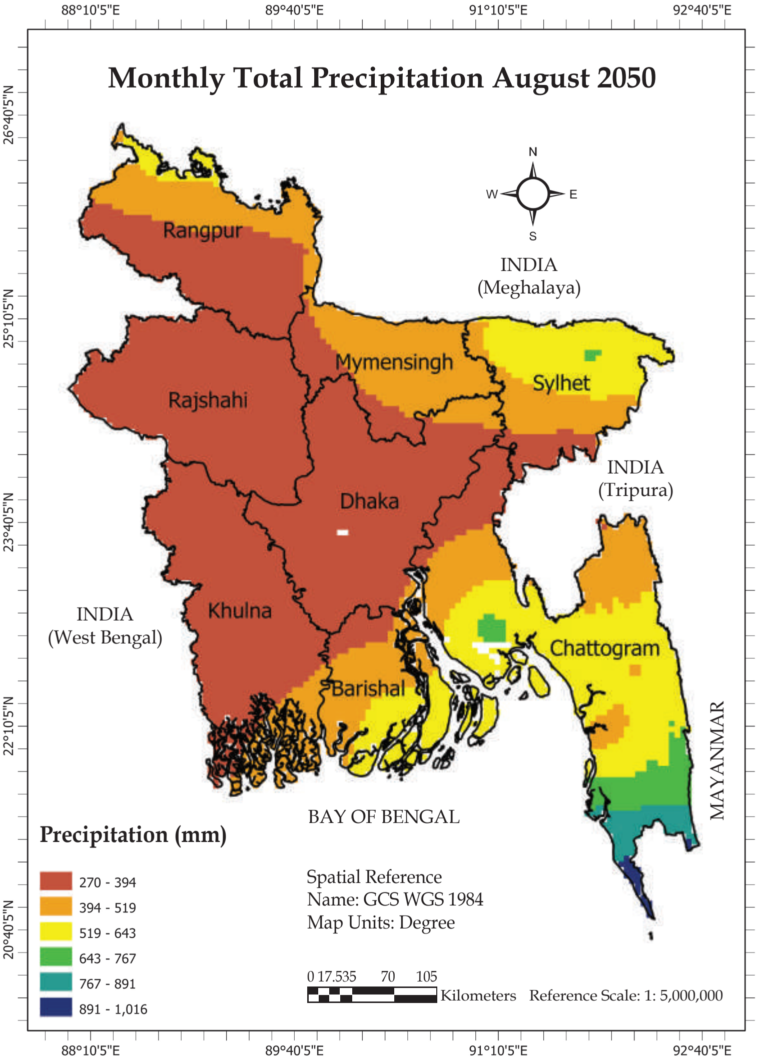


Figure 91. August month average of total precipitation for the year 2050 according to RCP 2.6

The forecasted August month average precipitation of Bangladesh according to RCP 2.6 model has been presented. The highest precipitated area will be the lower south-eastern part of Bangladesh, north-east and upper south-eastern side of Bangladesh will experience moderate to lower precipitation and rest of the area of country will enjoy lower precipitation (Figure 91).

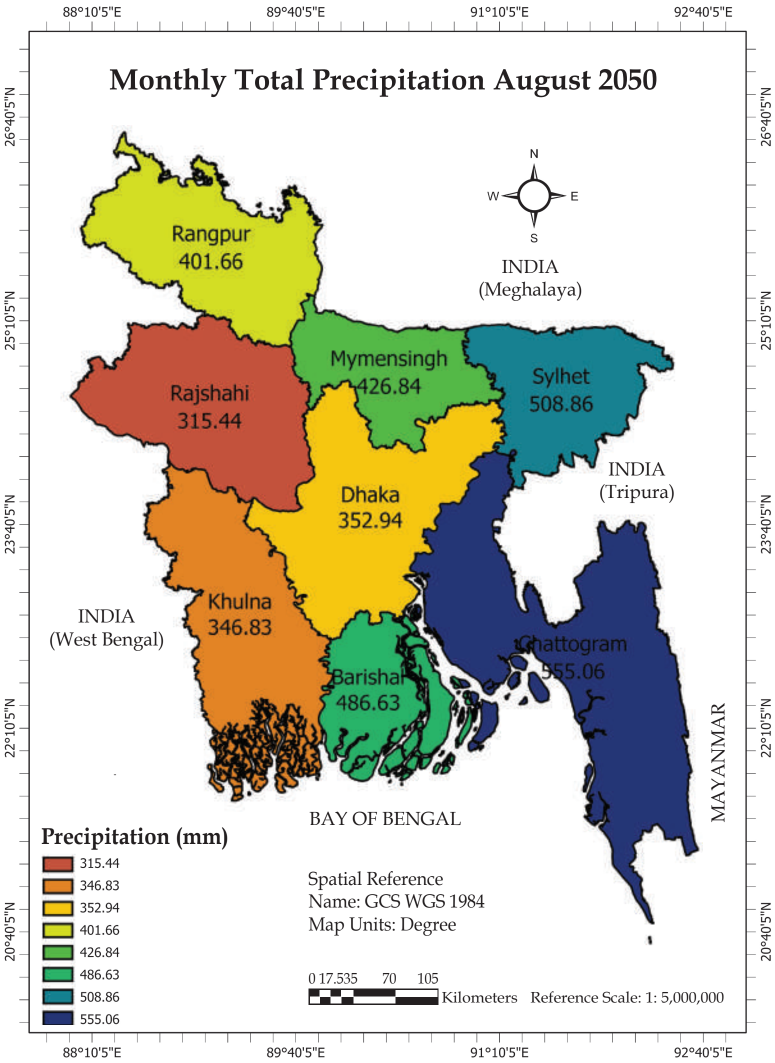


Figure 92. Division wise August month average of total precipitation for the year 2050 according to RCP 2.6

The division wise analyses shows that average precipitation in August month will be the highest in Chattogram division (555.06 mm) and Rajshahi will be the lowest precipitated division with an average of 315.44 mm (Figure 92).

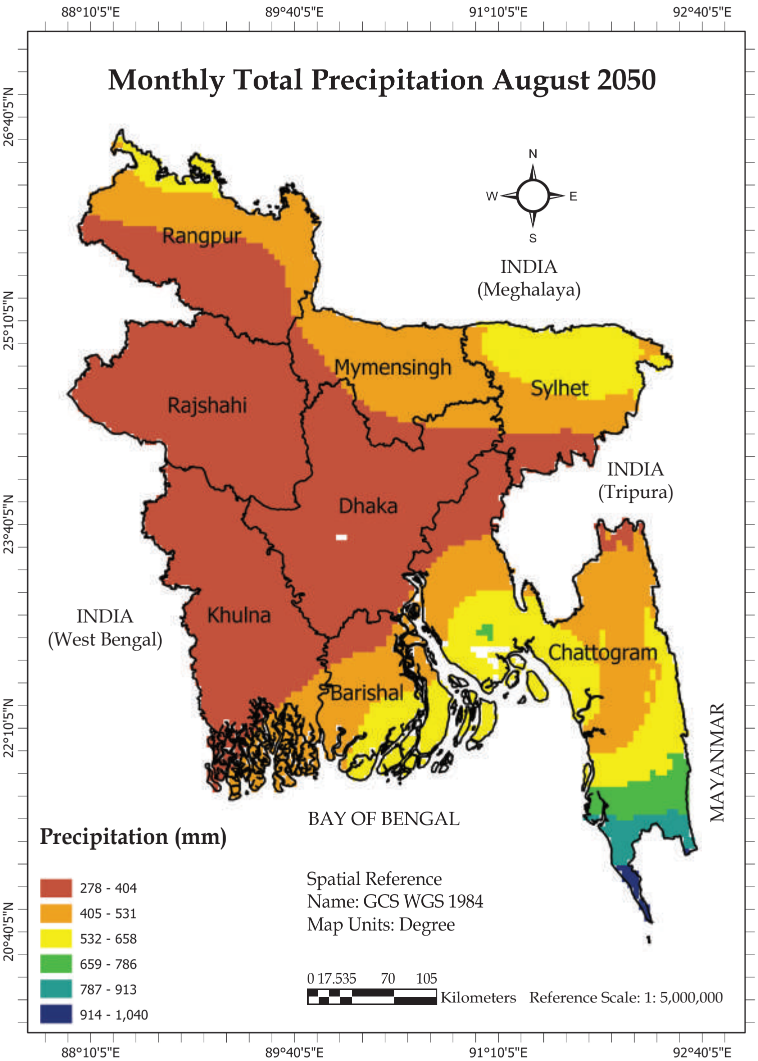


Figure 93. August month average of total precipitation for the year 2050 according to RCP 4.5

The forecasted precipitation of August month according to RCP 4.5 model in Bangladesh has been presented in Figure 48. The forecasted precipitation of Bangladesh is showing more or less the same as the RCP 2.6 model (Figure 93).

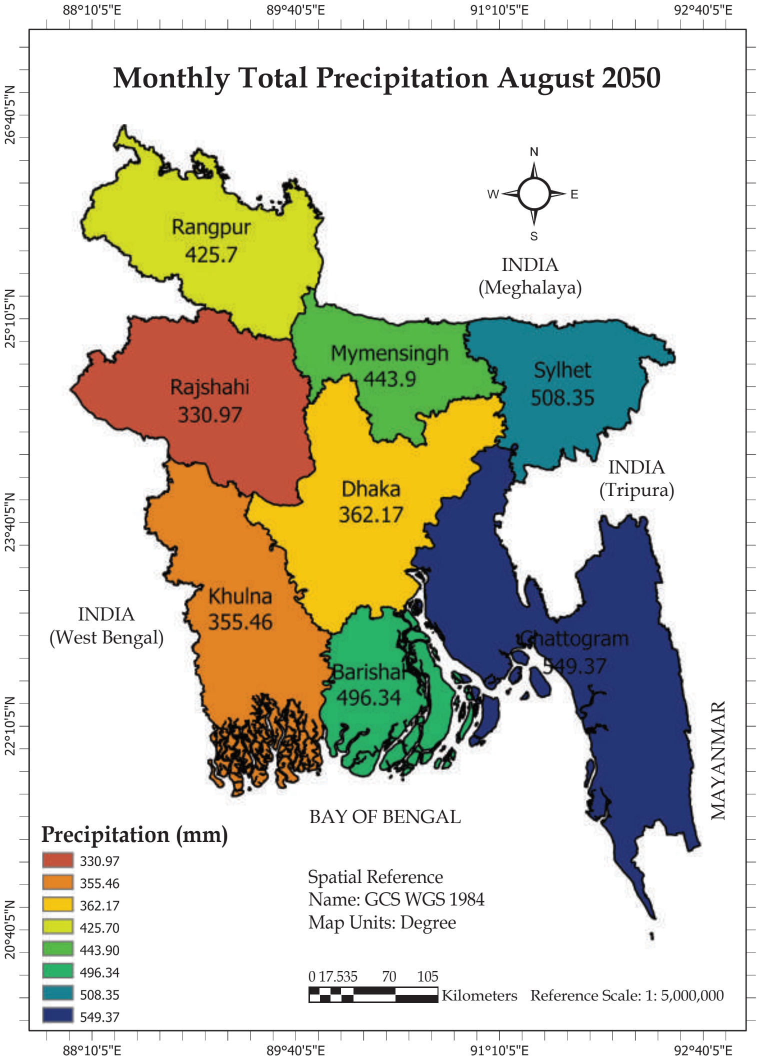


Figure 94. Division wise August month average of total precipitation for the year 2050 according to RCP 4.5

Figure 94 shows that the highest precipitation will be experienced in Chattogram division (549.37 mm) and the lowest precipitation division will be Rajshahi (330.97 mm).

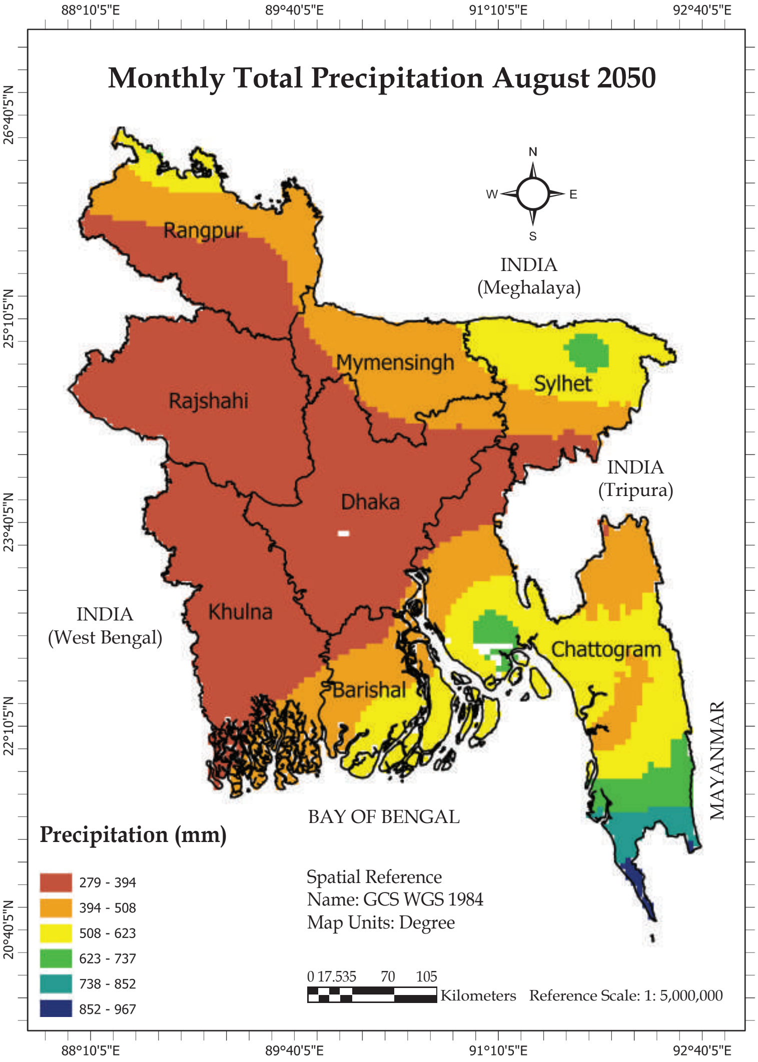


Figure 95. August month average of total precipitation for the year 2050 according to RCP 6.0

Figure 95 shows the forecasted August month average precipitation of Bangladesh according to RCP 6.0 model where the precipitation condition of Bangladesh is showing to be almost the same as the RCP 2.6 and 4.5 models.

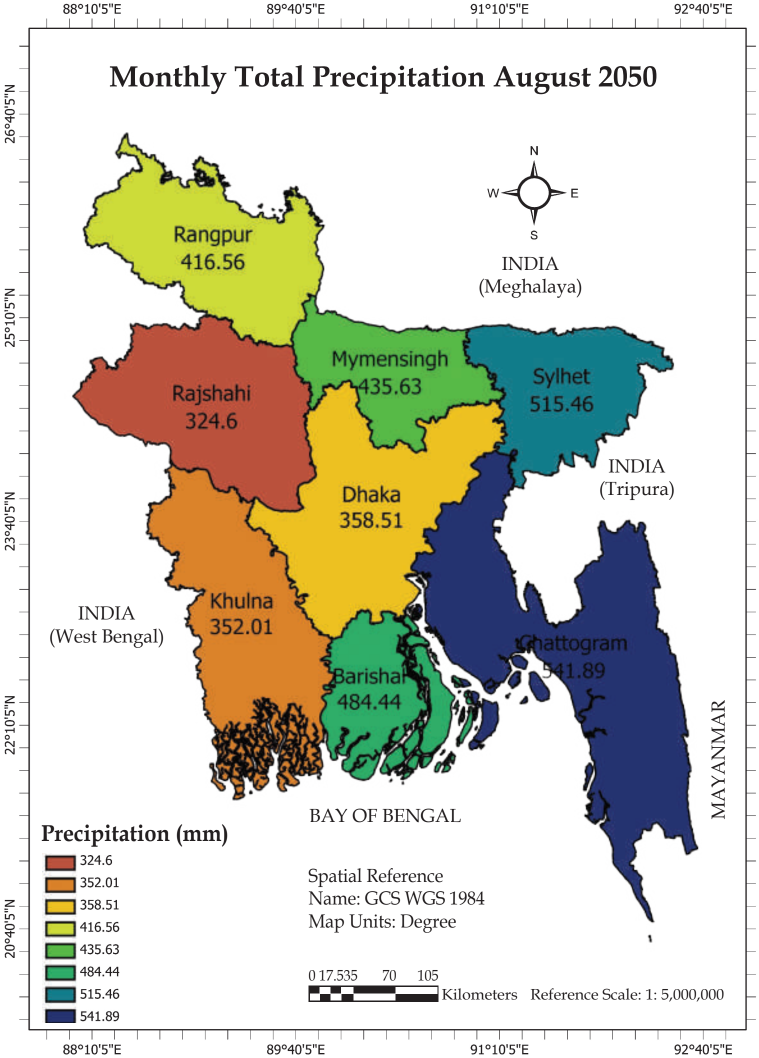


Figure 96. Division wise August month average of total precipitation for the year 2050 according to RCP 6.0

Figure 96 representing that the highest precipitation division will be Chattogram (541.89 mm) and the lowest precipitation division will be Rajshahi (324.6 mm).

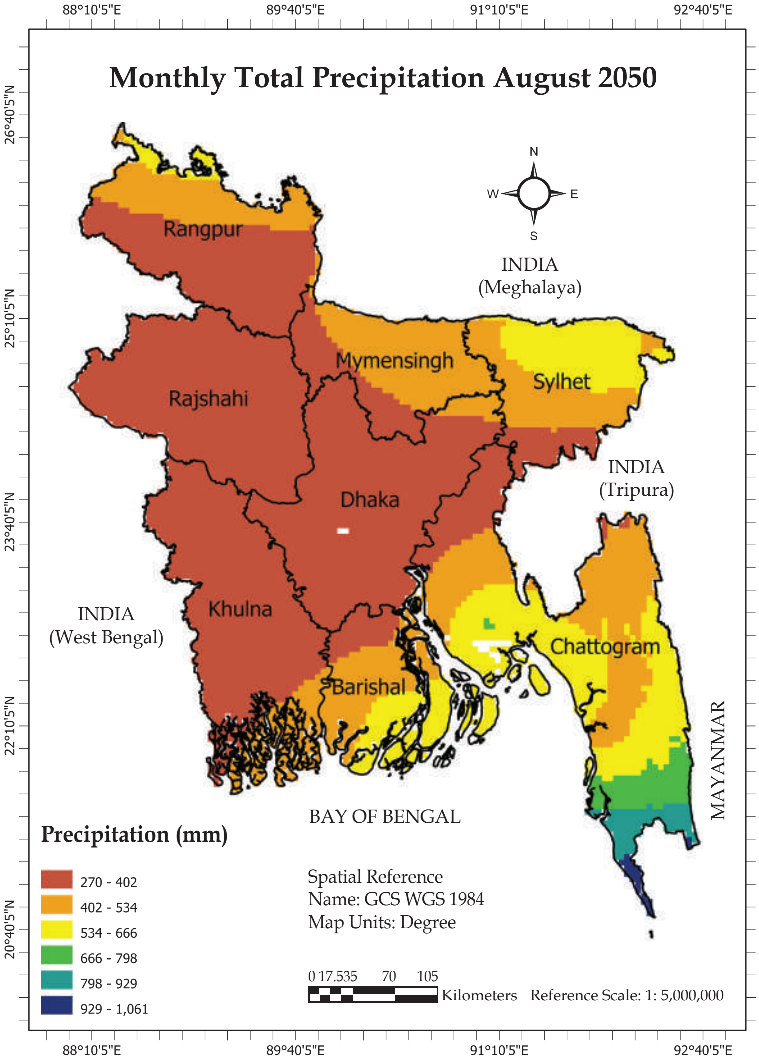


Figure 97. August month average of total precipitation for the year 2050 according to RCP 8.5

Forecast of 2050 by RCP 8.5 model for August month is presented in Figure 97, where most of the area covered by low precipitation area.

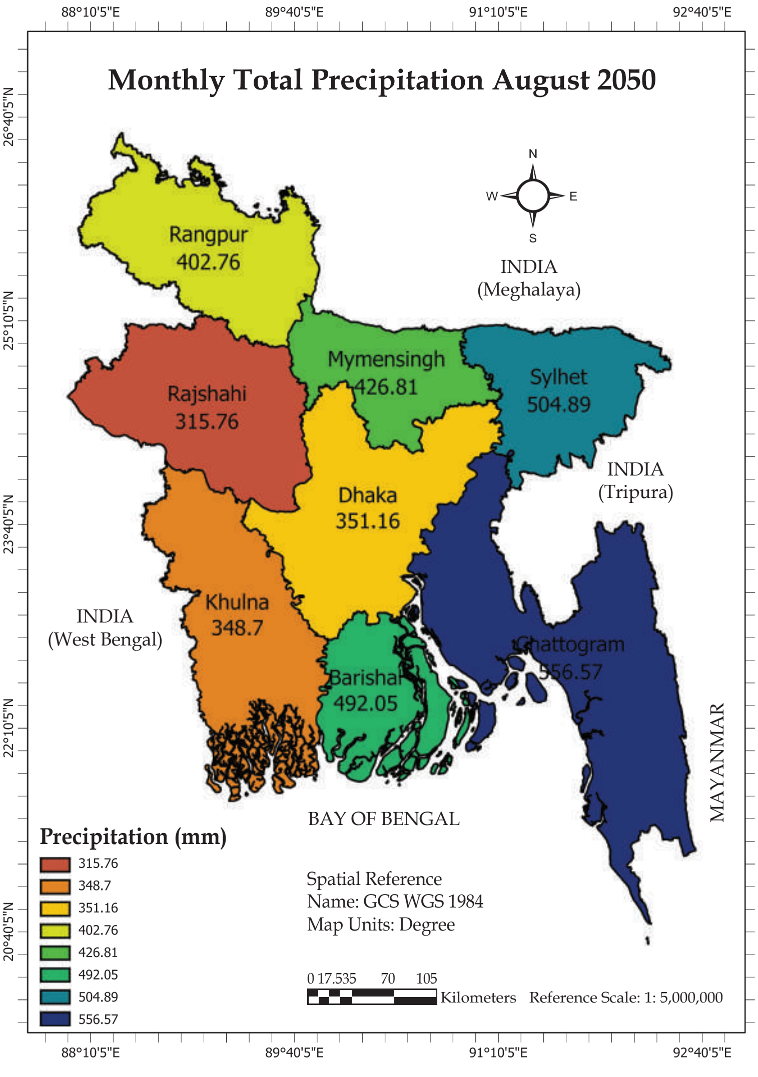


Figure 98. Division wise August month average of total precipitation for the year 2050 according to RCP 8.5

The forecasted precipitation results are not differing much with the RCP 2.6, 4.5, and 6.0 models. The highest precipitation division will be again Chattogram (566.57 mm) and the lowest precipitation division will be Rajshahi as 315.76 mm (Figure 98).

Table 10 : Summary of August month average total precipitation of 1970 to 2000, 2010 to 2018 and forecasted 2050 (By RCP model 2.6, 4.5, 6.0 and 8.5)

Division	Average Precipitation (mm) 1970 to 2000	Average Precipitation (mm) 2010 to 2018	Precipitation (mm) 2050 (RCP 2.6)	Precipitation (mm) 2050 (RCP 4.5)	Precipitation (mm) 2050 (RCP 6.0)	Precipitation (mm) 2050 (RCP 8.5)	Average of Precipitation (mm) 2050 (RCP 2.6, 4.5, 6.0 and 8.5)	Change of Precipitation (mm) 2050 to 2010-2018
Barishal	456.87	512.98	486.63	496.34	484.44	492.05	489.86	-23.12
Chattogram	540.21	629.20	555.06	549.37	541.89	556.57	550.72	-78.48
Dhaka	323.92	367.82	352.94	362.17	358.51	351.16	356.19	-11.63
Khulna	326.41	348.55	346.83	355.46	352.01	348.70	350.75	2.20
Mymensingh	365.09	409.02	426.84	443.90	435.63	426.81	433.30	24.28
Rajshahi	283.80	304.03	315.44	330.97	324.60	315.76	321.69	17.66
Rangpur	402.35	421.13	401.66	425.70	416.56	402.76	411.67	-9.46
Sylhet	456.79	537.27	508.86	508.35	515.46	504.89	509.39	-27.88

From the Table 10, it is found that in all divisions of Bangladesh average total precipitation (average by RCP 2.6, 4.5, 6.0, and 8.5 models) of August month in 2050 will be decreased in comparison to average total precipitation of 2010-2018 period, only exceptions are Khulna, Rajshahi, Mymensingh divisions.

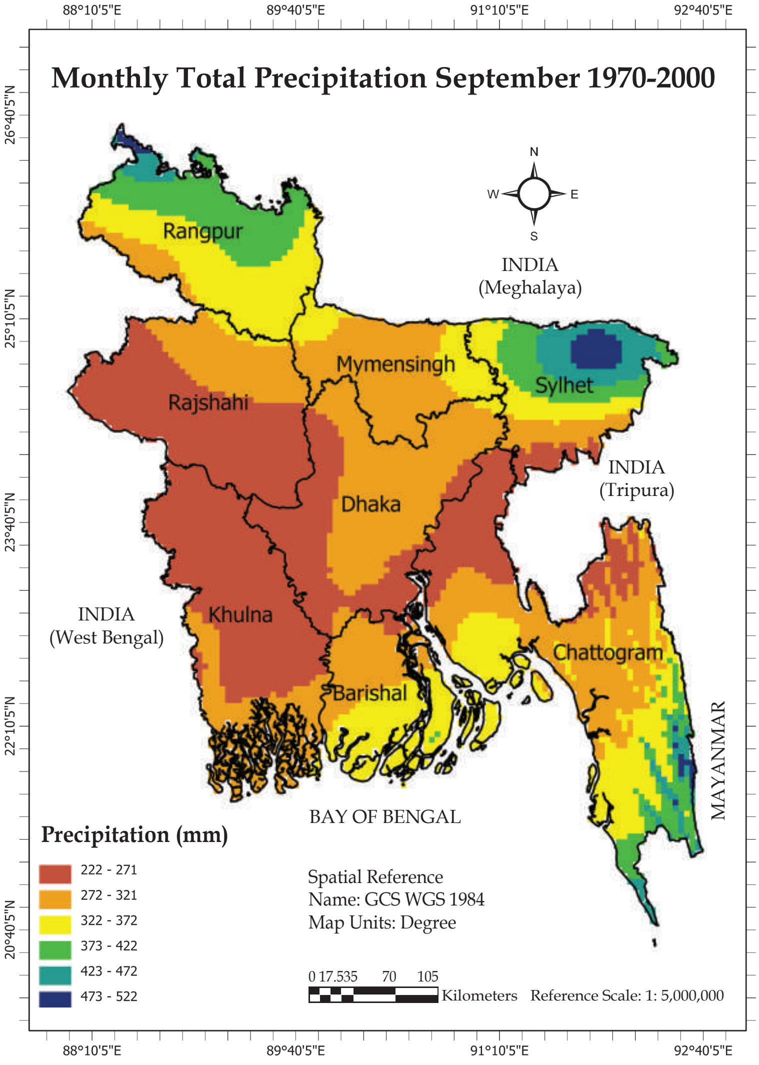


Figure 99. September month average of total precipitation from 1970-2000

Figure 99 represents the average total precipitation for September month during 1970-2000 in Bangladesh. The highest precipitation areas ware north-east, some part of north-west and lower south-eastern side of Bangladesh. The central part of Bangladesh was under moderate to lower precipitation and the lower precipitate area was the central western and eastern sides of the country.

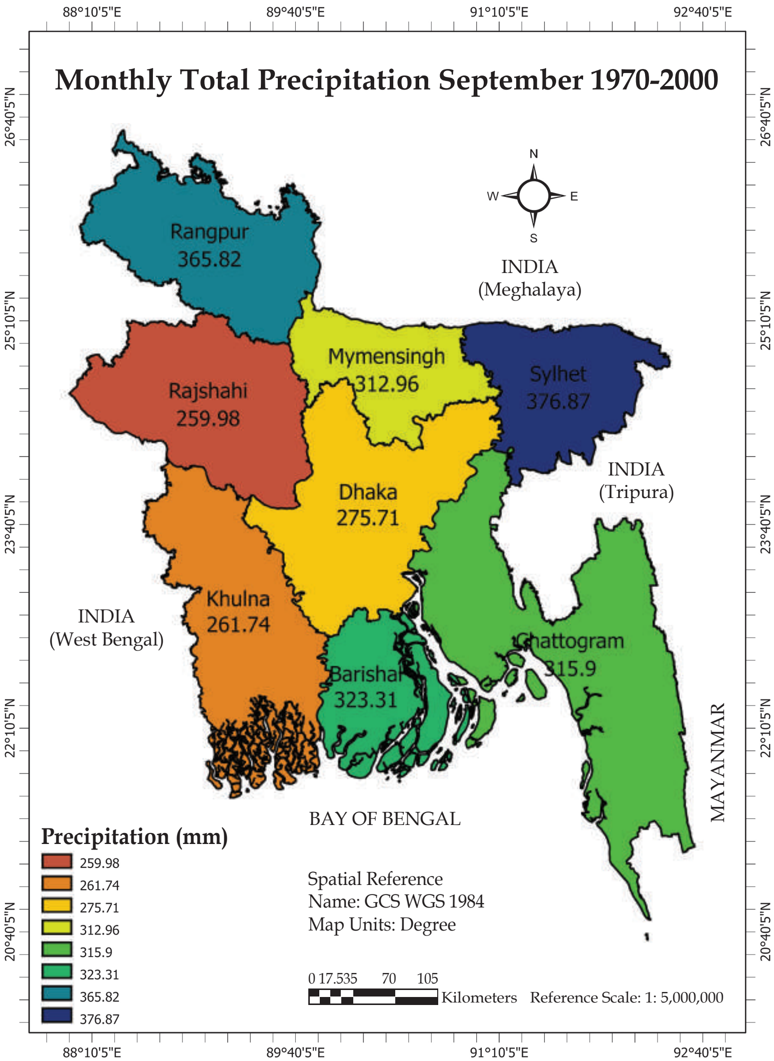


Figure 100. Division wise September month average of total precipitation from 1970-2000

The division-wise analyses shows that the average total precipitation during 1970-2000 in Sylhet division was the highest (376.87 mm) and the lowest precipitated division was Rajshahi where average precipitation was 259.68 mm followed by Khulna 261.74 mm (Figure 100).

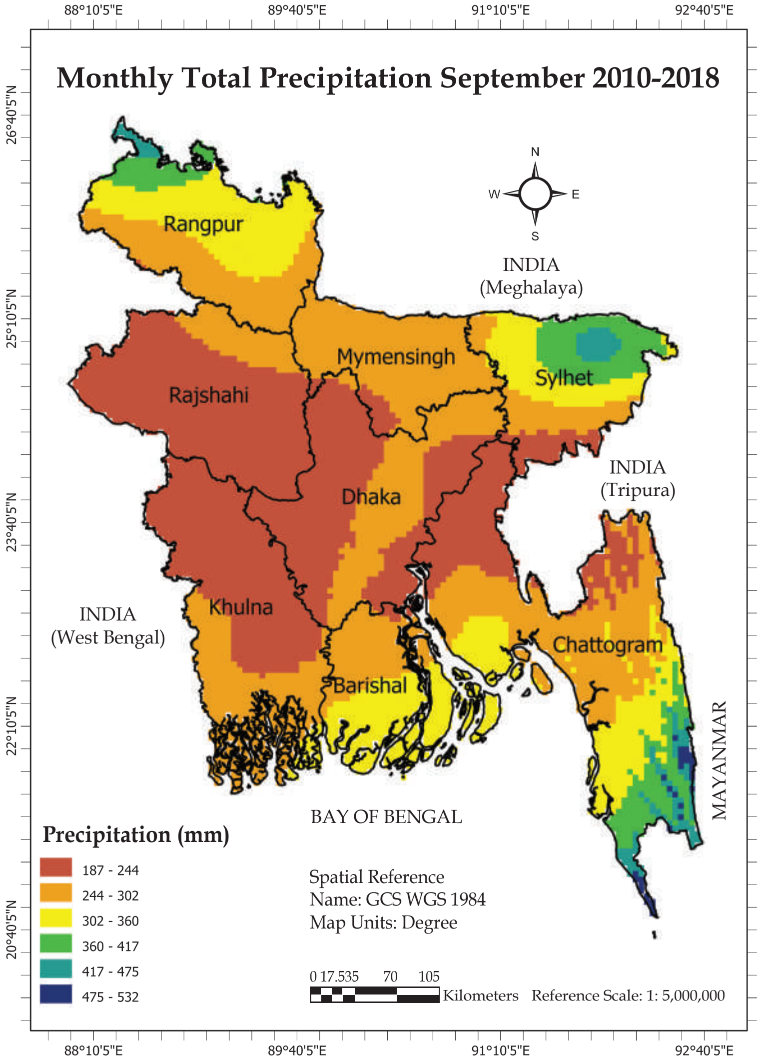


Figure 101. September month average of total precipitation from 2010-2018

The average precipitation for September month during 2010-2018 in Bangladesh has been presented in Figure 52. The high precipitation areas ware north-east, some part of the north-west and lower part south-eastern side of Bangladesh (Figure 101). The north and south-central part of the country were under moderate to lower precipitation and the lowest precipitate area was the central western and eastern sides of the country.

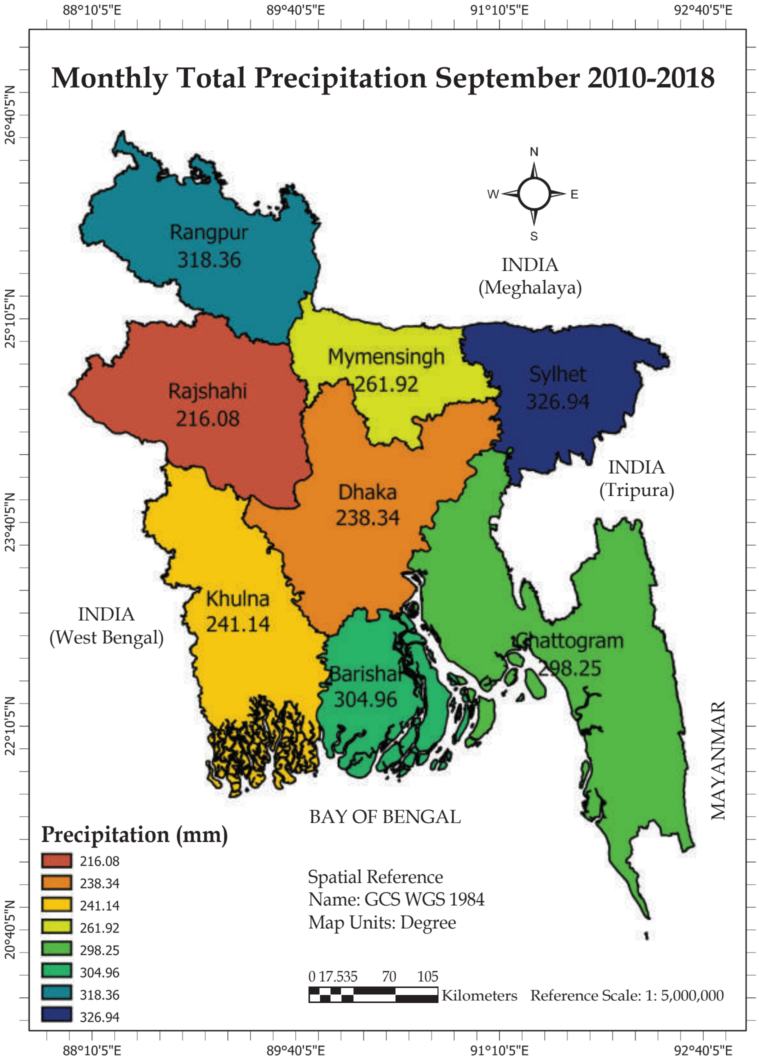


Figure 102. Division wise September month average of total precipitation from 2010-2018

Figure 102 is showing division-wise September month average total precipitation during 2010-2018, where Sylhet division experienced highest precipitation (326.94 mm) and the lowest was Rajshahi division (216.08 mm).

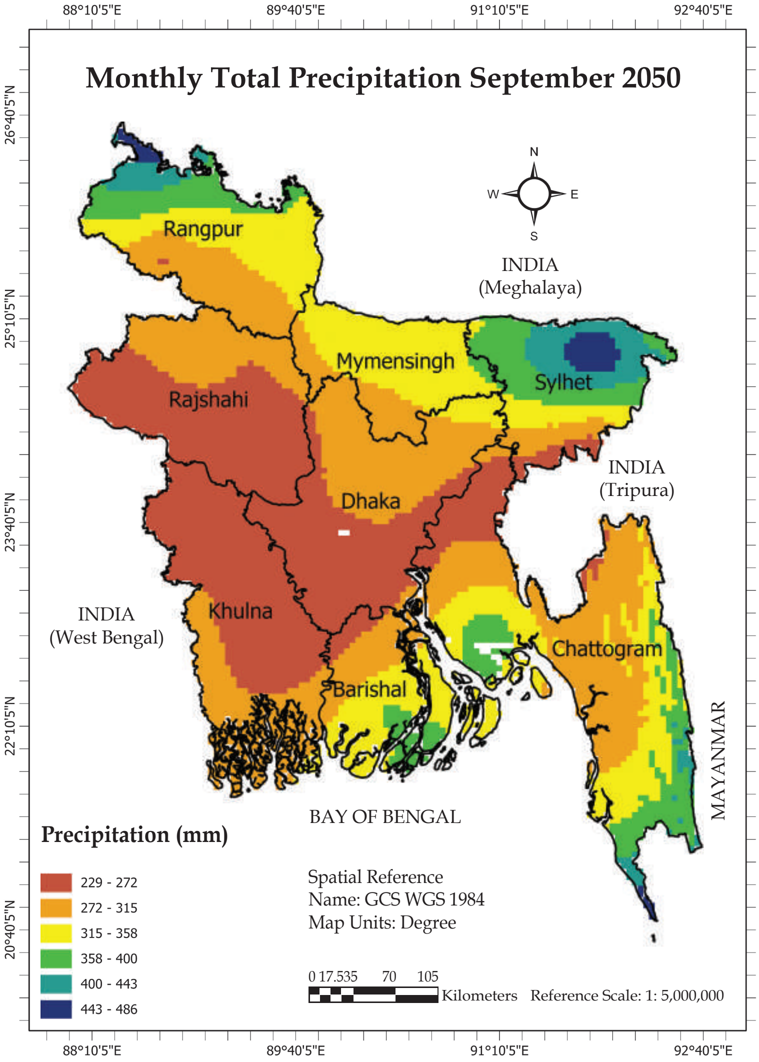


Figure 103. September month average of total precipitation for the year 2050 according to RCP 2.6

Result shows that the highest precipitated areas will be north-east, some parts of the north-west, and lower south-eastern side of Bangladesh. The central north and south part of the country will experience moderate to lower precipitation, and the lowest precipitation will be observed in the western and eastern sides of the central (Figure 103).

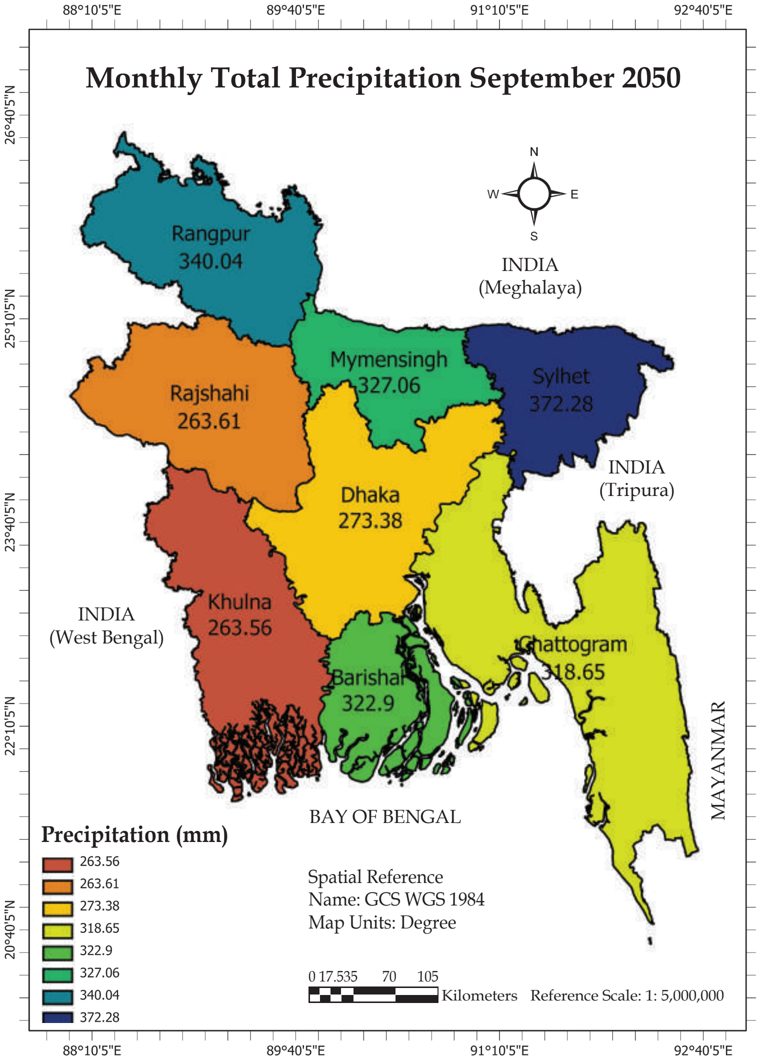


Figure 104. Division wise September month average of total precipitation for the year 2050 according to RCP 2.6

The division wise forecasting of September month average precipitation (Figure 104) shows that Sylhet will be the highest precipitation division (372.28 mm) and Khulna will be the lowest precipitated division (263.56 mm) followed by Rajshahi division (263.61 mm).

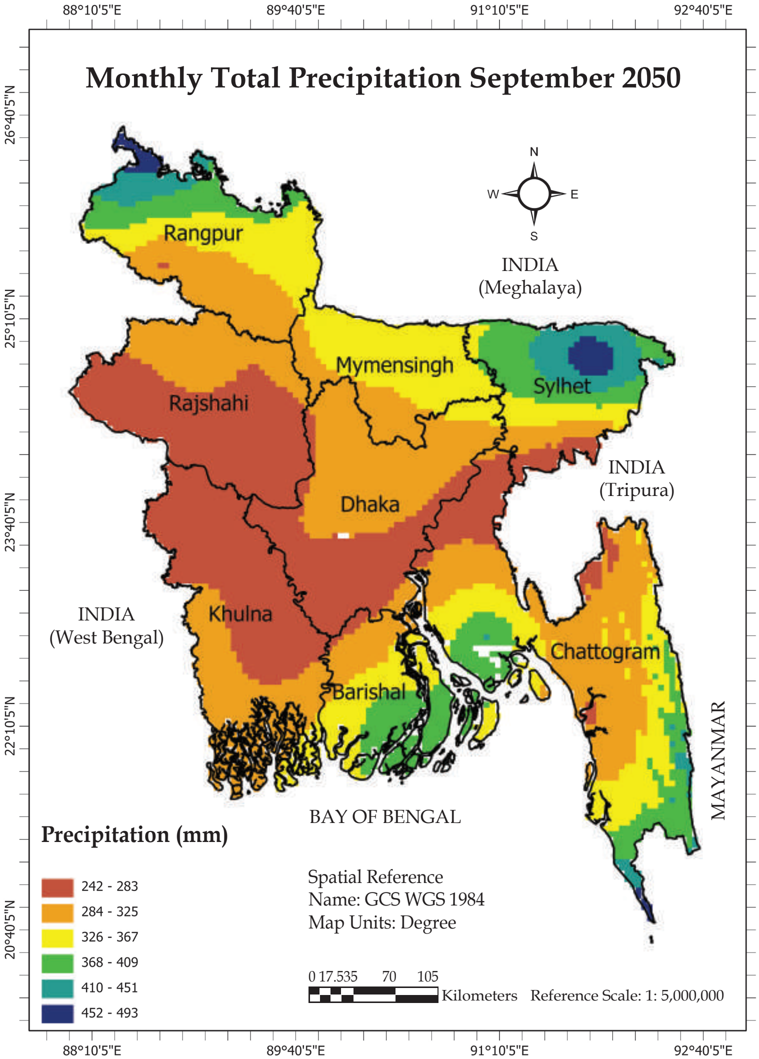


Figure 105. September month average of total precipitation for the year 2050 according to RCP 4.5

Figure 105 represents the forecasted September month average precipitation of Bangladesh by RCP 4.5 model, where the precipitation condition of Bangladesh is showing more or less the same as the RCP 2.6 model.

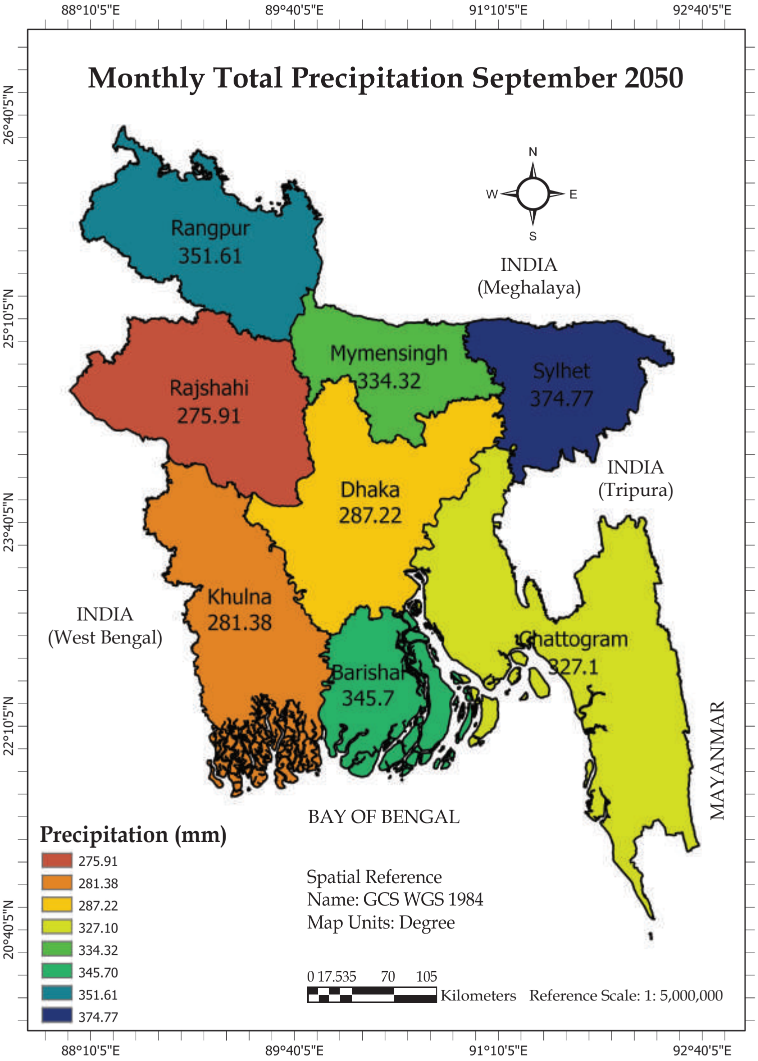


Figure 106. Division wise September month average of total precipitation for the year 2050 according to RCP 4.5

A division wise forecasted precipitation (Figure 106) shows that the highest precipitation division will be Sylhet (374.77 mm) and the lowest precipitation division will be Rajshahi (275.91 mm) followed by Khulna division (281.38 mm).

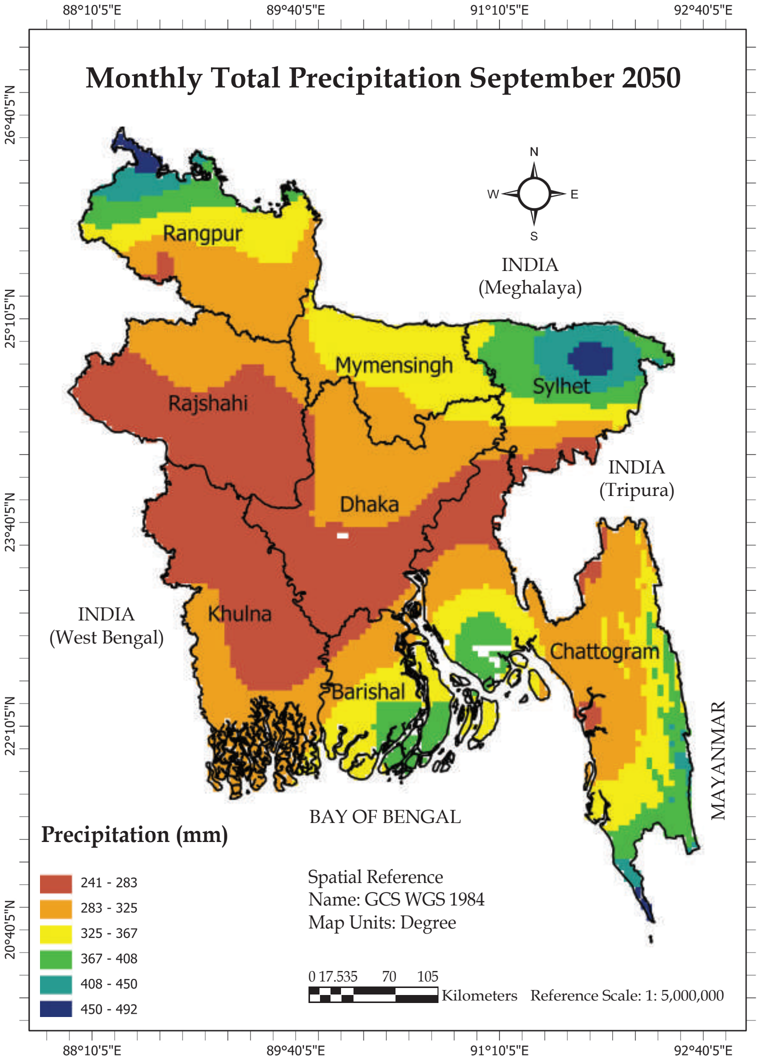


Figure 107. September month average of total precipitation for the year 2050 according to RCP 6.0

Figure 107 describing the forecasted September month average precipitation of Bangladesh according to RCP model 6.0 where the precipitation condition of Bangladesh is showing almost the same as the RCP model 2.6 and 4.5

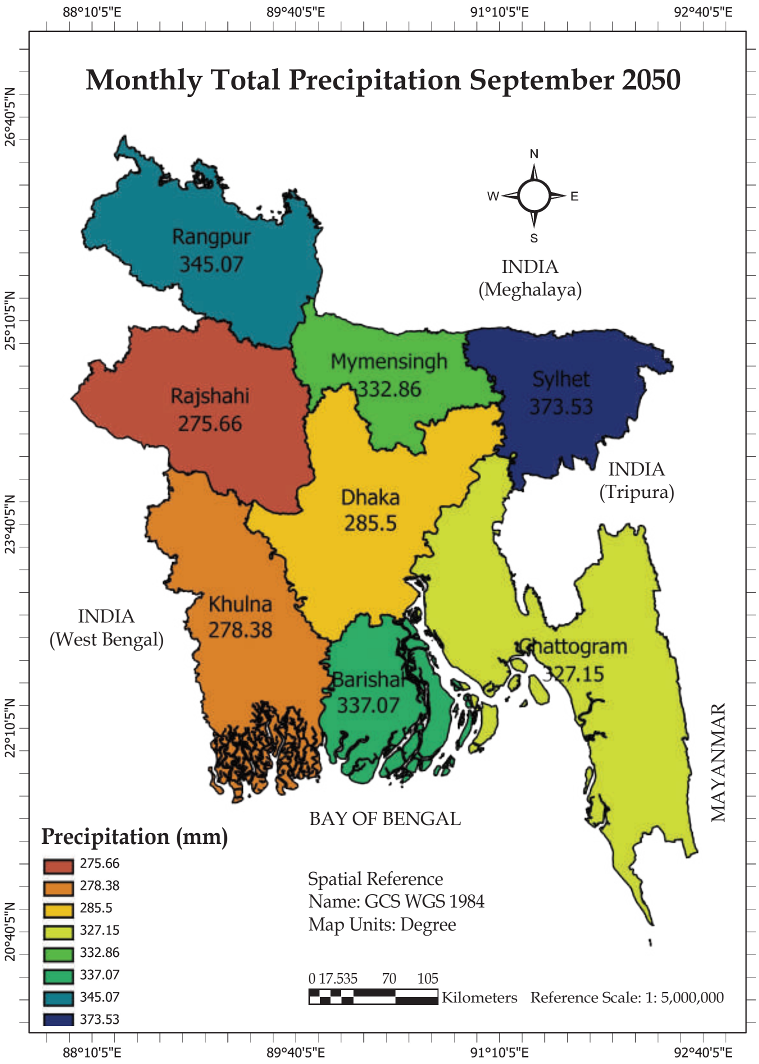


Figure 108. Division wise September month average of total precipitation for the year 2050 according to RCP 6.0

The division-wise maps show that the highest precipitation division will be Sylhet (373.53 mm) and Barishal (337.07 mm), on the other hand, the lowest precipitation division will be Rajshahi and Khulna division and their precipitation will be 275.66 mm and 278.38 mm respectively. (Figure 108)

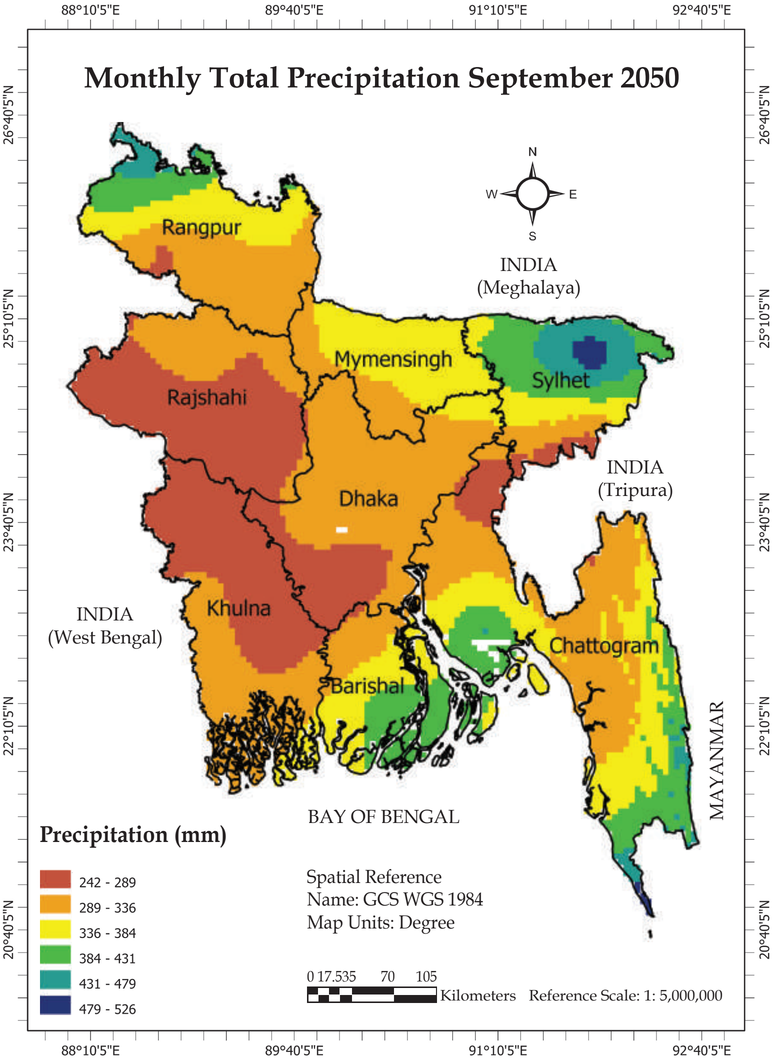


Figure 109. September month average of total precipitation for the year 2050 according to RCP 8.5

Figure 109 explaining the forecasted September month average precipitation of Bangladesh according to RCP model 8.5 where precipitation condition of Bangladesh is showing all most same as the RCP model 2.6, 4.5, and 6.0 just central-eastern part precipitation will be decreased.

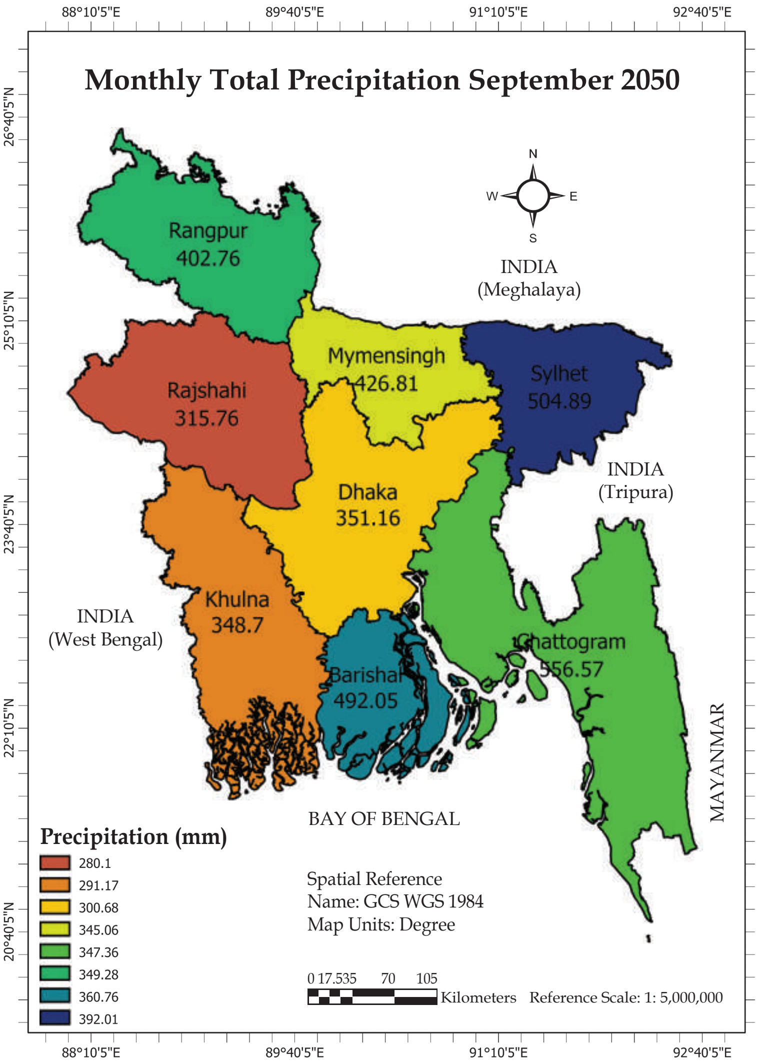


Figure 110. Division wise September month average of total precipitation for the year 2050 according to RCP 8.5

Figure 110 is showing highest precipitation division will be again Sylhet (504.89 mm) and lowest precipitation division will be the same as all others RCP model i.e., Rajshahi (315.76 mm).

Table 11: Summary of September month average total precipitation of 1970 to 2000, 2010 to 2018 and forecasted 2050 (By RCP model 2.6, 4.5, 6.0 and 8.5)

Division	Average Precipitation (mm) 1970 to 2000	Average Precipitation (mm) 2010 to 2018	Precipitation (mm) 2050 (RCP 2.6)	Precipitation (mm) 2050 (RCP 4.5)	Precipitation (mm) 2050 (RCP 6.0)	Precipitation (mm) 2050 (RCP 8.5)	Average of Precipitation (mm) 2050 (RCP 2.6, 4.5, 6.0 and 8.5)	Change of Precipitation (mm) 2050 to 2010-2018
Barishal	323.31	304.96	322.90	345.70	337.07	360.76	341.61	36.65
Chattogram	315.90	298.25	318.65	327.10	327.15	347.36	330.07	31.82
Dhaka	275.71	238.34	273.38	287.22	285.50	300.68	286.70	48.36
Khulna	261.74	241.14	263.56	281.38	278.38	291.17	278.62	37.48
Mymensingh	312.96	261.92	327.06	334.32	332.86	345.06	334.83	72.91
Rajshahi	259.98	216.08	263.61	275.91	275.66	280.10	273.82	57.74
Rangpur	365.82	318.36	340.04	351.61	345.07	349.28	346.50	28.14
Sylhet	376.87	326.94	372.28	374.77	373.53	392.01	378.15	51.21

In all the divisions of Bangladesh, average total precipitation (average by RCP 2.6, 4.5, 6.0, and 8.5 models) of September month in 2050 will be increased in comparison to average total precipitation during 2010 – 2018 (Table 11).

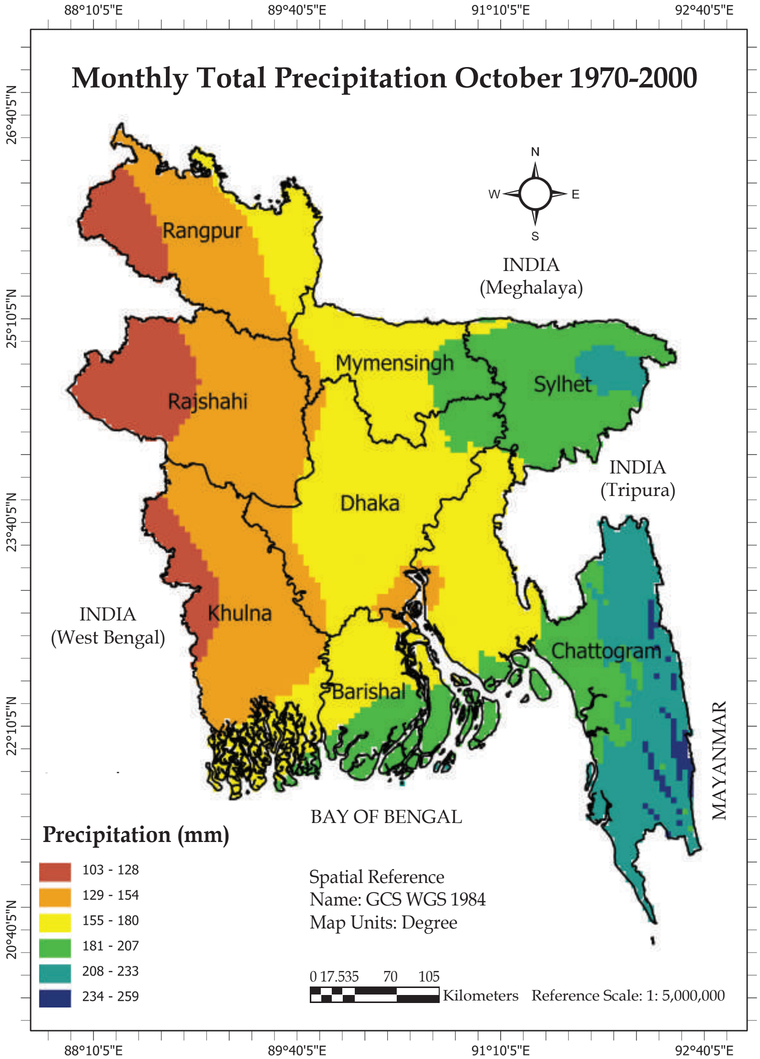


Figure 111. October month average of total precipitation from 1970-2000

The average precipitation scenario of October month during 1970 - 2000 in Bangladesh has been presented in Figure 57. The high precipitate areas were north-east and lower part of the south-east side of Bangladesh. The north- and south-central parts of the country ware under moderate precipitation and the lowest precipitate areas ware western side of the country (Figure 111).

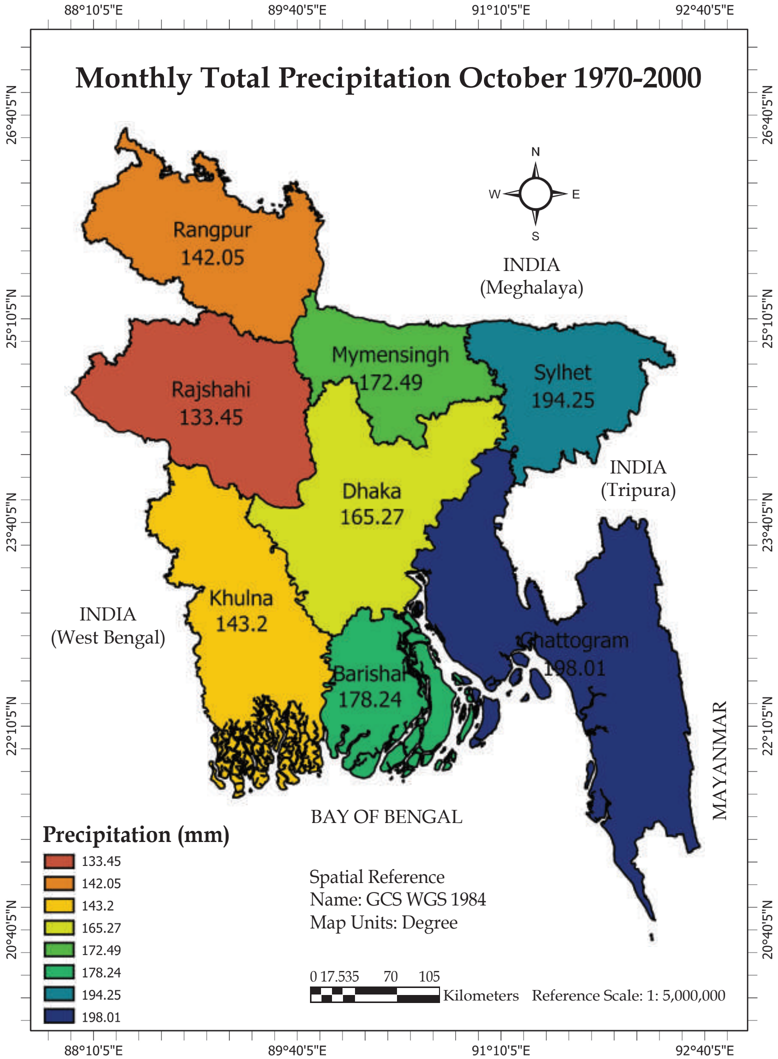


Figure 112. Division wise October month average of total precipitation from 1970-2000

Figure 112 is describing division-wise October month average total precipitation during 1970 - 2000 in Bangladesh. The Chattogram division experienced highest precipitation (198.01 mm) followed by Sylhet division (194.25 mm) and the lowest precipitated division was Rajshahi with average precipitation of 133.45 mm in October.

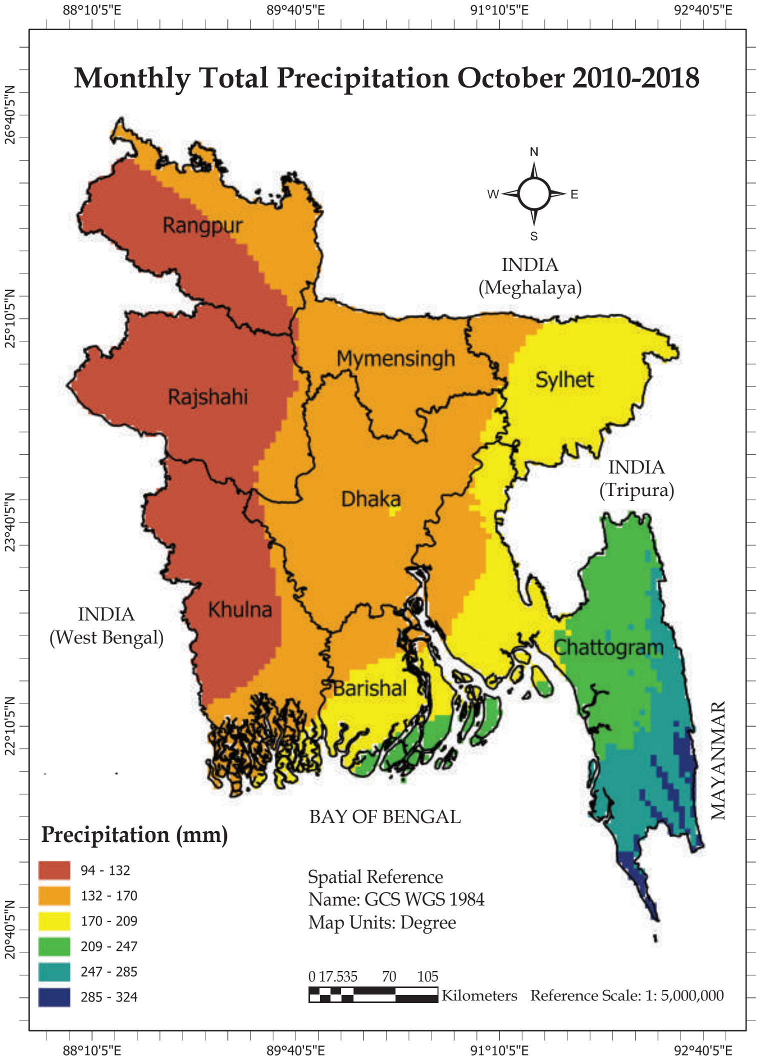


Figure 113. October month average of total precipitation from 2010-2018

Figure 113 is showing the average precipitation scenario of October month during 2010-2018 in Bangladesh, where the highest precipitated area was the lower part of the south-eastern side of Bangladesh. The north-eastern part was moderate, and western side experienced low precipitation.

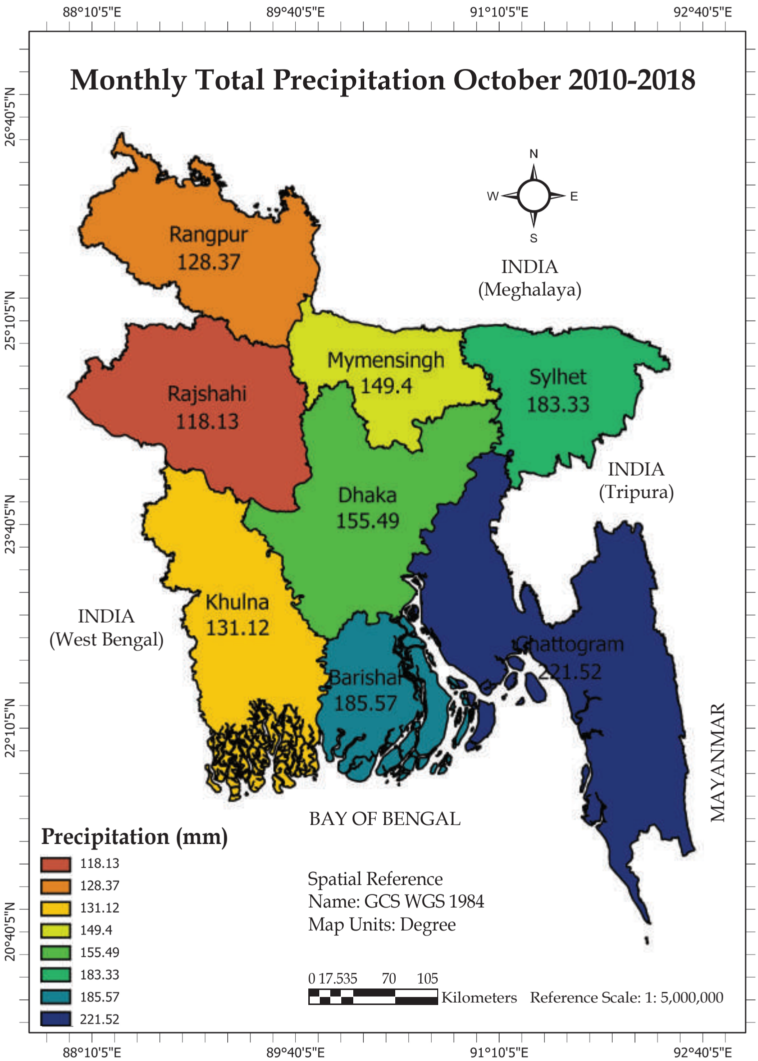


Figure 114. Division wise October month average of total precipitation from 2010-2018

Figure 114 is showing division-wise October month average precipitation during 2010-2018 in Bangladesh, where Chattogram division had the highest precipitation (221.52 mm) and that of the lowest was Rajshahi division (118.13 mm).

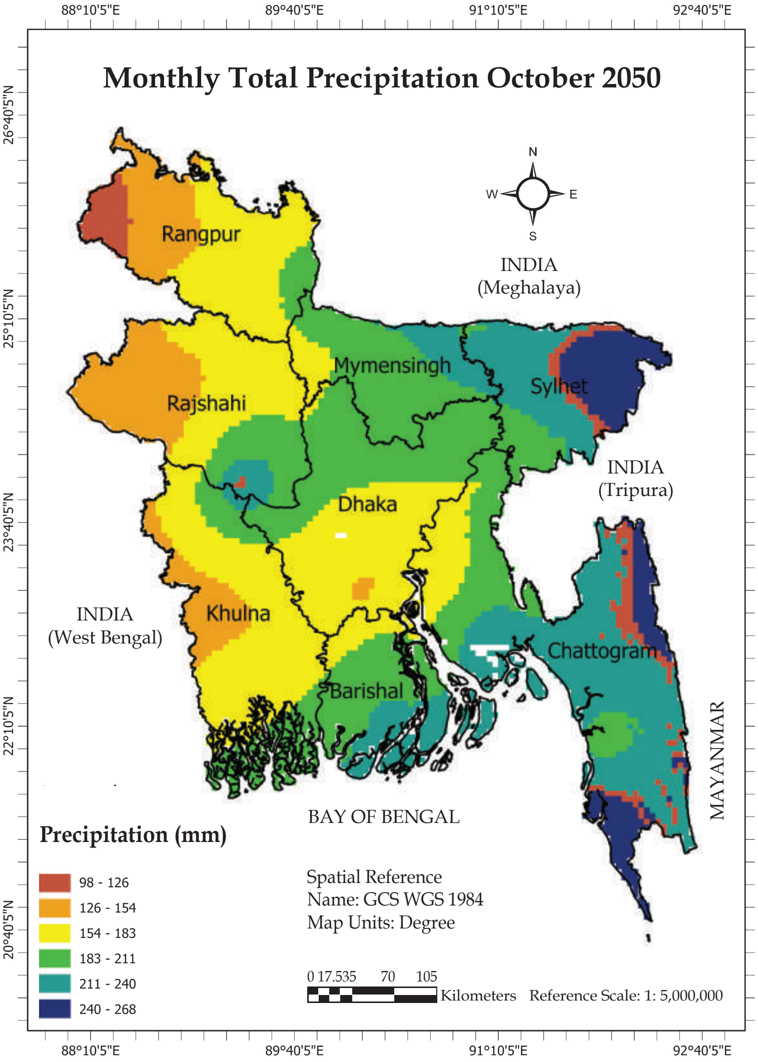


Figure 115. October month average of total precipitation for the year 2050 according to RCP 2.6

Figure 115 represents the highest precipitated areas will be the north-east and lower part of the south-eastern side of Bangladesh, the central part will experience a moderate and the lowest precipitation will be in a few parts of north-western, north-east and lower south-west sides of Bangladesh.

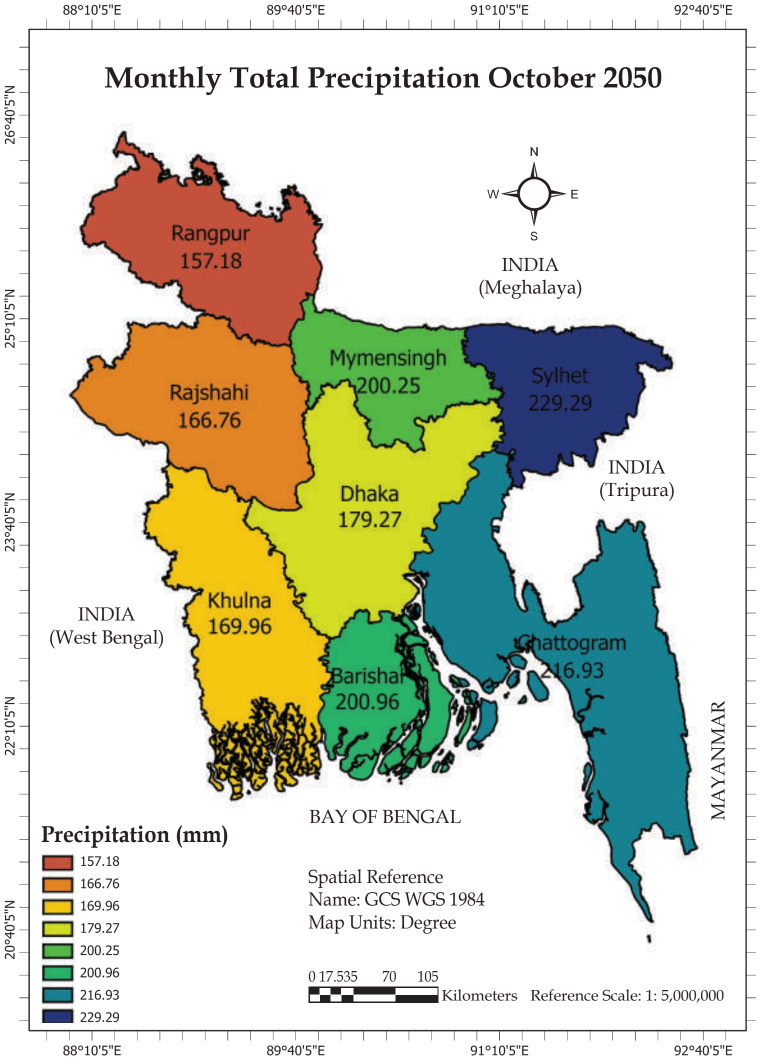


Figure 116. Division wise October month average of total precipitation for the year 2050 according to RCP 2.6

Figure 116 is showing the division-wise October month forecasted average precipitation of Bangladesh. The Sylhet will be the highest precipitate division (229.29 mm) in 2050 and the lowest precipitated division will be Rangpur (157.18 mm). Now, Rajshahi is the lowest precipitation division and affected by drought. The analyses showing Rangpur would be included in the drought prone areas in future.

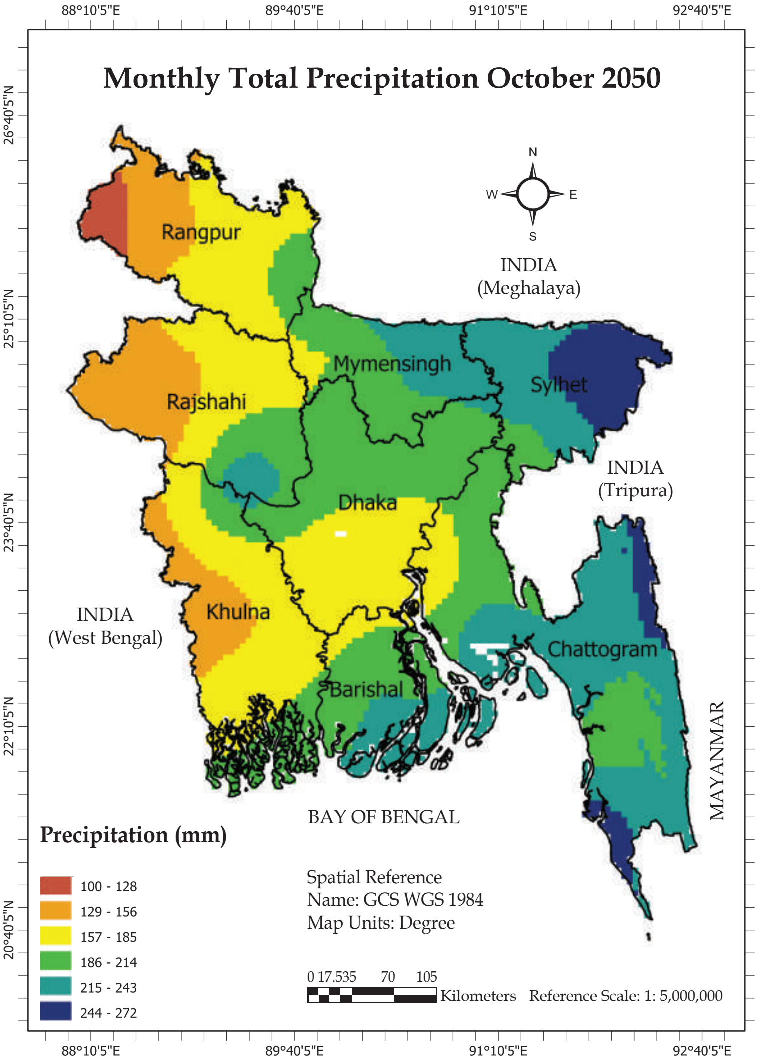


Figure 117. October month average of total precipitation for the year 2050 according to RCP 4.5

Figure 117 reveals the forecasted October month average precipitation of Bangladesh according to RCP 4.5 model, where the highest precipitated areas will be the northeast and lower part of the south-eastern sides of Bangladesh. The central part will be under the moderate to the high precipitation, and lowest precipitation areas will be the few parts of north-western side of Bangladesh.

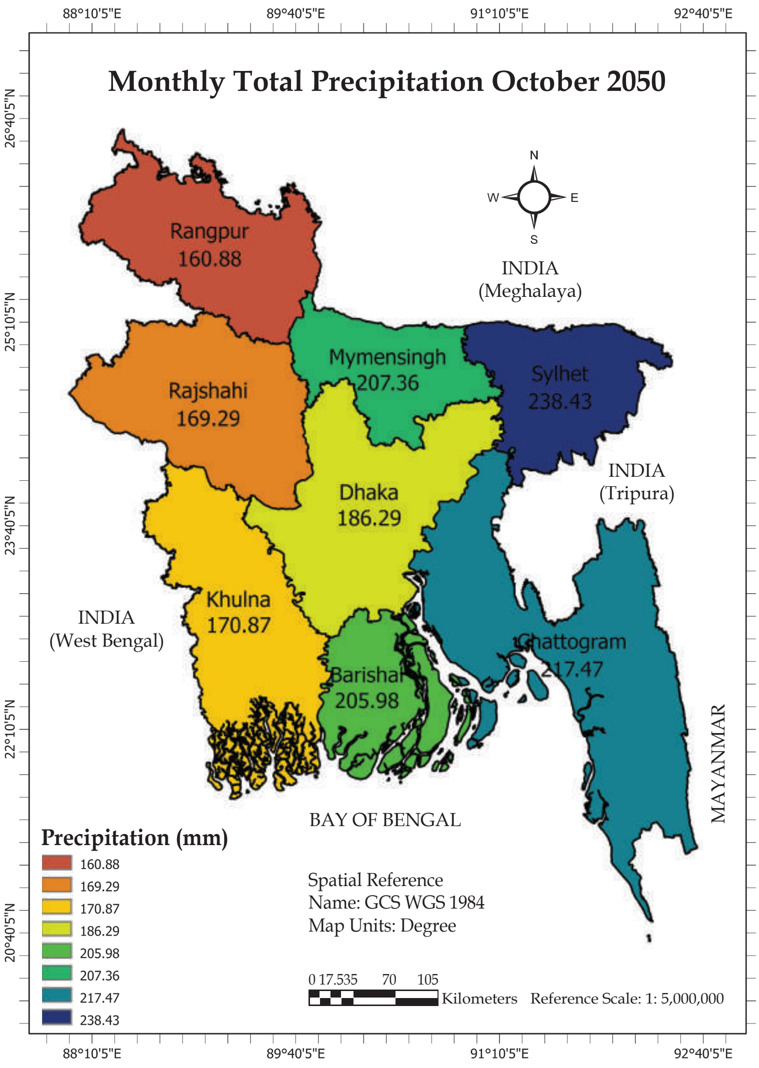


Figure 118. Division wise October month average of total precipitation for the year 2050 according to RCP 4.5

Figure 118 is showing that the highest precipitation division will be Sylhet (238.43 mm) and the lowest precipitation division will be Rangpur (160.88 mm) in 2050.

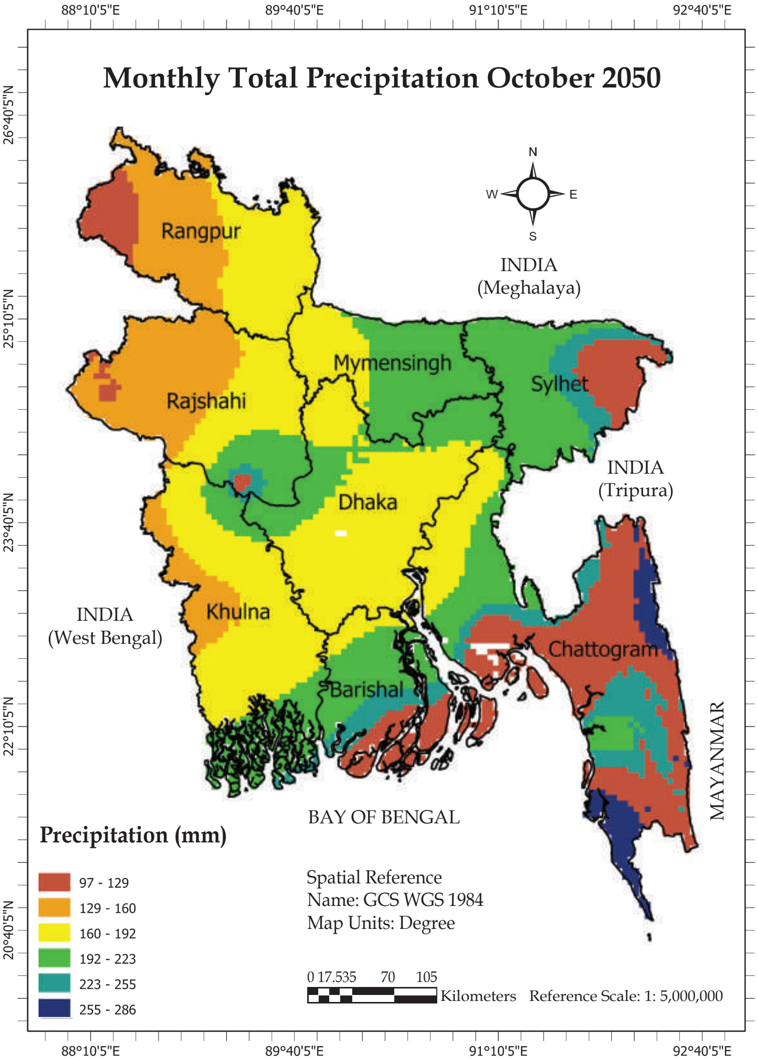


Figure 119. October month average of total precipitation for the year 2050 according to RCP 6.0

Figure 119 is representing the forecasted October month average precipitation of Bangladesh according to RCP 6.0 model, where the highest precipitated areas will be some lower part of the south-eastern side of Bangladesh. The central part will enjoy a moderate precipitation, and the lowest precipitation area will be few parts of the north-western, north-eastern and lower parts of the south-eastern side of Bangladesh.

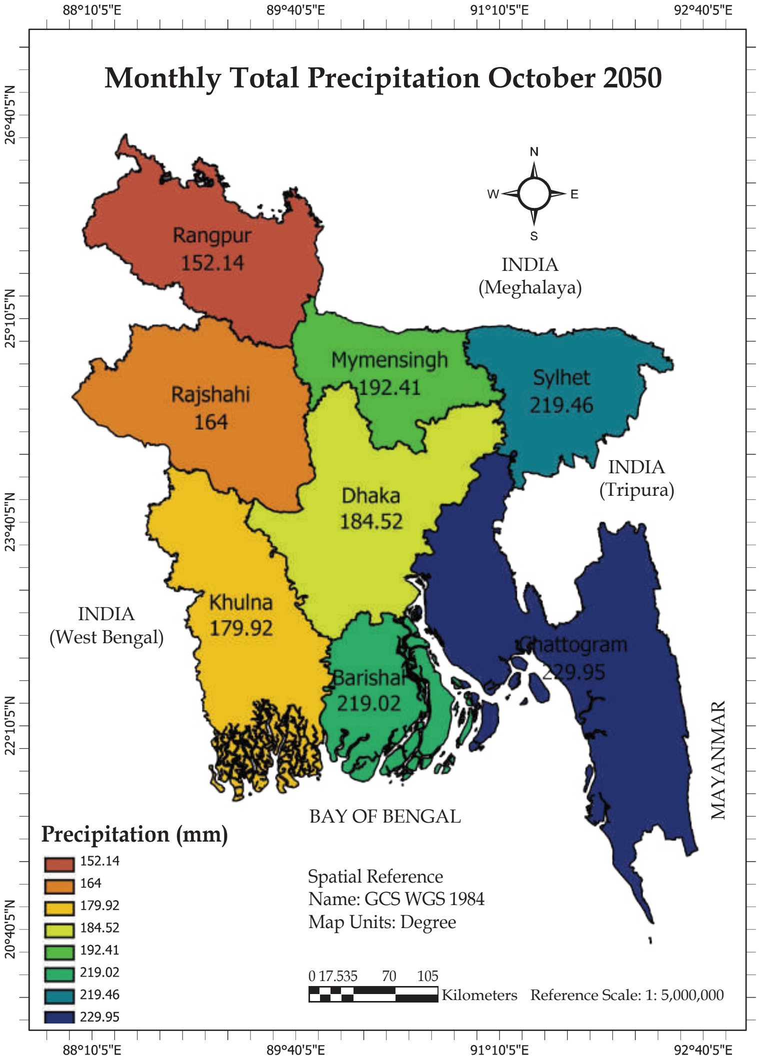


Figure 120. Division wise October month average of total precipitation for the year 2050 according to RCP 6.0

Figure 120 is delivering that the highest precipitation division will be Chattogram (229.95 mm) and the lowest precipitation division will be Rangpur (152.14 mm) in 2050.

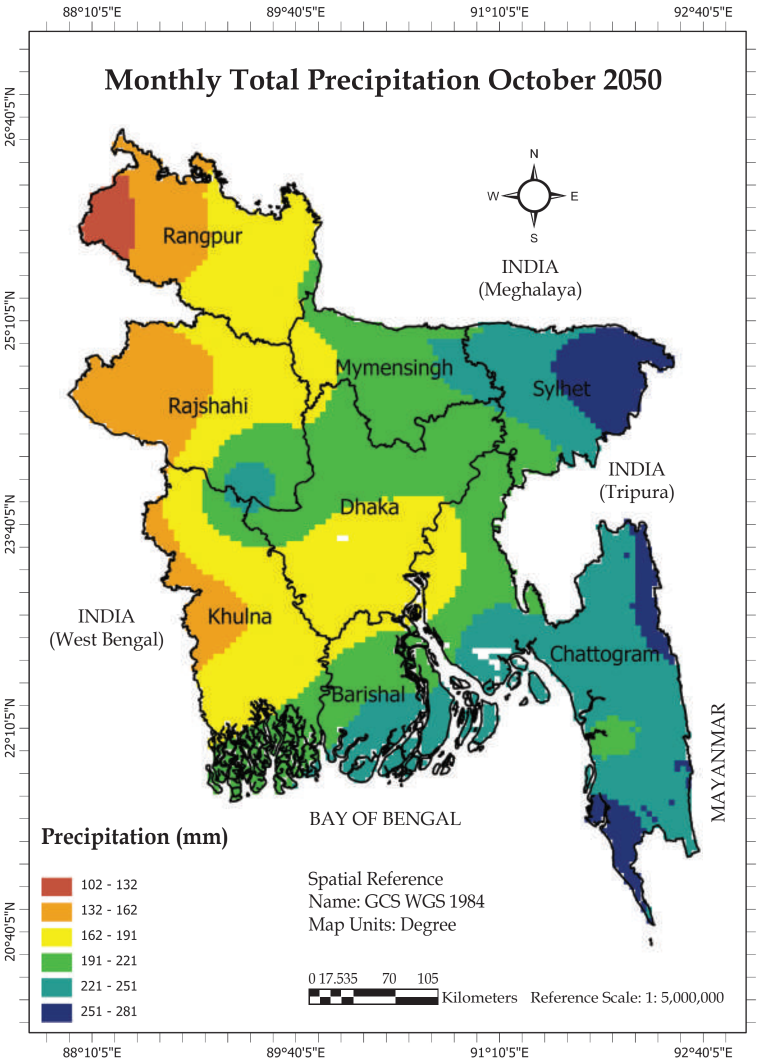


Figure 121. October month average of total precipitation for the year 2050 according to RCP 8.5

The forecasted October month average precipitation of Bangladesh according to RCP 8.5 model has been delivered by Figure 62. The precipitation condition of Bangladesh is showing almost the same as the RCP 4.5 model (Figure 121).

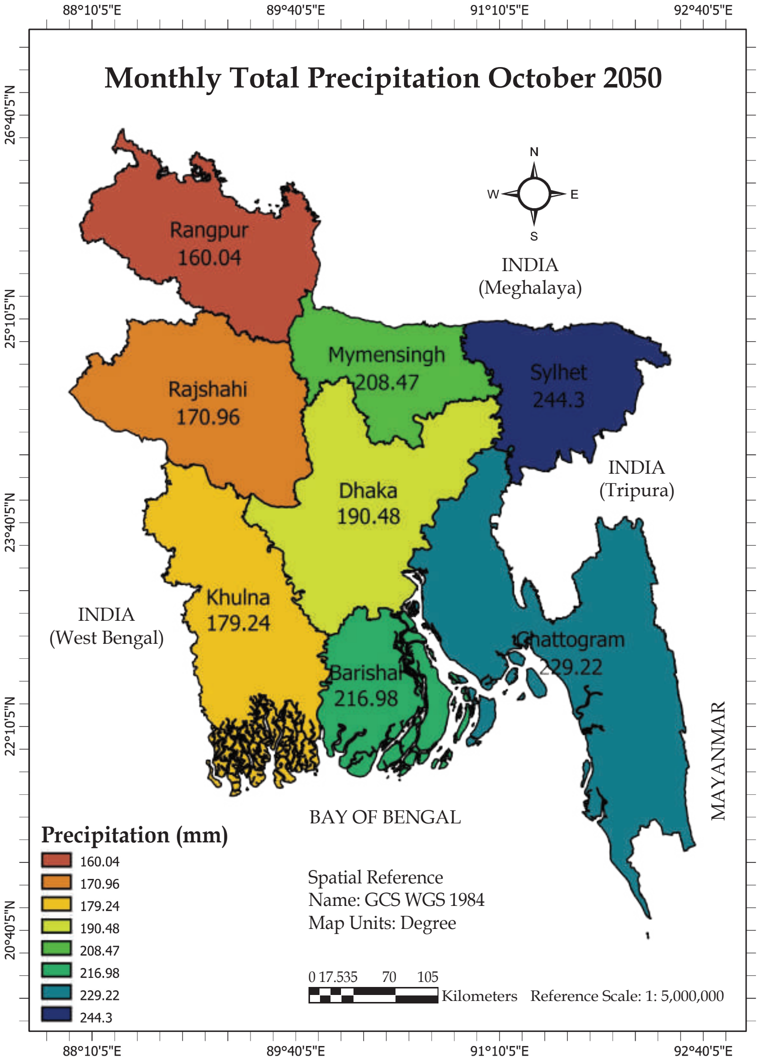


Figure 122 Division wise October month average of total precipitation for the year 2050 according to RCP 8.5

The division wise forecasting showed that the highest precipitation division will be Sylhet (244.3mm) and lowest precipitation division will be the same as all others RCP models i.e., Rangpur with the average precipitation as 160.04 mm (Figure 122).

Table 12: Summary of October month average total precipitation of 1970 to 2000, 2010 to 2018 and forecasted 2050 (By RCP model 2.6, 4.5, 6.0 and 8.5)

Division	Average Precipitation (mm) 1970 to 2000	Average Precipitation (mm) 2010 to 2018	Precipitation (mm) 2050 (RCP 2.6)	Precipitation (mm) 2050 (RCP 4.5)	Precipitation (mm) 2050 (RCP 6.0)	Precipitation (mm) 2050 (RCP 8.5)	Average of Precipitation (mm) 2050 (RCP 2.6, 4.5, 6.0 and 8.5)	Change of Precipitation (mm) 2050 to 2010-2018
Barishal	178.24	185.57	200.96	205.98	219.02	216.98	210.73	25.16
Chattogram	198.01	221.52	216.93	217.47	229.95	229.22	223.39	1.87
Dhaka	165.27	155.49	179.27	186.29	184.52	190.48	185.14	29.65
Khulna	143.20	131.12	169.96	170.87	179.92	179.24	175.00	43.88
Mymensingh	172.49	149.40	200.25	207.36	192.41	208.47	202.12	52.72
Rajshahi	133.45	118.13	166.76	169.29	164.00	170.96	167.75	49.62
Rangpur	142.05	128.37	157.18	160.88	152.14	160.04	157.56	29.19
Sylhet	194.25	183.33	229.29	238.43	219.46	244.30	232.87	49.54

In all the divisions of Bangladesh average total precipitation (average by RCP 2.6, 4.5, 6.0, and 8.5 models) of October month in 2050 will be increased in comparison to average total precipitation during 2010 - 2018. The forecasting also reveals that Sylhet division will be highest precipitation and Rangpur will be lowest precipitation.

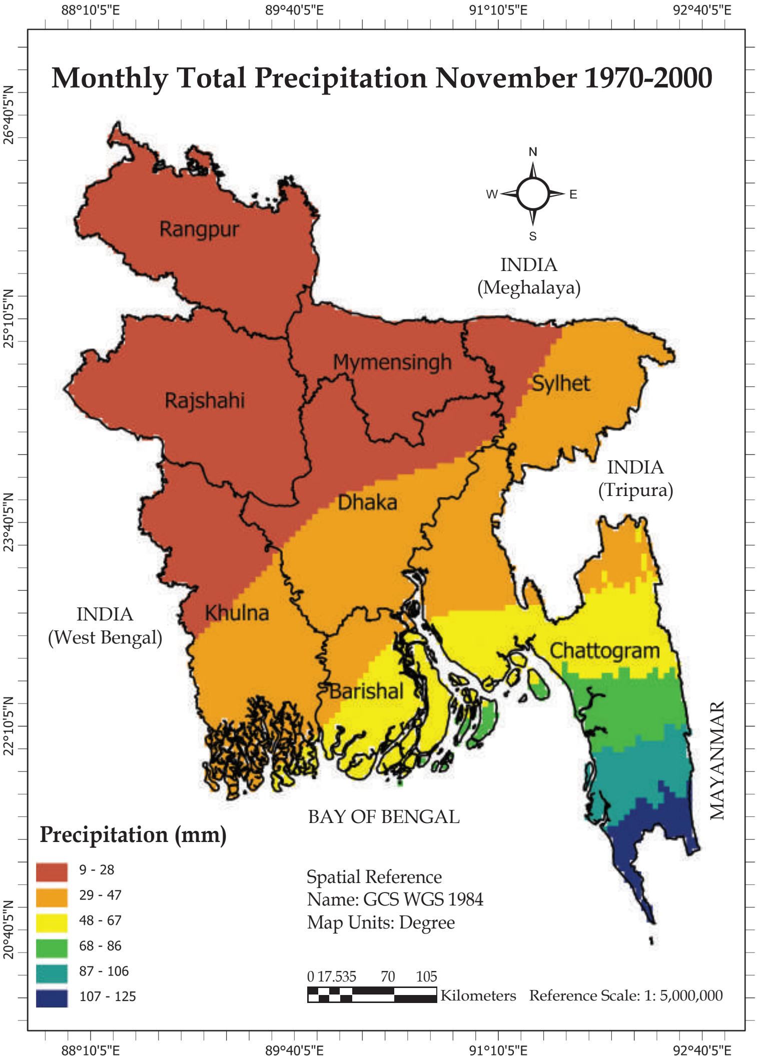


Figure 123. November month average of total precipitation from 1970-2000

Figure 123 represents the average precipitation of November month during the period 1970-2000 in Bangladesh. The highest precipitation was observed in the lower part of the south-east side of Bangladesh. The central and south part of Bangladesh had moderate precipitation and the lowest precipitation was in the upper north-western and north-central side of the country.

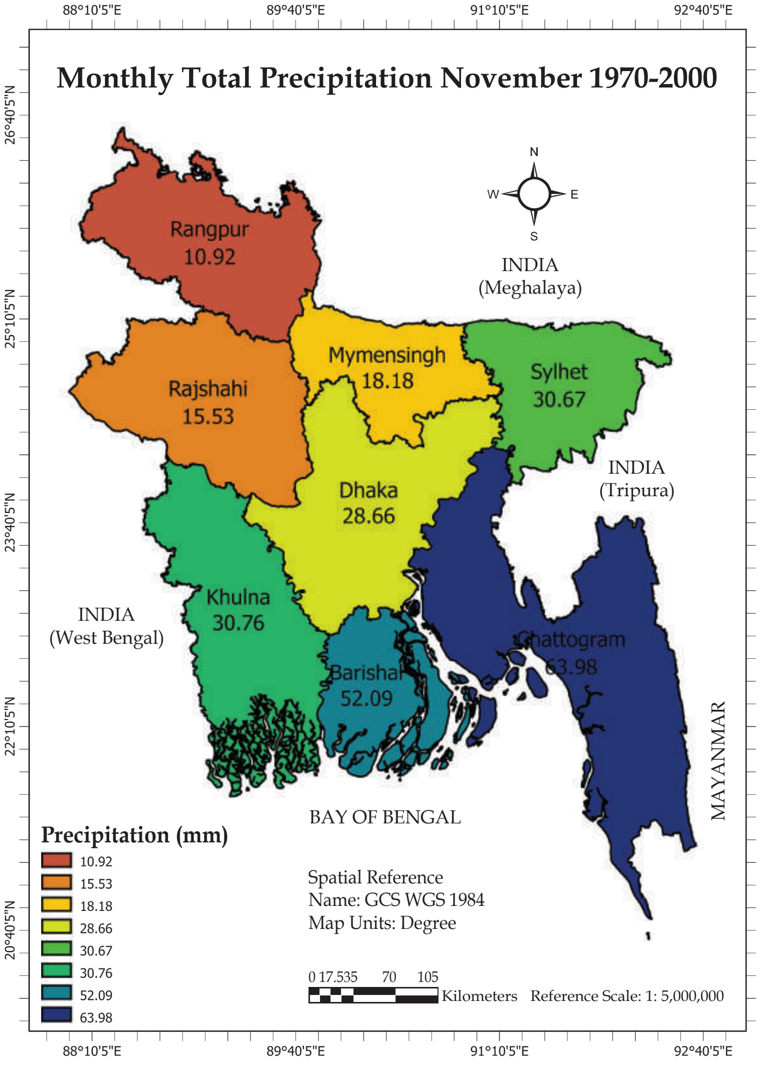


Figure 124. Division wise November month average of total precipitation from 1970-2000

Figure 124 shows the division-wise November month average precipitation during 1970-2000 in Bangladesh. It shows that Chattogram division had the highest precipitation (63.98 mm) and the lowest was in Rangpur division (10.92 mm).

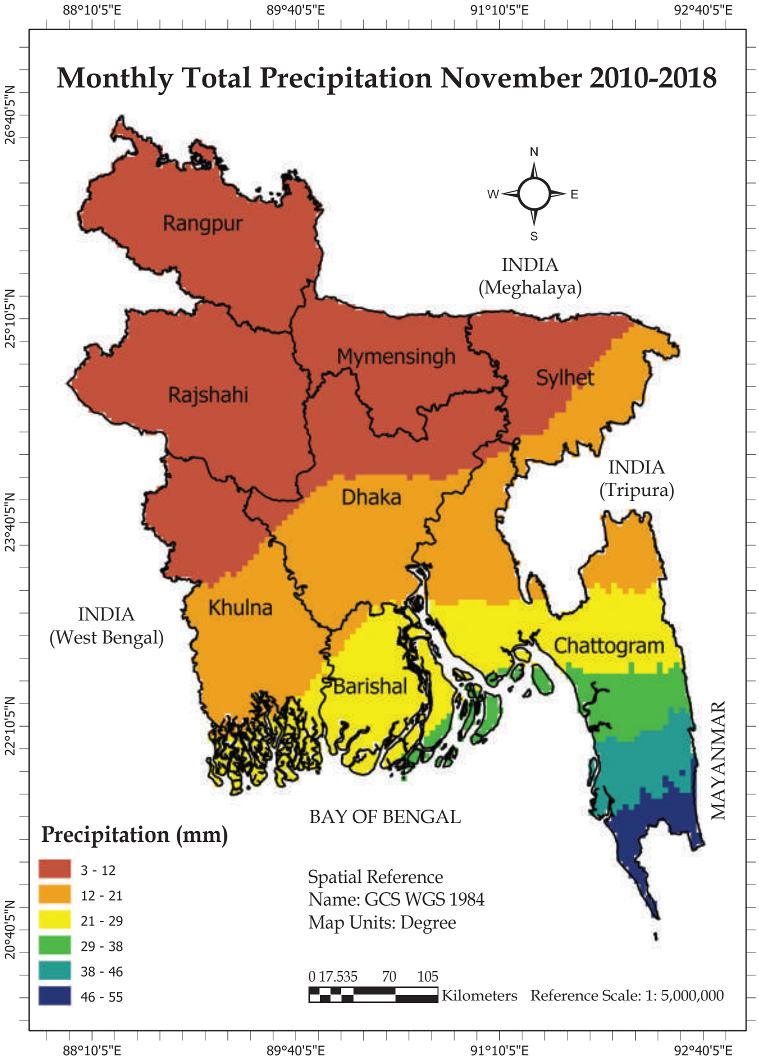


Figure 125. November month average of total precipitation from 2010-2018

Figure 125 is showing the average precipitation for November month during 2010-2018 in Bangladesh. The highest precipitation was observed in the lower part of the south-eastern side of the country. The central part had moderate and the lowest precipitation was in the upper north-western and north-central side of Bangladesh.

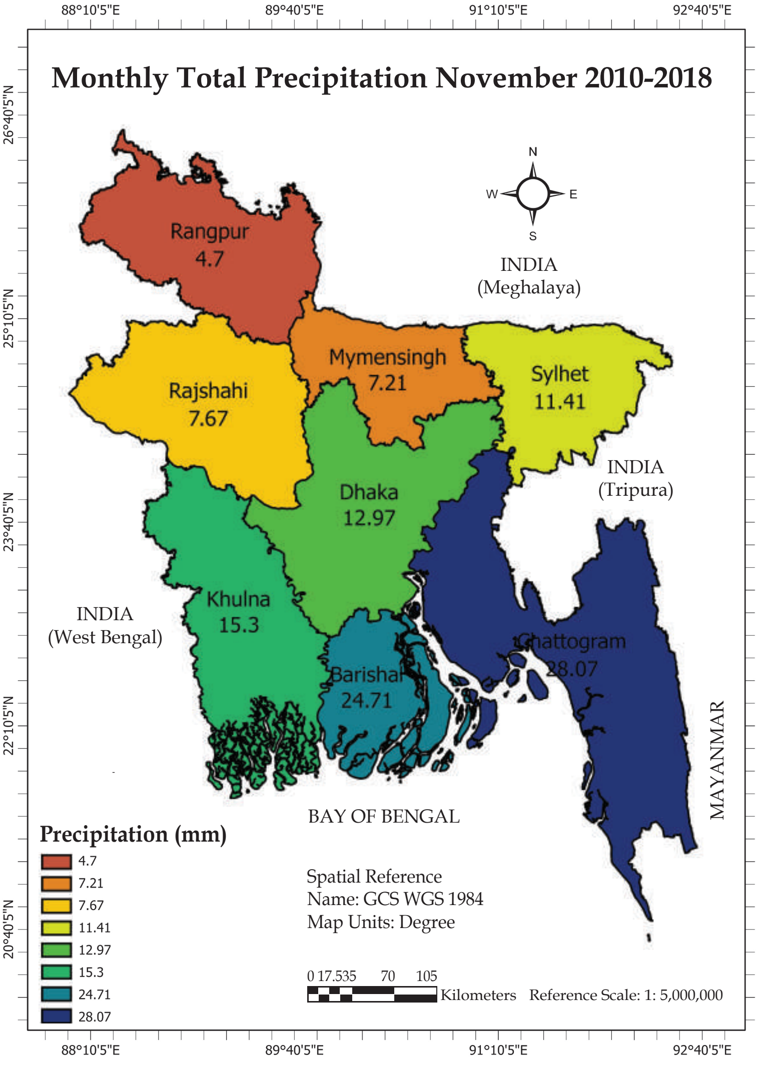


Figure 126. Division wise November month average of total precipitation from 2010-2018

A division-wise representation (Figure 126) shows that Chattogram division had the highest precipitation (28.07 mm) and the lowest was in Rangpur division (4.7 mm).

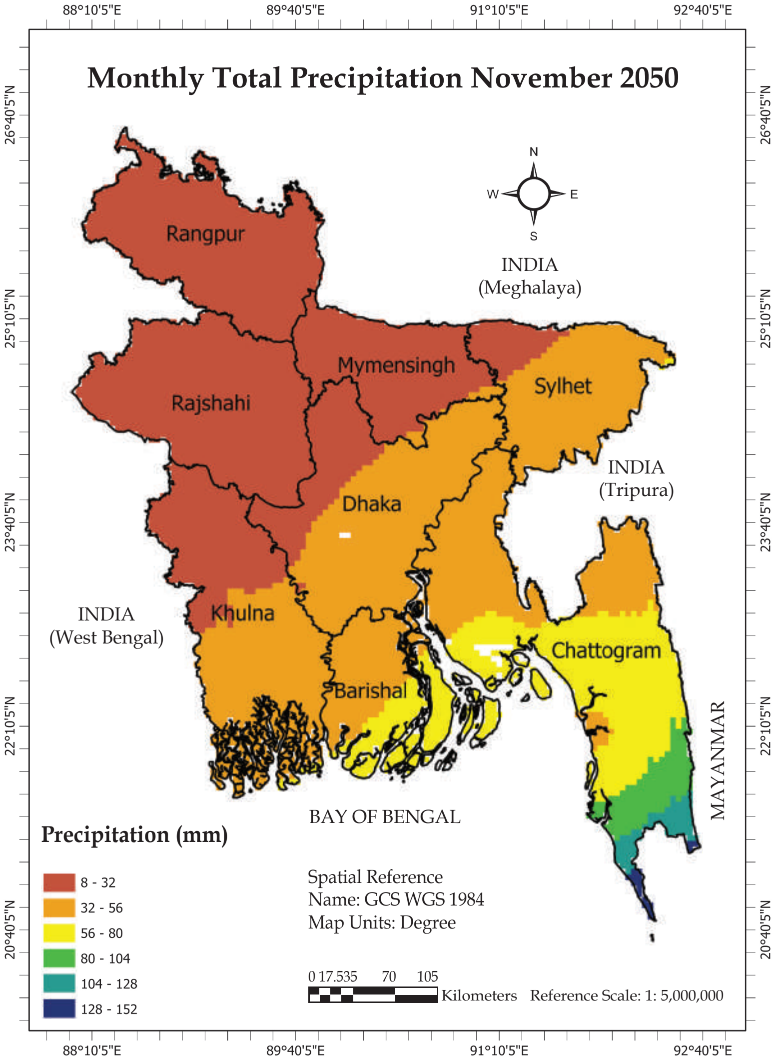


Figure 127. November month average of total precipitation for the year 2050 according to RCP 2.6

Figure 127 is presenting the forecasted November month average precipitation of Bangladesh according to RCP 2.6 model. The highest precipitation will be in the lower part of the south-eastern side of Bangladesh. The central part will have moderate, and the north-western and north-central sides will have the lowest precipitation.

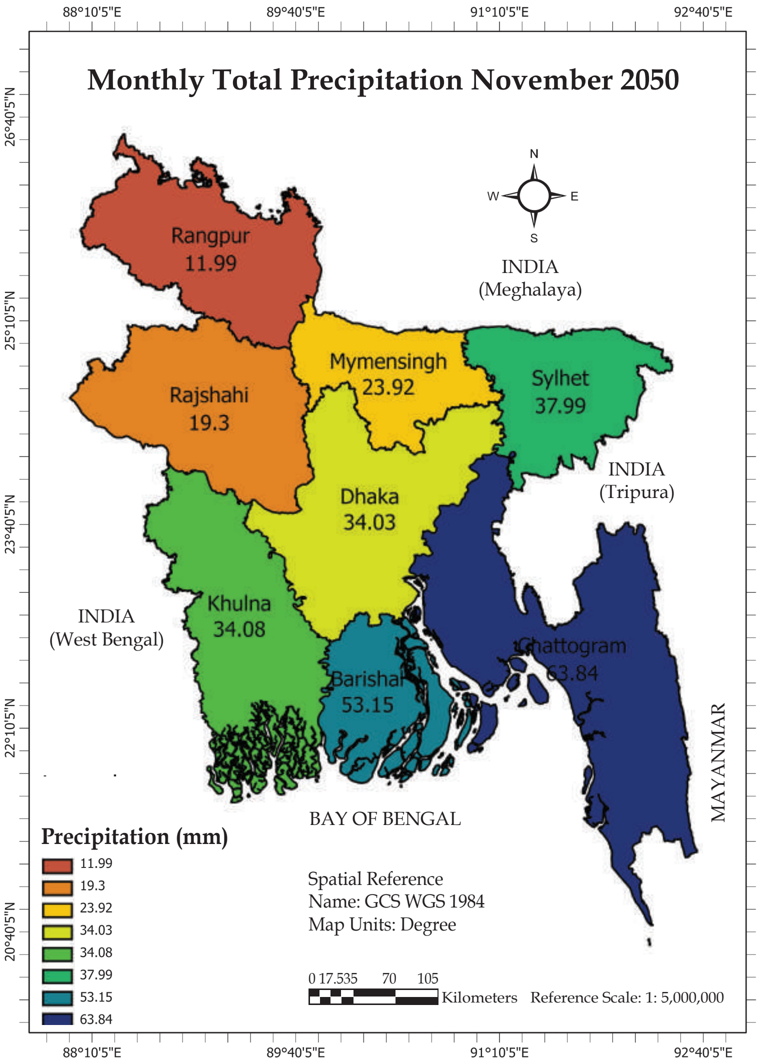


Figure 128. Division wise November month average of total precipitation for the year 2050 according to RCP 2.6

Figure 128 is showing the division-wise forecasts of November month average precipitation of Bangladesh according to RCP 2.6 model. The results suggest that Chattogram division will have the highest precipitation (63.84 mm) and Rangpur division will have the lowest precipitation (11.99 mm) in 2050.

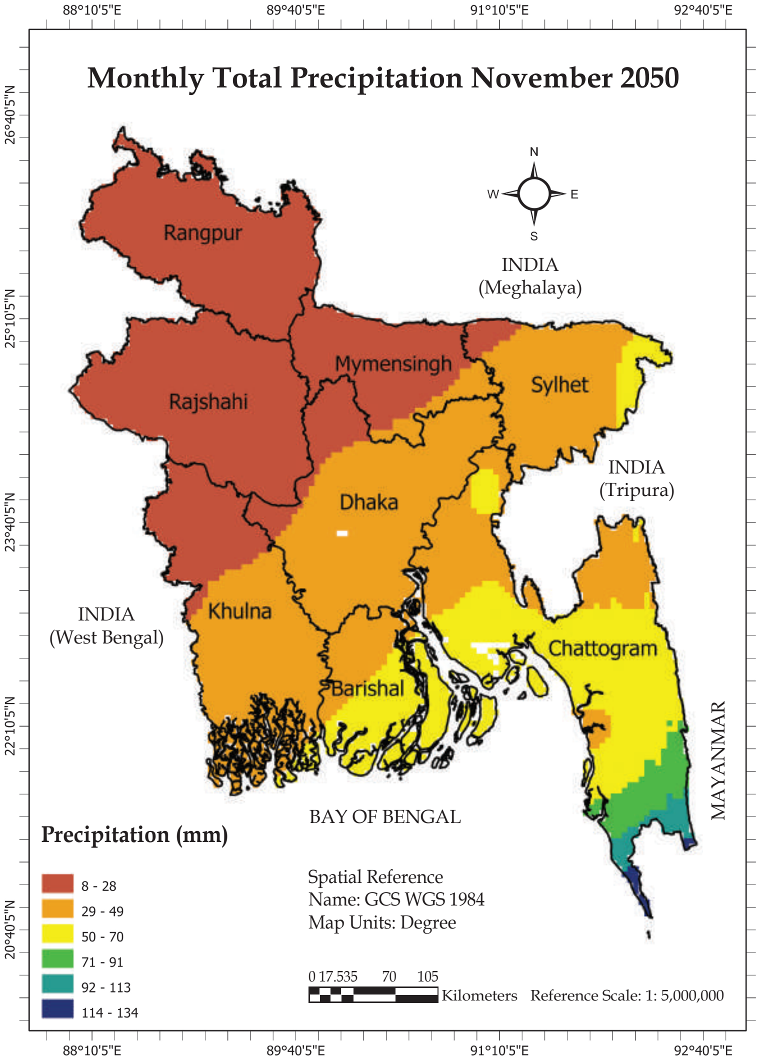


Figure 129. November month average of total precipitation for the year 2050 according to RCP 4.5

Figure 129 is showing the forecasted November month average precipitation of Bangladesh using RCP 4.5 model. The forecasts is showing that the precipitation condition of Bangladesh will be more or less similar as the RCP 2.6 model.

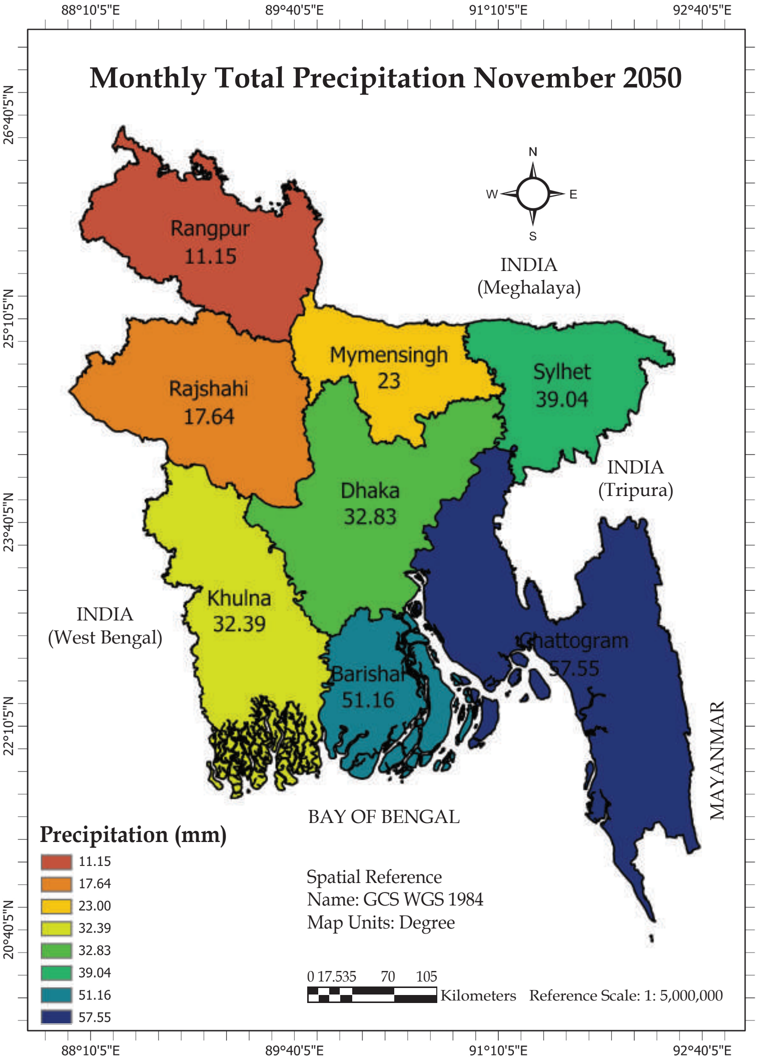


Figure 130. Division wise November month average of total precipitation for the year 2050 according to RCP 4.5

Figure 130 represents that the highest precipitation division will be Chattogram (57.55 mm) and the lowest will be Rangpur division (11.15 mm) in 2050.

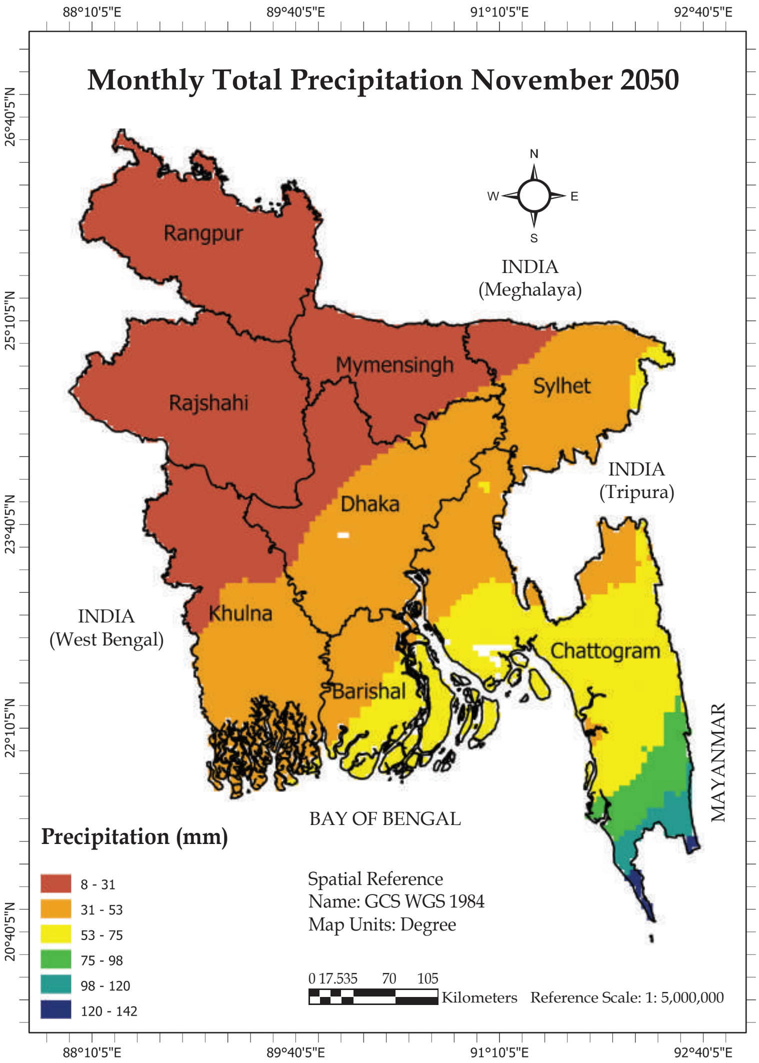


Figure 131. November month average of total precipitation for the year 2050 according to RCP 6.0

Figure 131 is describing the forecasted November month average precipitation of Bangladesh according to RCP 6.0 model. This model generates almost similar results as the RCP 2.6 and 4.5 models about the future precipitation condition of Bangladesh.

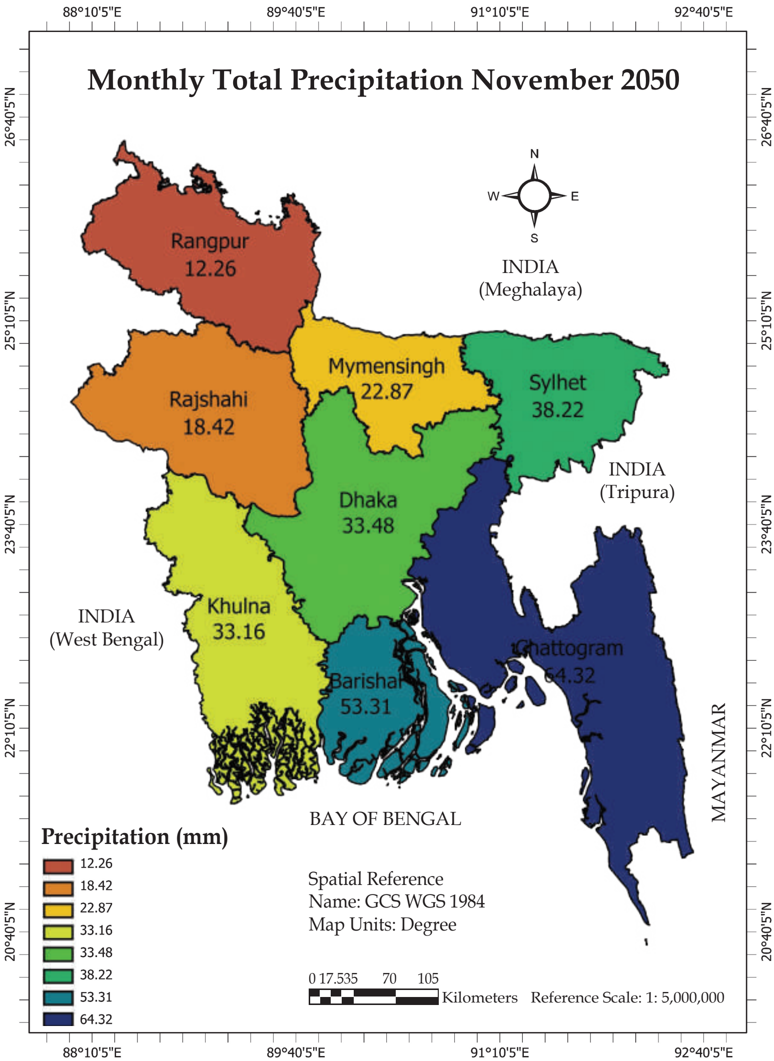


Figure 132. Division wise November month average of total precipitation for the year 2050 according to RCP 6.0

Figure 132 shows that the highest precipitation division will be Chattogram (64.32 mm) and the lowest will be Rangpur division (12.26 mm).

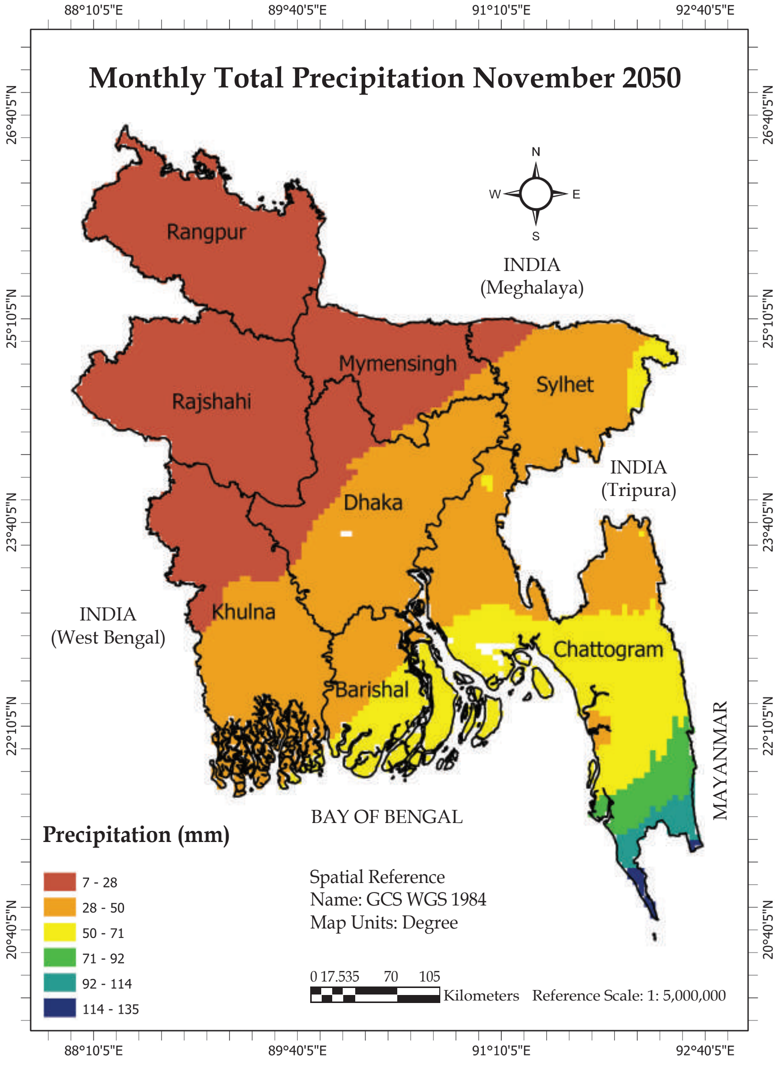


Figure 133. November month average of total precipitation for the year 2050 according to RCP 8.5

Figure 133 is explaining forecasted November month average precipitation of Bangladesh according to RCP 8.5 model. The model also generate almost similar results as the other RCP models. The central southern part's precipitation will be decreased by 2050.

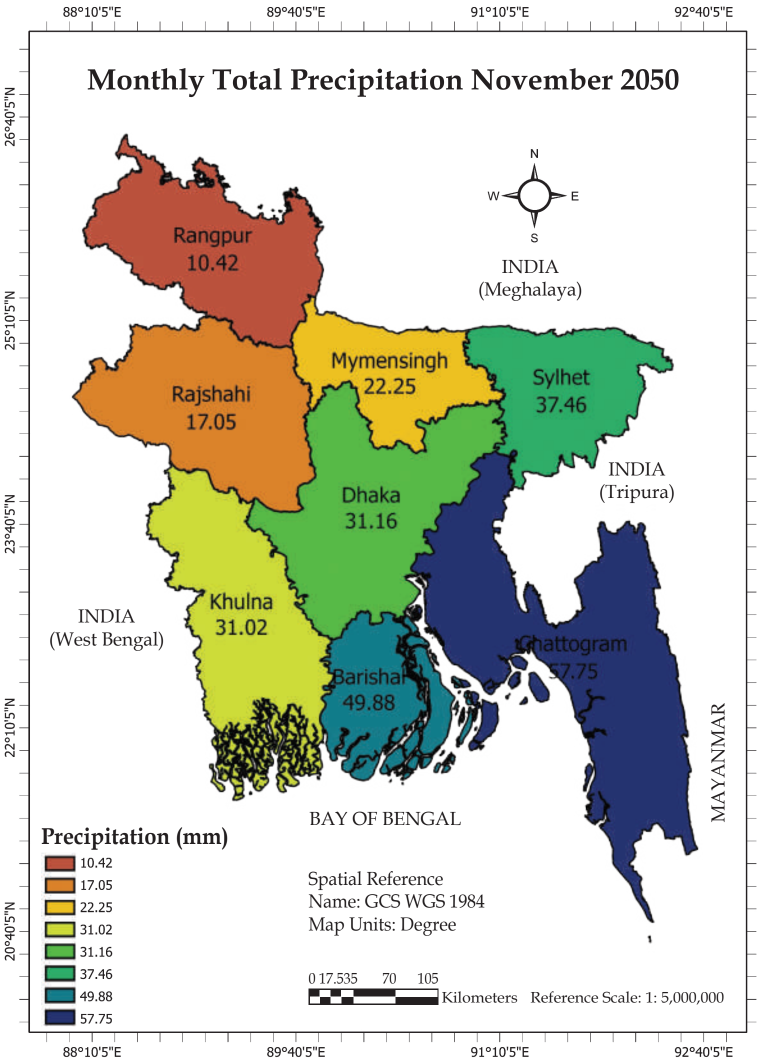


Figure 134. Division wise October month average of total precipitation for the year 2050 according to RCP 8.5

Figure 134 is showing that the highest precipitation division will be Chattogram (57.75 mm) and lowest precipitation division will be the same as all others RCP model i.e., Rangpur (10.42 mm).

Table 13 : Summary of November month average total precipitation of 1970-2000, 2010-2018 and forecasted 2050 (By RCP 2.6, 4.5, 6.0 and 8.5 models)

Division	Average Precipitation (mm) 1970 to 2000	Average Precipitation (mm) 2010 to 2018	Precipitation (mm) 2050 (RCP 2.6)	Precipitation (mm) 2050 (RCP 4.5)	Precipitation (mm) 2050 (RCP 6.0)	Precipitation (mm) 2050 (RCP 8.5)	Average of Precipitation (mm) 2050 (RCP 2.6, 4.5, 6.0 and 8.5)	Change of Precipitation (mm) 2050 to 2010-2018
Barishal	52.09	24.71	53.15	51.16	53.31	49.88	51.87	27.16
Chattogram	63.98	28.07	63.84	57.55	64.32	57.75	60.87	32.80
Dhaka	28.66	12.97	34.03	32.83	33.48	31.16	32.87	19.90
Khulna	30.76	15.30	34.08	32.39	33.16	31.02	32.66	17.36
Mymensingh	18.18	7.21	23.92	23.00	22.87	22.25	23.01	15.80
Rajshahi	15.53	7.67	19.30	17.64	18.42	17.05	18.10	10.43
Rangpur	10.92	4.70	11.99	11.15	12.26	10.42	11.46	6.76
Sylhet	30.67	11.41	37.99	39.04	38.22	37.46	38.18	26.77

From the Table 13, it is found that in all divisions of Bangladesh average total precipitation (average by RCP 2.6, 4.5, 6.0, and 8.5 models) of November month in 2050 will be increased in comparison to average precipitation during 2010-2018.

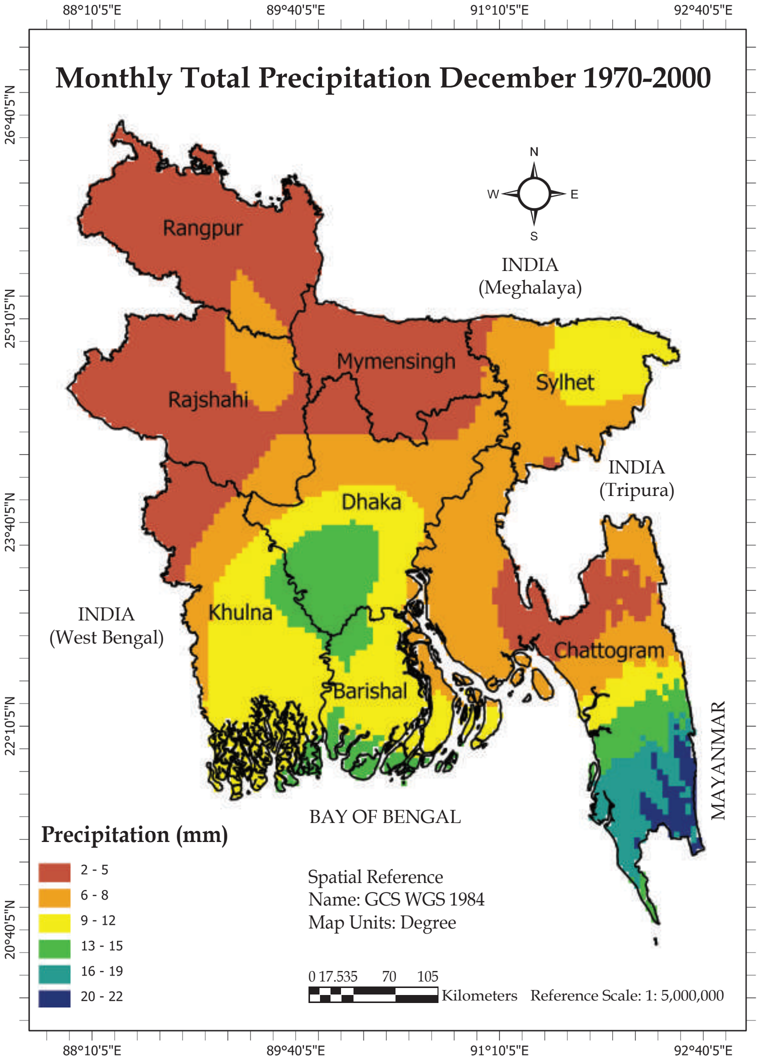


Figure 135. December month average of total precipitation from 1970-2000

Shows the average total precipitation for December month during 1970-2000 in Bangladesh. The highest precipitation was in the south-west side of Bangladesh. The central and south parts of the country were under moderate precipitation and the lowest precipitation was in the north-western side of Bangladesh (Figure 135).

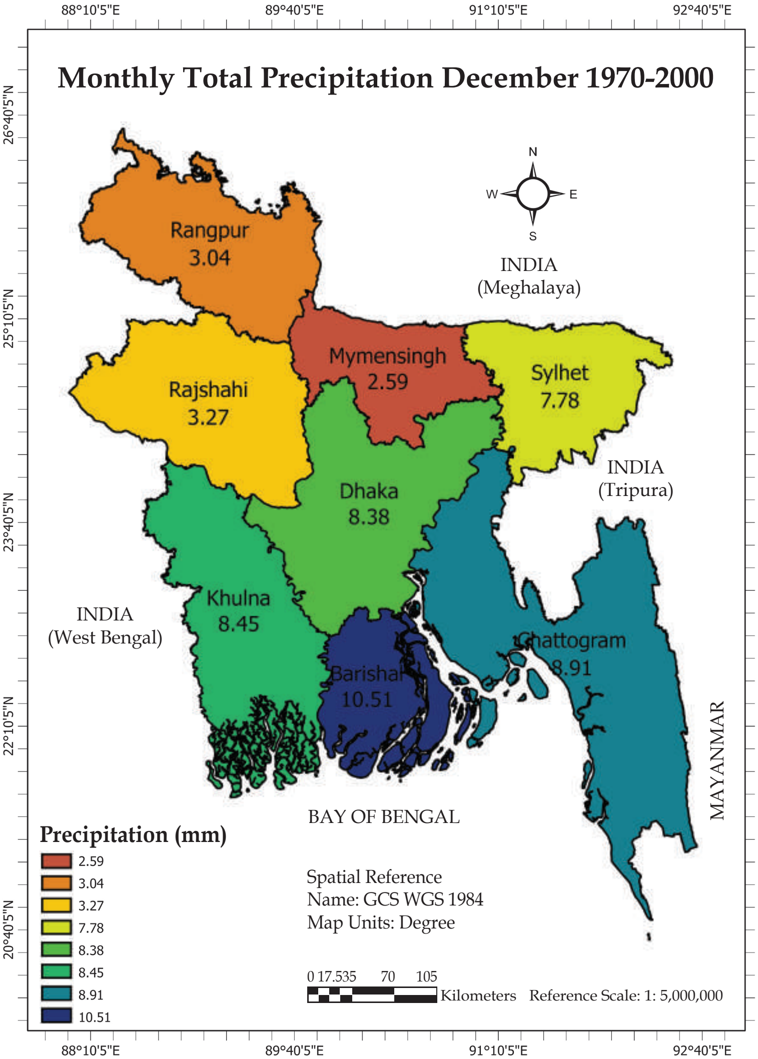


Figure 136. Division wise December month average of total precipitation from 1970-2000

Figure 136 is describing division-wise December months' average total precipitation during 1970-2000 in Bangladesh. Barishal division experienced the highest precipitation (10.51 mm) and the lowest was in Mymensingh where average precipitation was 2.59 mm.

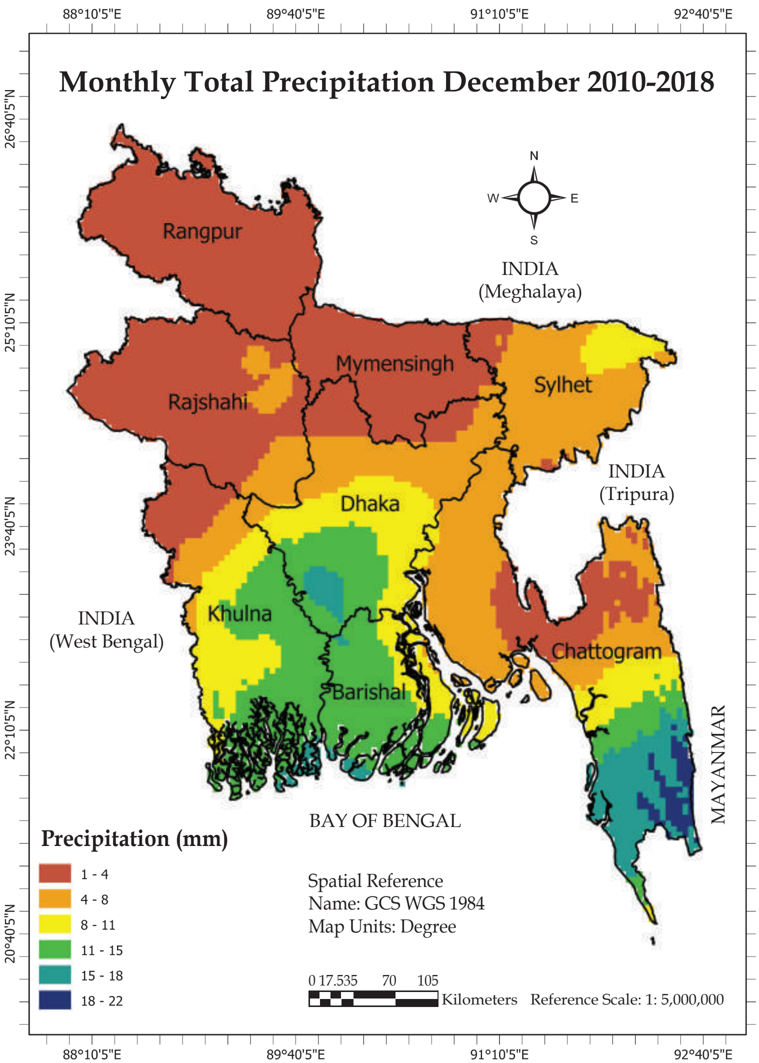


Figure 137. December month average of total precipitation from 2010-2018

Figure 137 is showing the average total precipitation for December month during 2010-2018 in Bangladesh, where the highest precipitation was in the southwest side of Bangladesh. The central and south parts of Bangladesh ware under moderate precipitation and the lowest precipitate area was the north-western side of the country.

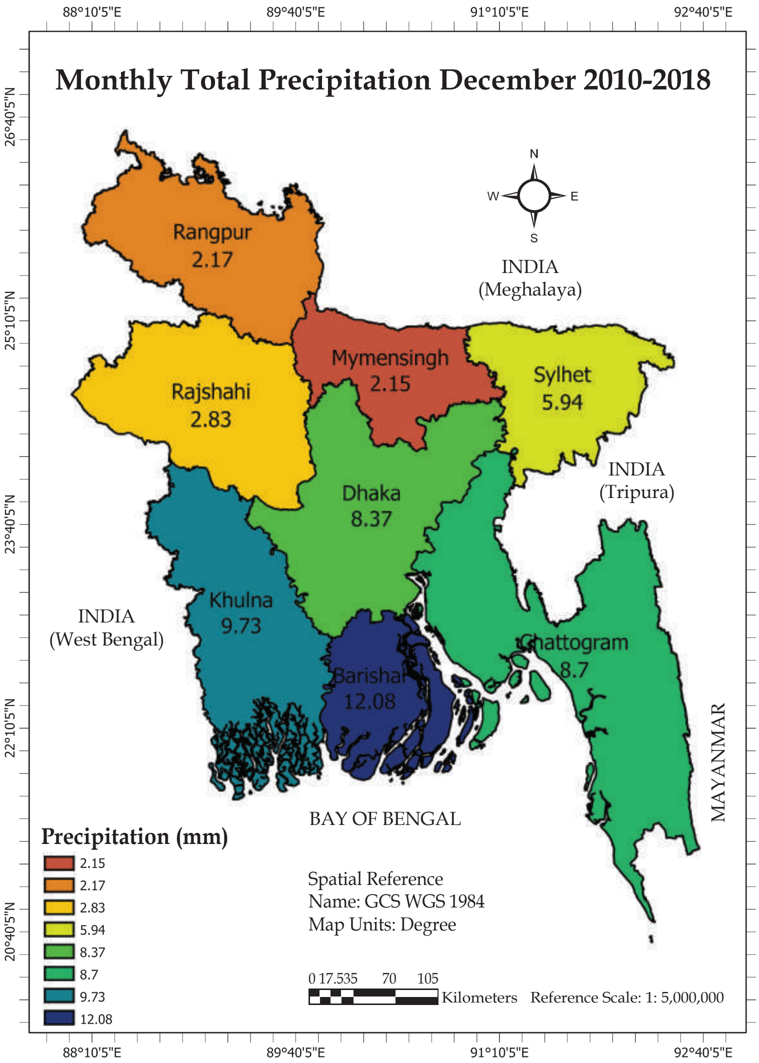


Figure 138. Division-wise December month average of total precipitation from 2010-2018

Figure 138 is describing division-wise December months' average total precipitation during 2010-2018 in Bangladesh where Barishal division had the highest precipitation (12.08 mm) and the lowest precipitation was in Mymensingh division (2.15 mm).

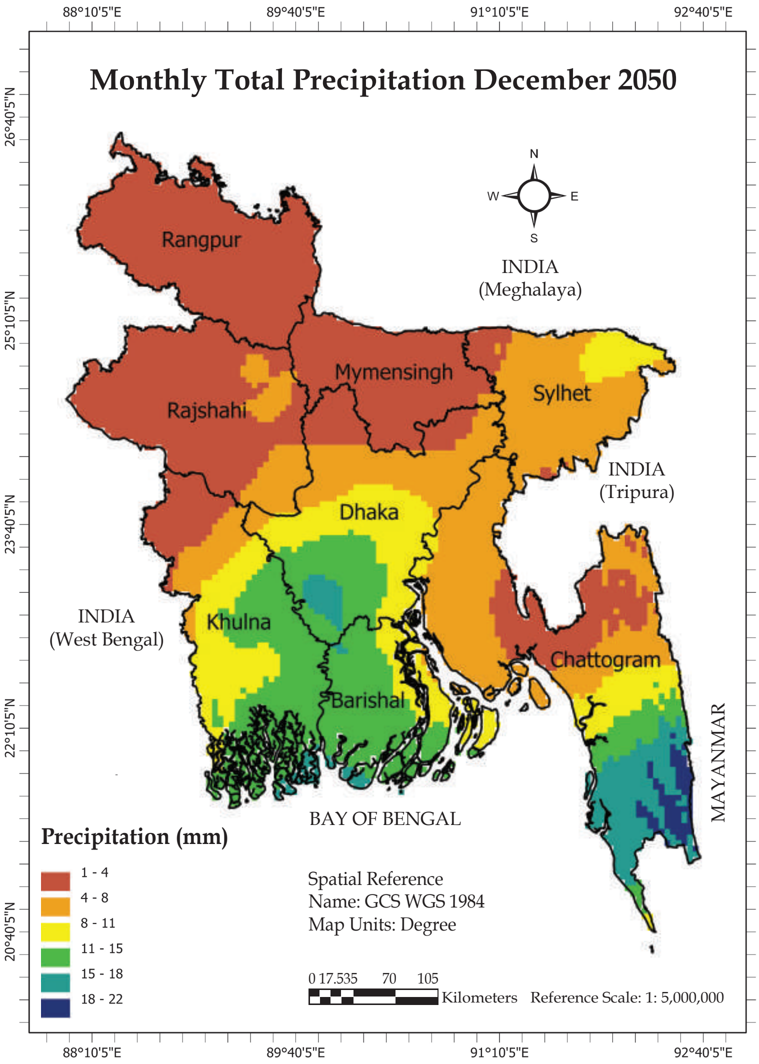


Figure 139. December month average of total precipitation for the year 2050 according to RCP 2.6

Figure 139 is describing the forecasted December month average precipitation of Bangladesh according to RCP 2.6 model. The highest precipitation will be the southwest side of Bangladesh. The central and south parts of the country will have a moderate precipitation and the lowest precipitation will be the north-western, central-north, and few areas of the east side of Bangladesh.

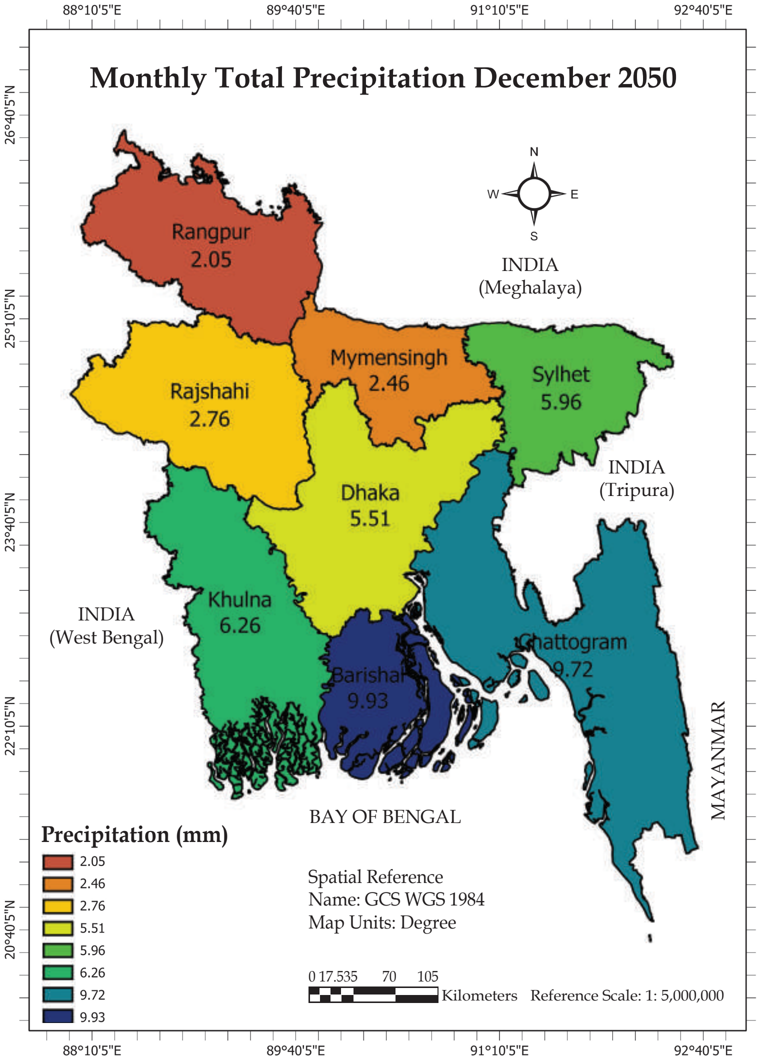


Figure 140. Division wise December month average of total precipitation for the year 2050 according to RCP 2.6

Figure 140 is showing the division wise December month average precipitation. Barishal division will have the highest precipitation (9.93 mm) and the lowest precipitated division will be shifted from Mymensingh (2000-2018) to Rangpur division (2.05 mm) in 2050.

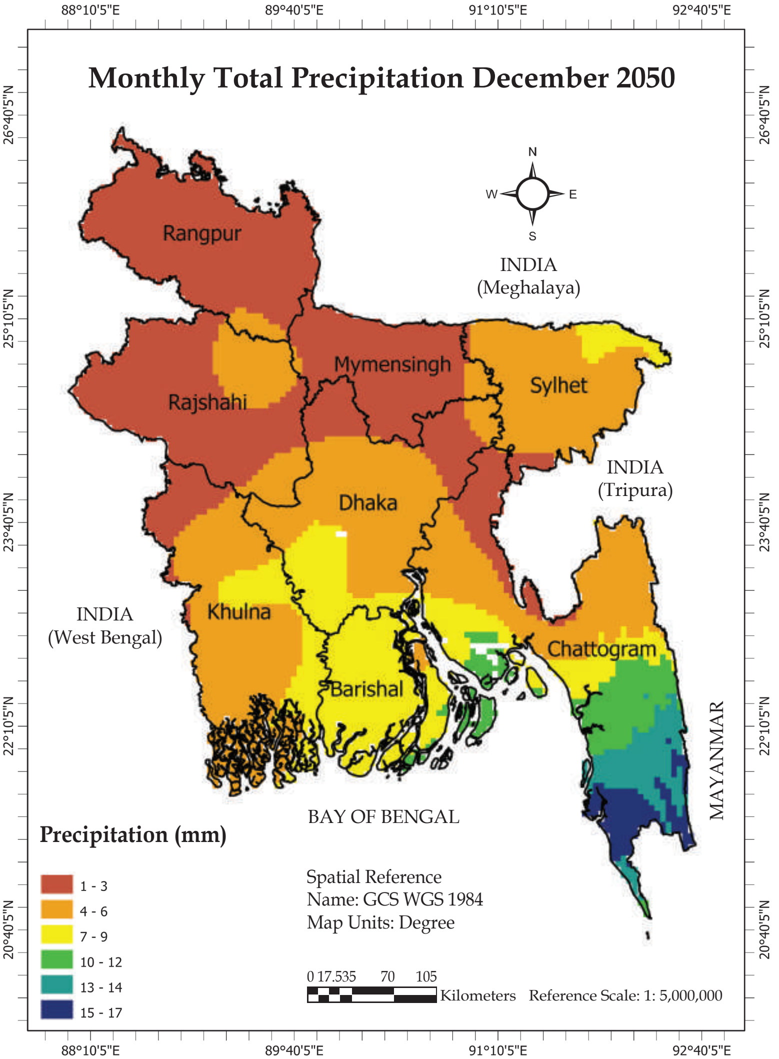


Figure 141. December month average of total precipitation for the year 2050 according to RCP 4.5

Figure 141 shows the forecasted December month average precipitation of Bangladesh by RCP 4.5 model, where the precipitation condition of Bangladesh is showing more or less the same as the RCP 2.6 model.

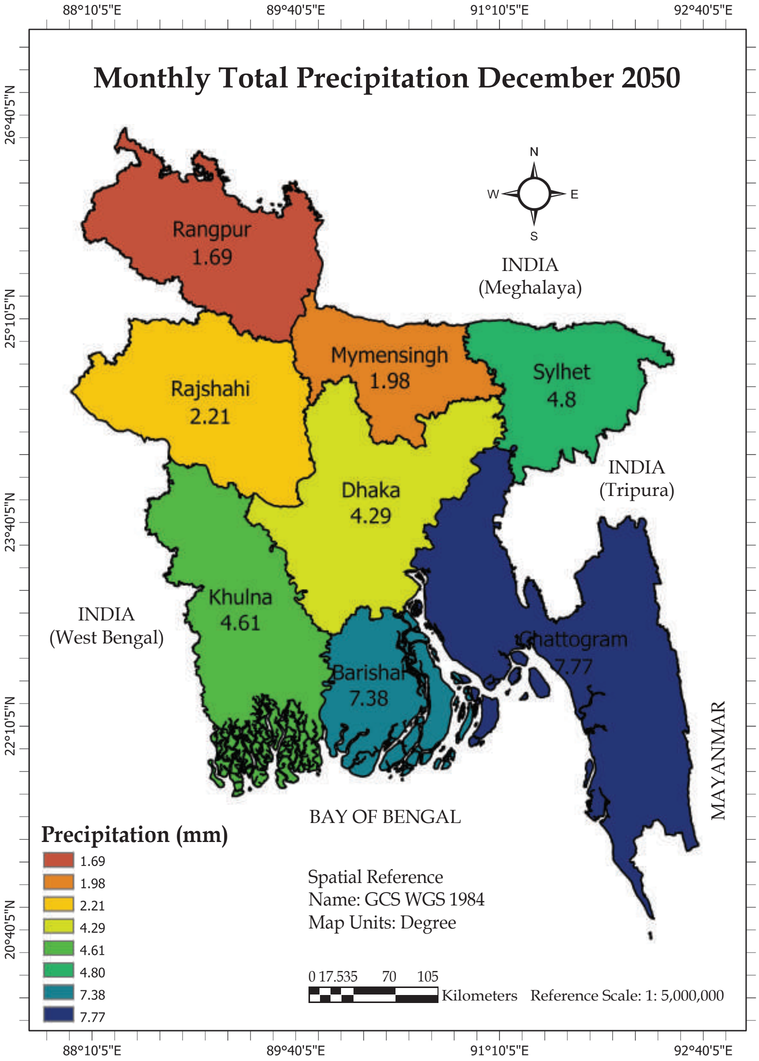


Figure 142. Division wise December month average of total precipitation for the year 2050 according to RCP 4.5

Figure 142 shows a division-wise forecasting and found that the highest precipitation will be in Chattogram division (7.77 mm) followed by Barishal division (7.38 mm). The lowest precipitation will be in Rangpur division (1.69 mm) followed by Mymensingh (1.98 mm) in 2050.

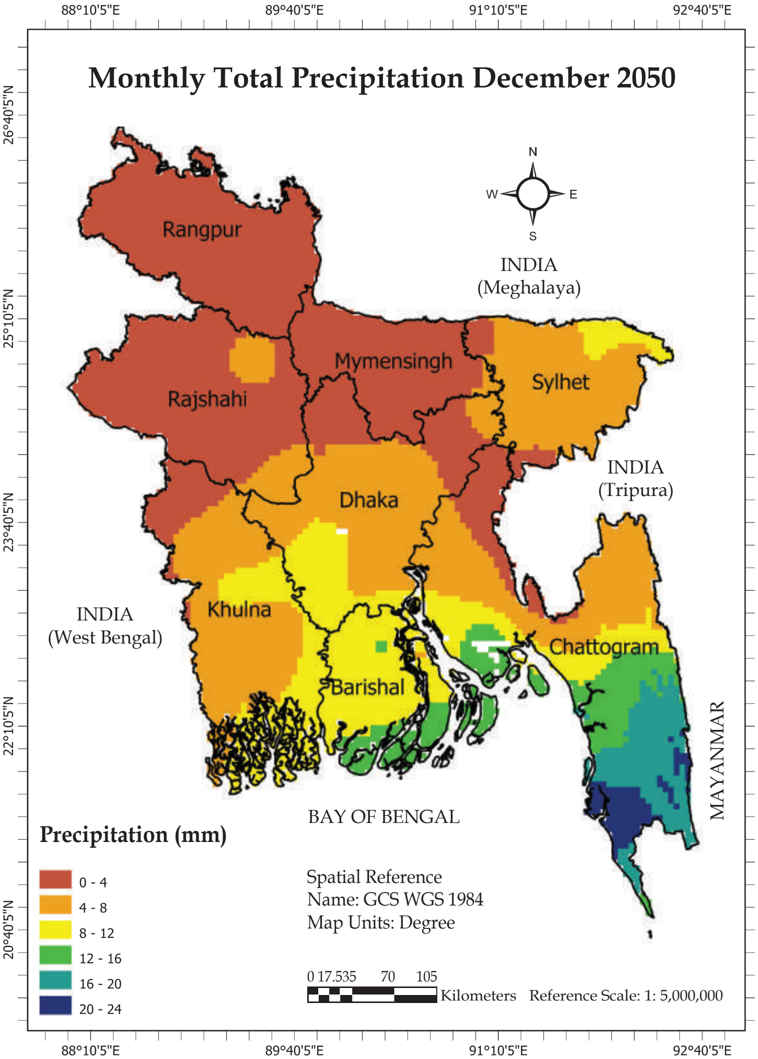


Figure 143. December month average of total precipitation for the year 2050 according to RCP 6.0

Figure 143 describes the forecasted December month average precipitation of Bangladesh by RCP 6.0 model, where the precipitation condition of Bangladesh is showing to be almost the same as the RCP 2.6 and 4.5 models forecast.

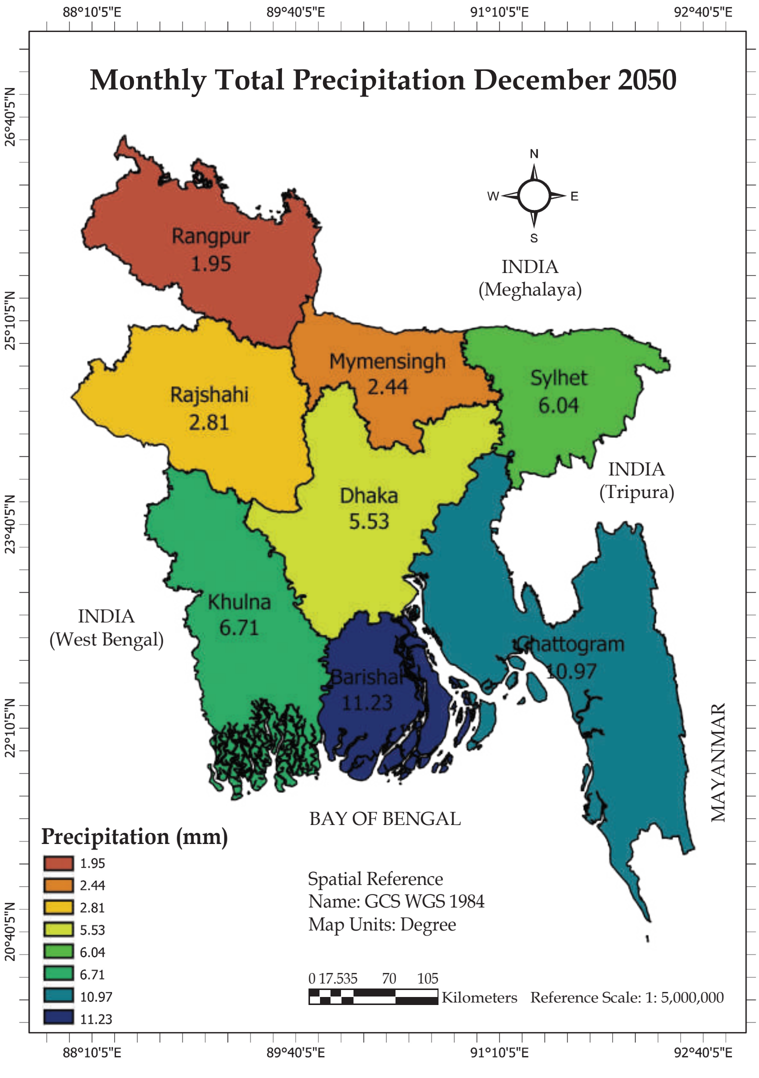


Figure 144. Division wise December month average of total precipitation for the year 2050 according to RCP 6.0

Figure 144 shows that the highest precipitation will be in Barishal division (11.23 mm) followed by Chattogram division (10.97 mm). The lowest precipitation will be Rangpur division (1.95 mm) in 2050.

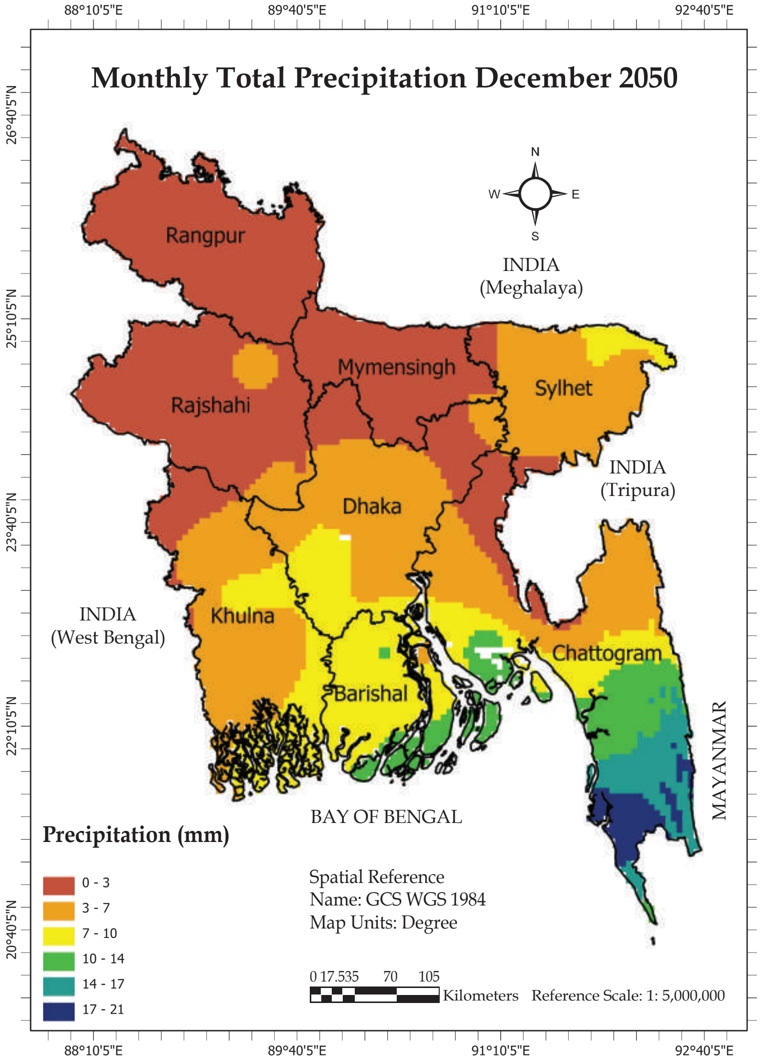


Figure 145. December month average of total precipitation for the year 2050 according to RCP 8.5

Figure 145 is explaining the forecasted December month average precipitation of Bangladesh according to RCP 8.5 model. The precipitation condition of Bangladesh is showing to be almost similar with the RCP 2.6, 4.5, and 6.0 models.

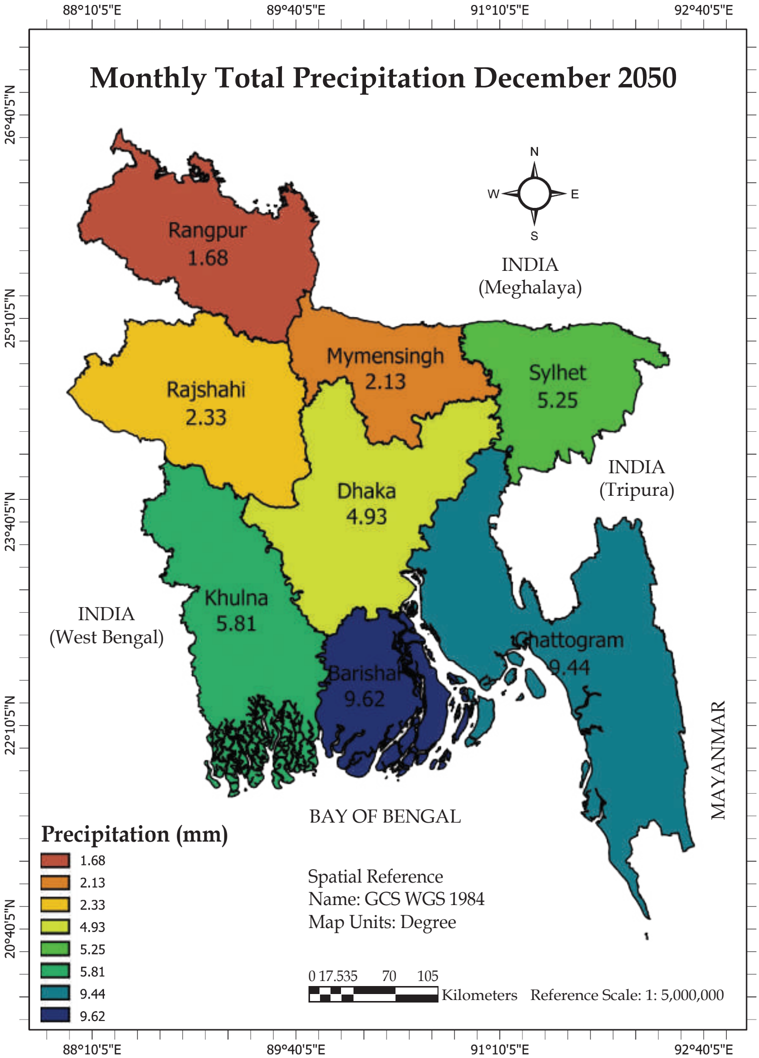


Figure 146. Division wise December month average of total precipitation for the year 2050 according to RCP 8.5

Figure 146 is showing that the highest precipitation division will be Barishal (9.62 mm) and lowest precipitation division will be Rangpur (1.68 mm) in 2050.

Table 14: Summary of December month average total precipitation of 1970 to 2000, 2010 to 2018 and forecasted 2050 (By RCP model 2.6, 4.5, 6.0 and 8.5)

Division	Average Precipitation (mm) 1970 to 2000	Average Precipitation (mm) 2010 to 2018	Precipitation (mm) 2050 (RCP 2.6)	Precipitation (mm) 2050 (RCP 4.5)	Precipitation (mm) 2050 (RCP 6.0)	Precipitation (mm) 2050 (RCP 8.5)	Average of Precipitation (mm) 2050 (RCP 2.6, 4.5, 6.0 and 8.5)	Change of Precipitation (mm) 2050 to 2010-2018
Barishal	10.51	12.08	9.93	7.38	11.23	9.62	9.54	-2.54
Chattogram	8.91	8.7	9.72	7.77	10.97	9.44	9.48	0.78
Dhaka	8.38	8.37	5.51	4.29	5.53	4.93	5.07	-3.30
Khulna	8.45	9.73	6.26	4.61	6.71	5.81	5.85	-3.88
Mymensingh	2.59	2.15	2.46	1.98	2.44	2.13	2.25	0.10
Rajshahi	3.27	2.83	2.76	2.21	2.81	2.33	2.53	-0.30
Rangpur	3.04	2.17	2.05	1.69	1.95	1.68	1.84	-0.33
Sylhet	7.78	5.94	5.96	4.80	6.04	5.25	5.51	-0.43

From the Table 14 represents that in all divisions of Bangladesh average total precipitation (Average by RCP 2.6, 4.5, 6.0, and 8.5 models) of December month in 2050 will be decreased in comparison to average total precipitation during 2010-2018, only exceptions are Chattogram and Mymensingh divisions where precipitation will be increased a little.

7 POLICY IMPLICATION

7.1 Background

The Bangladesh Delta Plan (BDP) 2100 is a comprehensive, long-term strategy for managing water and land across Bangladesh. In the face of the opportunities and challenges that arise from the intersection of water, climate change, and human activity, it supports the nation's long-term progress. Precipitation prediction scenario is important for water governance and management decision.

Agriculture is the basic element of development. Future precipitation prediction and agricultural production are closely related, as accurate and reliable precipitation forecasts can significantly impact the success and sustainability of agricultural production. Accurate precipitation forecasting is essential to enhancing yield by enabling farmers to make choices regarding planting, irrigation, and fertilizing. Farmers can use water more efficiently and boost yields by having a better understanding of anticipated precipitation patterns, which will eventually result in increased crop yields and improved food security. Additionally, it can assist with risk management and disaster planning in the case of severe weather.

This section of the study is formed to summarize the potential impacts of future precipitation in Bangladesh and the way out of its policy implication in the context of Bangladesh. However, the mentioned implications are also suitable for countries having challenges of climate change like Bangladesh.

7.2 Impacts of Change in Precipitation Pattern

Decreased precipitation: A decrease in precipitation can result in water scarcity and reduced crop yields, particularly in regions that are already facing water stress. Policy-relevant messages include promoting water conservation practices, investing in water storage infrastructure, and developing drought-resistant crops.

Increased precipitation: An increase in precipitation can lead to flooding, soil erosion, and damage to crops. Policy-relevant messages include investing in drainage systems, improving land management practices, and promoting the development of crops that are more resistant to excessive water.

Extreme precipitation events: Extreme precipitation events, such as heavy rainfall or severe droughts, can result in significant damage to crops and infrastructure. Policy-relevant messages include investing in disaster preparedness and risk management, promoting the use of early warning systems, and supporting the development of crops that are more resilient to extreme weather conditions.

Shifts in precipitation patterns: Changes in precipitation patterns can result in shifts in crop production patterns, leading to changes in food availability and prices. Policy-relevant messages include investing in agricultural research and development, promoting the use of climate-smart agriculture practices, and developing early warning systems to respond to changes in precipitation patterns.

Climate change: The impacts of climate change on precipitation patterns are complex and uncertain, but are likely to result in changes in the distribution, frequency, and intensity of precipitation events. Policy-relevant messages include reducing greenhouse gas emissions, promoting climate-resilient agriculture, and supporting the development of new climate-smart agriculture practices.

Water management: Changes in precipitation patterns can have significant impacts on water management practices, particularly in areas that are already facing water stress. Policy-relevant messages include investing in water conservation and storage infrastructure, promoting efficient water use practices, and encouraging the development of drought-resistant crops.

Agriculture and food security: Changes in precipitation patterns can have significant impacts on agriculture and food security, particularly in regions that are heavily dependent on agriculture. Policy-relevant messages include promoting climate-resilient agriculture practices, supporting the development of new crop varieties that are better adapted to changing precipitation patterns, and investing in agricultural research and development.

Ecosystem services: Changes in precipitation patterns can have significant impacts on ecosystem services, such as soil fertility and water quality. Policy-relevant messages include promoting sustainable land use practices, protecting natural ecosystems and their ability to provide ecosystem services, and investing in soil conservation and restoration efforts.

Human health: Changes in precipitation patterns can have significant impacts on human health, particularly in regions that are vulnerable to water-borne diseases. Policy-relevant messages include investing in water and sanitation infrastructure, promoting water conservation practices, and supporting public health efforts to prevent and respond to water-borne diseases.

Integration with other policy areas: Addressing the impacts of precipitation on rice production requires an integrated approach that considers the interplay of multiple factors, such as water management, agriculture and food security, ecosystem services, and human health. Policy-relevant messages include promoting inter-sectoral collaboration, integrating climate-smart agriculture practices into other development initiatives, and supporting research and development efforts to address the challenges posed by changing precipitation patterns.

7.3 Benefits of Precipitation Scenario

Taking action to address the impacts of precipitation can have multiple benefits, including:

Improved water management: Effective water management practices can help to mitigate the impacts of water scarcity and improve water availability for agriculture, particularly in areas that are already facing water stress.

Increased crop productivity: Investing in climate-resilient agriculture practices, such as the development of drought-resistant crops, can help to improve crop productivity and ensure food security in the face of changing precipitation patterns.

Reduced risks from extreme weather events: Implementing disaster preparedness and risk management strategies, such as early warning systems, can help to reduce the risks from extreme weather events, such as heavy rainfall or severe droughts.

Improved human health: Investing in water and sanitation infrastructure, promoting water conservation practices, and supporting public health efforts can help to improve human health, particularly in regions that are vulnerable to water-borne diseases.

Enhanced ecosystem services: Promoting sustainable land use practices and protecting natural ecosystems can help to enhance ecosystem services, such as soil fertility and water quality, and promote sustainable agriculture.

Climate change mitigation: Reducing greenhouse gas emissions and promoting climate-smart agriculture practices can help to mitigate the impacts of climate change and reduce the risks posed by changing precipitation patterns.

Improved food security: Ensuring food security in the face of changing precipitation patterns requires an integrated approach that considers the interplay of multiple factors, including water management, agriculture and food security, ecosystem services, and human health.

Increased economic growth: Investing in agricultural research and development, promoting the use of climate-smart agriculture practices, and supporting the development of new crops can help to increase agricultural productivity and drive economic growth.

Increased agricultural income: Improving crop productivity and promoting climate-smart agriculture practices can help to increase agricultural income and support rural livelihoods.

Better natural resource management: Implementing sustainable land use practices, promoting water conservation, and protecting natural ecosystems can help to improve natural resource management and reduce the risk of environmental degradation.

Improved energy security: Promoting the use of renewable energy sources, such as solar or wind power, and reducing greenhouse gas emissions can help to improve energy security and reduce dependence on fossil fuels.

Better disaster response and preparedness: Investing in disaster preparedness and risk management strategies, such as early warning systems, can help to reduce the risks from extreme weather events and improve disaster response efforts.

Increased access to finance: Investing in agricultural research and development, promoting the use of climate-smart agriculture practices, and supporting the development of new crops can help to increase access to finance for farmers, particularly smallholder farmers who are most vulnerable to the impacts of changing precipitation patterns.

Improved governance: Encouraging inter-sectoral collaboration, integrating climate-smart agriculture practices into other development initiatives, and supporting research and development efforts to address the challenges posed by changing precipitation patterns can help to improve governance and promote sustainable development.

7.4 Potential Impacts on Bangladesh

In Bangladesh, divisional precipitation prediction scenarios can be used to understand the potential impacts of changing precipitation patterns on different regions of the country. Bangladesh is divided into eight administrative divisions, each with its own unique climate and precipitation patterns. By developing divisional precipitation prediction scenarios, it is possible to assess the potential impacts of changing precipitation patterns on each division and to identify the regions that are most vulnerable to water scarcity or extreme weather events.

For example, the divisional precipitation prediction scenarios in Bangladesh may show that the northern divisions, such as Rangpur or Rajshahi, are likely to face increased water stress due to declining rainfall and increasing temperatures. On the other hand, the coastal divisions, such as Chittagong or Barisal, may be more vulnerable to extreme weather events, such as cyclones or floods, due to the changing precipitation patterns and sea level rise.

By understanding the divisional precipitation prediction scenarios in Bangladesh, it is possible to target investments in climate-resilient agriculture, water management, and disaster preparedness efforts more effectively, ensuring that resources are directed to the regions that need them most. Moreover, divisional precipitation prediction scenarios can inform decision-making at the local, regional, and national levels, helping to build a more resilient and sustainable future for the country.

Future precipitation prediction scenarios are critical for building a more resilient and sustainable future for Bangladesh, ensuring that the country is better prepared to meet the challenges posed by changing precipitation patterns. By doing so, it is possible to support sustainable development, improve food security, and reduce the risks posed by water scarcity and extreme weather events.

Agriculture: Bangladesh is heavily dependent on agriculture, and precipitation patterns have a direct impact on crop productivity and rural livelihoods. By understanding future precipitation patterns, it is possible to plan for and mitigate the impacts of water scarcity and extreme weather events, improving food security and supporting sustainable agriculture.

Water management: Bangladesh is a water-stressed country, with high levels of water scarcity, particularly during the dry season. Understanding future precipitation patterns is critical for improving water management and reducing the risks posed by water scarcity.

Climate resilience: Bangladesh is one of the most vulnerable countries to the impacts of climate change, including sea-level rise, increased frequency of extreme weather events, and changing precipitation patterns. By understanding future precipitation patterns, it is possible to build a more resilient and sustainable future for Bangladesh, reducing the risks posed by changing climate patterns.

Decision-making: Future precipitation prediction scenarios can inform decision-making, guiding investment in sustainable development, and promoting inter-sectoral collaboration to address the challenges posed by changing precipitation patterns.

Sustainable development: By understanding future precipitation patterns, it is possible to support the achievement of the Sustainable Development Goals (SDGs), including SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), and SDG 13 (Climate Action), by promoting sustainable and climate-resilient agriculture, improving water management, and reducing the risks posed by changing precipitation patterns.

Disaster risk reduction: Bangladesh is prone to natural disasters such as floods, cyclones, and drought, which can have devastating impacts on the economy, environment, and communities. Understanding future precipitation patterns is critical for improving disaster risk reduction efforts and reducing the impacts of extreme weather events.

Water resources management: Bangladesh has limited water resources, and future precipitation patterns will have a direct impact on the availability and distribution of water. By understanding future precipitation patterns, it is possible to improve water resources management and reduce the risks posed by water scarcity.

Energy security: Bangladesh is dependent on hydropower for energy generation, and future precipitation patterns will have a direct impact on energy security. Understanding future precipitation patterns is critical for improving energy security and reducing the risks posed by changes in water availability.

Infrastructure planning: Bangladesh is undergoing rapid urbanization, and the infrastructure required to support this growth must be resilient to changing precipitation patterns. Understanding future precipitation patterns is critical for planning and investing in climate-resilient infrastructure.

Environmental conservation: Bangladesh is rich in biodiversity, and the country’s ecosystems play a vital role in maintaining ecosystem services and supporting sustainable development. Understanding future precipitation patterns is critical for conserving the country’s biodiversity and reducing the impacts of changing climate patterns.

7.5 Importance of Future Precipitation Prediction Scenarios in the Agricultural Sector of Bangladesh

Future precipitation prediction scenarios are of vital importance for the agricultural sector of Bangladesh, as they provide insight into the potential impacts of changing precipitation patterns on the country's agriculture sector and the farmers who depend on it. It is possible to improve agriculture and reduce the risks posed by changing precipitation patterns, supporting sustainable agriculture, food security, and disaster risk reduction.

Importance for sustainable agriculture: Future precipitation patterns will have a direct impact on the availability and distribution of water, which is critical for the success of agriculture in Bangladesh. Understanding future precipitation prediction scenarios is critical for improving the efficiency of water use, reducing the risks posed by water scarcity, and supporting sustainable agriculture.

Key to adapting to climate change: Bangladesh is vulnerable to the impacts of climate change, including changing precipitation patterns, increased frequency of extreme weather events, and rising temperatures. Understanding future precipitation prediction scenarios is critical for improving the adaptation of the agricultural sector to the impacts of climate change and reducing the risks posed by changing precipitation patterns.

Essential for food security: Bangladesh's agricultural sector is a critical component of the country's food security, and improving agriculture will have a direct impact on food security. Understanding future precipitation prediction scenarios is critical for improving food security and reducing the risks posed by water scarcity and extreme weather events.

Inform decision-making: Future precipitation prediction scenarios provide essential information for decision-making in the agricultural sector, including crop planning, irrigation planning, and investment in climate-resilient infrastructure. By understanding future precipitation patterns, it is possible to make informed decisions that reduce the risks posed by changing precipitation patterns and support sustainable agriculture.

Essential for improving disaster risk reduction: Bangladesh is prone to natural disasters such as floods, cyclones, and drought, which can have devastating impacts on the economy, environment, and communities. Understanding future precipitation prediction scenarios is critical for improving disaster risk reduction efforts and reducing the impacts of extreme weather events on the agricultural sector.

7.6 The Implication of Precipitation Prediction in Rice Production

In addition to optimizing water use and improving yields, future precipitation prediction has several key uses in rice production:

Timing of planting: Precise precipitation forecasts help farmers determine the optimal time to plant, ensuring that the crop has enough water to grow properly.

Irrigation planning: By predicting future precipitation, farmers can determine how much irrigation will be needed and when allowing them to conserve water and reduce costs.

Fertilization planning: Precipitation prediction can also inform farmers about the optimal times to apply fertilizers, ensuring that the crop receives the necessary nutrients at the right time.

Adaptation to climate change: With changing climate patterns, future precipitation prediction is becoming increasingly important for the rice industry to adapt and prepare for potential shifts in rainfall patterns and water availability.

Risk management: Precise precipitation predictions can help farmers prepare for and mitigate the impact of extreme weather events such as droughts or heavy rainfall, reducing the risk of crop losses and increasing resilience.

Overall, future precipitation prediction plays a crucial role in ensuring the success and sustainability of rice production, and its impact will only continue to grow as climate change becomes an increasingly pressing concern.

Crop planning and selection: By knowing the expected precipitation patterns in the coming years, farmers can plan and select the appropriate crop varieties to plant, which are well-adapted to the local climate conditions.

Infrastructure planning: Long-term precipitation predictions can inform decisions about the construction of irrigation systems and water storage facilities, ensuring that they are designed to meet the future water needs of the crops.

Resource allocation: By having a better understanding of future precipitation patterns, farmers and organizations can make informed decisions about resource allocation, such as budgeting for irrigation systems, water storage, and other infrastructure.

Climate-smart agriculture: A long-term precipitation prediction is an important tool for the implementation of climate-smart agriculture practices, allowing farmers to make informed decisions about water management, crop selection, and fertilization.

Policy formulation: Precise long-term precipitation predictions can also inform government and policymakers in developing strategies for adapting to and mitigating the impacts of climate change on agriculture and food security.

7.7 Policy-Relevant Messages

Prediction scenarios in Bangladesh involve understanding the potential impacts of changing precipitation patterns on different regions of the country. The interpretation of these scenarios can help to inform policy decisions, guide resource allocation, and support decision-making for sustainable development.

In general, the interpretation of divisional precipitation prediction scenarios in Bangladesh would highlight the following key points:

Vulnerability of different regions: The scenarios can help to identify the regions that are most vulnerable to water scarcity, flood, extreme weather events, or other impacts of changing precipitation patterns.

Impacts on agriculture: The scenarios can help to assess the potential impacts of changing precipitation patterns on agriculture, including crop productivity, the likelihood of crop loss, and the availability of irrigation water.

Adaptation strategies: The scenarios can inform the development of adaptation strategies, such as water management, climate-resilient agriculture, and disaster preparedness efforts, to reduce the risks posed by changing precipitation patterns.

Resource allocation: The scenarios can help to guide the allocation of resources, including investment in climate-smart agriculture, water management, and disaster preparedness efforts.

Climate risk assessment: The scenarios can inform a comprehensive climate risk assessment for each division, helping to identify the key risks posed by changing precipitation patterns, including water scarcity, crop failures, and increased frequency of extreme weather events.

Local and regional impacts: The scenarios can highlight the local and regional impacts of changing precipitation patterns, including the impact on local communities, ecosystem services, and regional economies.

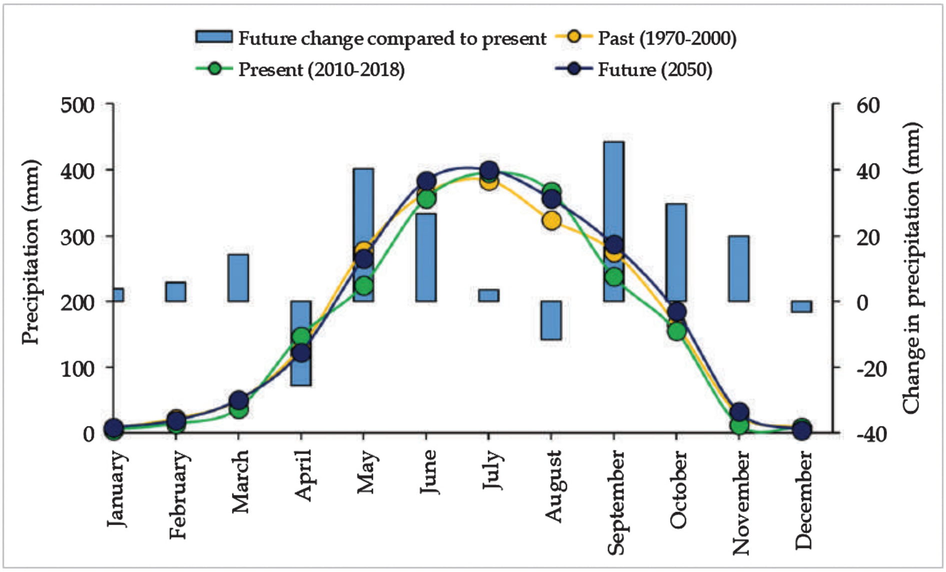
Future trends: The scenarios can provide insight into future trends in precipitation patterns, helping to inform long-term planning and investment in climate-resilient and adaptation actions. Also, would help to identify hot spots for generating actionable climate-smart strategic decisions.

Impact on health: The scenarios can assess the potential impacts of changing precipitation patterns on human health, including the risk of water-borne diseases, food insecurity, and malnutrition.

Sustainable development goals: The scenarios can support the achievement of the Sustainable Development Goals (SDGs), including SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), and SDG 13 (Climate Action), by promoting sustainable and climate-resilient agriculture, improving water management, and reducing the risks posed by changing precipitation patterns.

7.8 Precipitation Projection in Bangladesh: Implications for Rice Crop

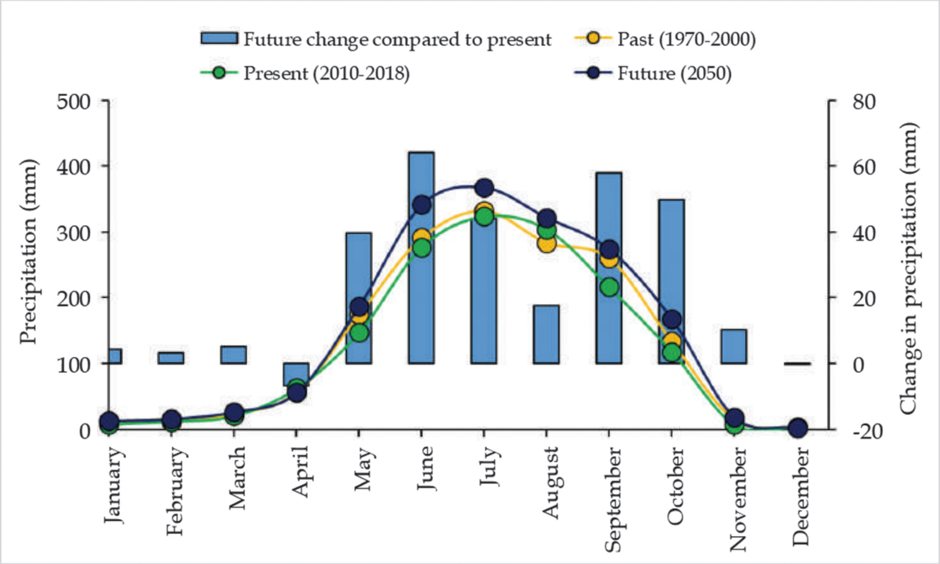
Dhaka



In Dhaka division, the future precipitation pattern over the months of a year will be almost similar to the past and present precipitation of the respective months, i.e., very low precipitation in January and February, in March precipitation start increase and goes to pick in July and start decreasing and comes to very low again in November and December. However, in the year 2050, the precipitation will be increased in the months with the exception for April, August, and December. The increment will be the highest in September (about 50mm) followed by May (about 40 mm). On the other hand, the least precipitation will be in April (about 25mm decreased). The yearly average precipitation in Dhaka division will be increased in 2050 (Figure XX). At present, the precipitation in July is the highest. Almost 70% of the total precipitation occurred in that month. The future projection shows that the highest precipitation in Dhaka division might shift to May and/or June than July in 2050. However, it is important to note that weather patterns can be highly variable and difficult to predict with certainty, especially over longer timeframes, as the direction of momentum can change anytime. Therefore, it is important to continue monitoring weather patterns and use updated information from reputable sources such as the Bangladesh Meteorological Department to inform decisions about water management, agriculture, and other activities that may be affected by precipitation patterns.

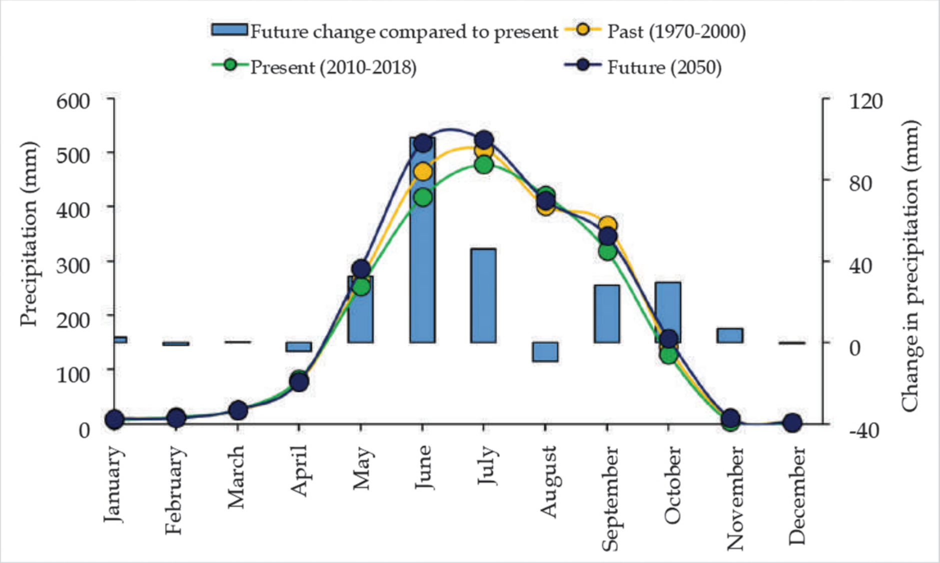
Increased rainfall in May and November can have a positive impact on paddy cultivation as it helps prepare the land for transplantation. Farmers in our country usually plant Aman paddy in May and Boro paddy in November. Rainfall projections for 2050 show an increase of about 41 mm of rainfall in May and about 20 mm in November. Adequate rainfall during the early stage of crop growth is crucial for good crop establishment, and an increase in rainfall during these months can improve the chances of a successful crop. However, it's important to note that too much rainfall can also have a negative impact on paddy cultivation, leading to waterlogging, flooding, and other related problems. Hence, farmers need to carefully monitor and manage the water supply during the growing season to ensure optimal crop growth. Moreover, Aman and Boro seasons paddy are harvested in October and April, respectively. The analysis shows that the rainfall in 2050 will be less than the present. The projected decrease in rainfall during the harvest season can be beneficial for farmers, as it can help in drying out the fields and facilitating the harvesting and storage of paddy.

Rajshahi



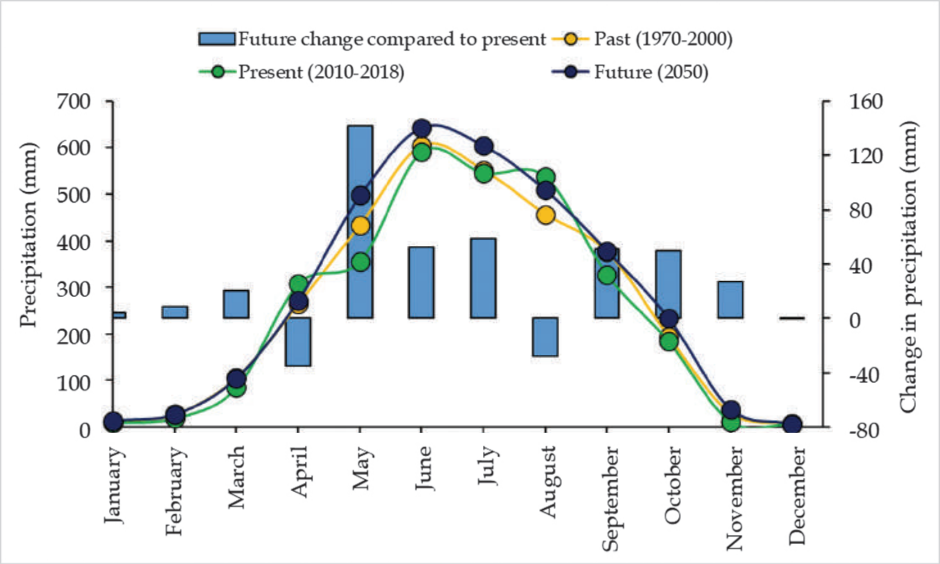
Like the present scenario, most of Rajshahi's precipitation will occur between May and October, with July and June serving as the wettest months. Precipitation will increase in all months but April, with the highest rates of increment in June, followed by September, October, and July. Again, increased rainfall in May and November will benefit Aman and Boro plantations. Due to the approximately 55mm more rainfall in October than the current situation, Aman harvesting may be hampered during 2050. The future precipitation pattern in the Dhaka division might shift to be higher in June than July. However, the future precipitation in May might be similar to the present scenario (Figure XX).

Rangpur



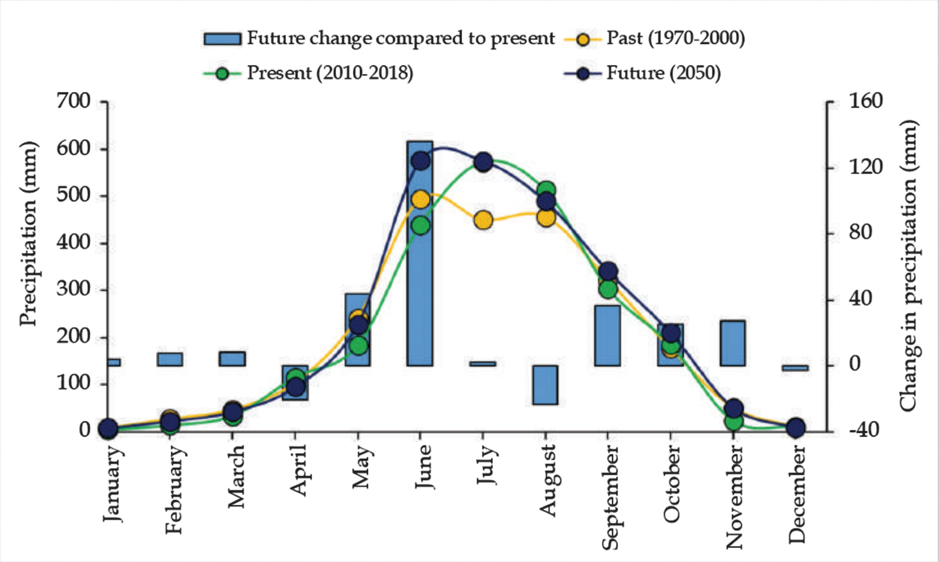
The past, present, and future monthly precipitation pattern of Rangpur division is presented by Figure XX. In 2050, all months will see an increase in precipitation, the only exception is August. June will see a very high increase in precipitation, resulting in two peak months (June and July), which will be much deviation from the current situation (only one peak in July). Like present, most of the rain in 2050 will fall between May and September. May's increased precipitation might be advantageous for Aman transplanting. In case of Rangpur, there may have higher precipitation in June than in July and it might be also similar to the present scenario in May.

Sylhet



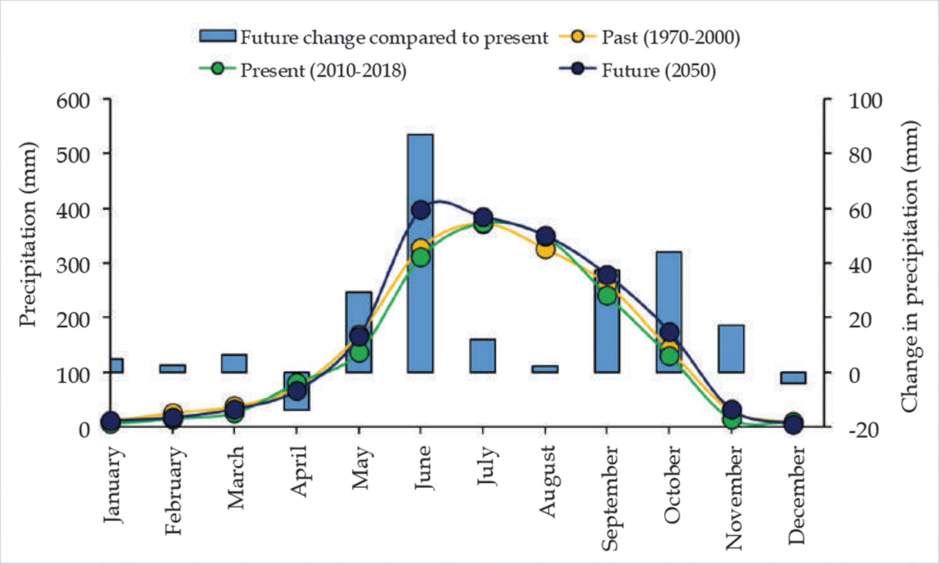
In Sylhet division, all months will have more precipitation than present, only exceptions are April, and August. As like as present situation, June will have the highest precipitation in 2050. The precipitation increment will be the highest in May month. The precipitation amount will be more than 300mm during April to September months. Usually, Sylhet has the highest precipitation and so will be in 2050. More rain in May and November will help paddy farming in the Sylhet division as well. Aman harvesting might be impeded by the roughly 49 mm more rainfall in October than the present amount. The precipitation might be higher in May than that of July (Figure XX).

Barishal



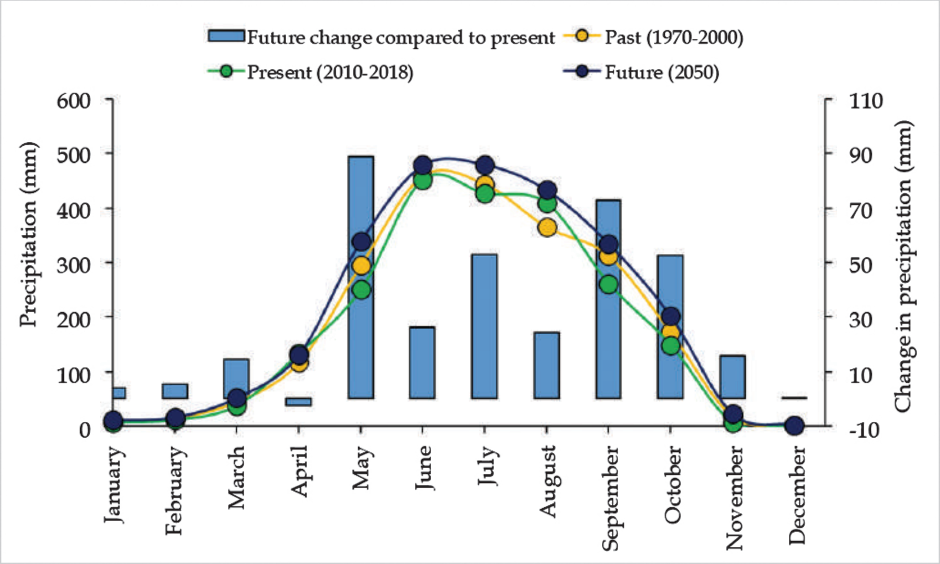
In Barishal, increment of precipitation in 2050 will be the highest in June month in compared to present condition and June will be the peak precipitated month rather than July (the current peak). The precipitation will increase in every month, the exceptions are April and August. Like other divisions, paddy transplanting will be beneficial with more rains in May and November, for Aman and Boro seasons, respectively. The precipitation in Barishal might be higher in May and June than in July (Figure XX).

Khulna



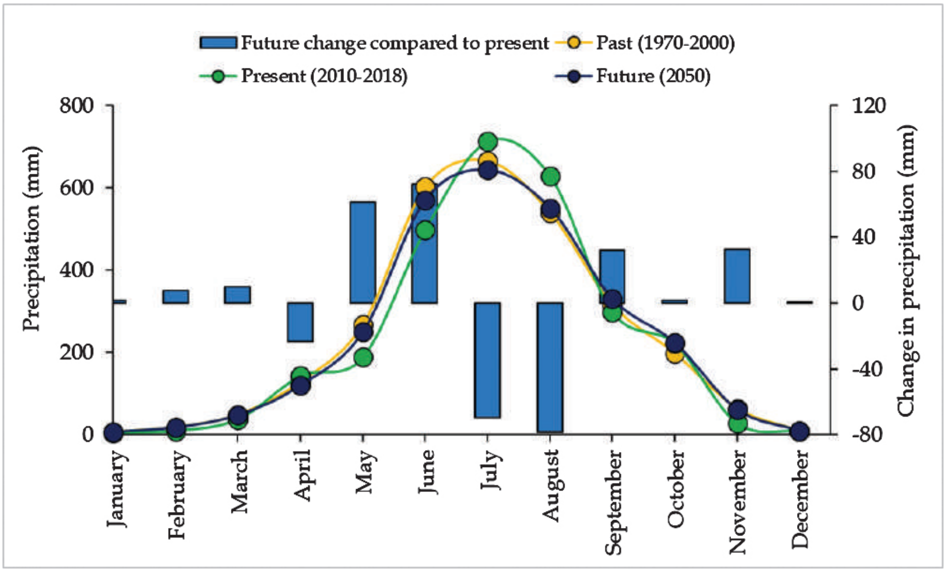
The future projection shows that the only April and December months will be having decreasing precipitation in the Khulna division (Figure XX). Precipitation will increase in June by the most amount (around 85mm) compared to current precipitation. June will also be the month with the most precipitation (about 400mm), followed by July. It seems the paddy farmers will get the benefit of increased rainfall in May and November, for transplanting Aman and Boro paddy, respectively. However, a 40mm more rainfall than present might hamper Aman harvesting in October. Like Dhaka and Barishal, in Khulna, the precipitation might be higher in May and June than July.

Mymensingh



The distribution of future precipitation by month in the Mymensingh division will be almost like the past and present scenarios (Figure XX). The peak precipitation months will be June and July. Precipitation totals from June through September will remain over 300mm. Precipitation will increase the most in May month than it is now, followed by September and October. Aman and Boro seasons' transplanting of paddy in May and November, respectively, more rain than at present (May about 89mm and November about 15mm) will help paddy farming. It might be more challenging to harvest Aman because there was roughly 55mm more rain in October than that is right now. Like Sylhet, the precipitation might be higher in May than July at Mymensingh division.

Chottogram



In Chattogram division, July will be the highest precipitated month though this month will have the second highest reduction of precipitated (Figure XX). The highest reduction in precipitation will be in August. Monthly distribution of precipitation in the future will be almost like the past and present scenarios. More rainfall in May and November, generally will create a more suitable environment for Aman and Boro paddy transplanting, respectively. Like Dhaka, Khulna and Barishal, the future precipitation in Chattogram division might be higher in May and June than July.

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EXECUTIVE SUMMARY

Bangladesh is still significantly reliant on agriculture, and agriculture has a significant relation with climate. Bangladesh's food production is threatened by climate change. Predicting future climate changes is extremely crucial for smart agricultural planning and adapting to climate change. Precipitation is an important climatic factor and play a vital role in agricultural production. Thus prediction of precipitation is helpful for agricultural planners and decision makers. The Coupled Model Intercomparison Project (CMIP) is a cooperative framework in climatology that aims to increase climate change knowledge organized by World Climate Research Programme's (WCRP) is co-sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of UNESCO and the International Science Council. The fifth and sixth phases of the Coupled Model Intercomparison Project (CMIP5) produce a cutting-edge multi-model dataset aimed at improving our understanding of climate variability and change. CMIP5 simulations are being carried out by more than 20 modeling groups utilizing more than 50 models. In this study, we attempted to create monthly precipitation maps of Bangladesh divided into three phases: past (1970-2000), present (2000-2018), and future (2040-2060 or 2050) by forecasting precipitation results from GCMs of CMIP5 and CMIP6 and comparing projected precipitation with observed precipitation. The study focuses on precipitation projections for all four Representative Concentration Pathways (i.e., RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5). The four RCPs constitute 'low' (RCP 2.6),'medium' (RCP 4.5), 'high' (RCP 6.0), and 'very high' (RCP 8.5), greenhouse gas concentration (rather than emissions) trajectory scenarios. To assemble and analyze climate data and generate precipitation maps, we used GIS techniques such as raster statistics, raster extraction, and zonal statistics. All month's precipitation will be increased except April, August and November. Like the present situation in 2050, eastern side of Bangladesh will have the highest precipitation area and the lowest precipitation area will be the north-western side of Bangladesh. Different RCP model implies different result but differences are not so significant. The findings would be useful to formulate agricultural plan under the climate change situation in Bangladesh.

DOI- https://doi.org/10.59036/978-984-35-3975-5

978-984-35-3975-5