BANGLADESH DELTA PLAN 2100

Baseline Studies : Volume 2

Disaster and Environmental Management

Editors
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Baseline Studies on
Disaster and Environmental Management

Volume 2

Baseline Study 8: Climate Change
Baseline Study 9: Disaster Management
Baseline Study 10: Environmental Pollution
Baseline Study 11: Ecological Setting

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June 2018

BDP 2100 Publication No. 02

Baseline Studies on Disaster and Environmental Management

June 2018

Technical Assistance

BanDuDeltAS (Bangladesh-Dutch Delta Advisory Services) consisting of Twynstra Gudde (Lead Partner), Deltares, ECORYS, D.EFAC.TO, Euroconsult-Mott MacDonald, Wageningen University and Research Centre, Witteveen+Bos, UNESCO-IHE. Subcontractors are Climate Adaptation Services Foundation, Center for Environmental and Geographic Information Services (CEGIS), Institute of Water Modelling (IWM).

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Prepared and Published by
Bangladesh Delta Plan (BDP) 2100 Formulation Project

General Economics Division (GED)
Bangladesh Planning Commission
Government of the People's Republic of Bangladesh
Sher-e-Bangla Nagar, Dhaka 1207, Bangladesh
www.plancom.gov.bd

Disclaimer

Baseline studies were conducted to review past performances, to generate information and knowledge, identify caveats and draw policy lessons and observe inter-sectoral impacts relating to water resources, land and agricultural practices, and analyse climate change impacts. All these have been done to formulate delta action plan based on strategies developed through research by eminent scientists and professionals. Data, information and statements provided in the studies entirely belong to the authors, as such, GED bears no responsibility of inaccuracy, if any of data or statement.

Printed by
The Goodluck Printers
13, naya Paltan Dhaka-1000

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

Message

I am happy to know that the General Economics Division (GED) of Bangladesh Planning Commission is publishing the Baseline Studies in six (6) volumes which were prepared for formulation of the Bangladesh Delta Plan (BDP) 2100.

Over the past 47 years since independence Bangladesh has secured tremendous gains in development. Bangladesh has achieved food self-sufficiency and the economy is gradually transforming from an agrarian base towards a modern manufacturing and services economy. Making this growth sustainable is even more challenging in the face of extreme adverse climate variability, with frequent storm and tidal surges, flooding, and droughts. I am confident that the BDP 2100 will amply guide us in realizing the vision that is aspired in the plan of being a prosperous country beyond 2041 and also contribute directly in making the growth sustainable by ensuring long term water and food security, economic growth and environmental sustainability while effectively reducing vulnerability to natural disasters and building resilience to climate change and other delta challenges. I hope BDP 2100 will also contribute to the making of 5 year plans as well as contribute to achieving SDG's and other national policy goals.

The Baseline Studies generated both quantitative and qualitative benchmark information for relevant subject areas of the plan and identified critical areas for future intervention. It also forms the basis for determining strategies and measures that have been suggested in BDP 2100 for different climatic Hotspots.

I am particularly pleased to note that BDP 2100 being a techno-economic plan, is the first attempt in our national planning history to formulate a real long term plan prepared by GED. The publication of the Baseline Studies in book form which served as basis for the preparation of the BDP 2100 has immense importance to keep the institutional memory preserved. These will be useful references to the policymakers, development partners, academics, researchers, students and professionals alike to further research endeavor and knowledge sharing.

In this instance, I would congratulate relevant officials of GED of Bangladesh Planning Commission for their hard work in compiling the Baseline Studies in book form. My sincere appreciation goes to the experts in their respective fields for completing the Background Studies for formulation of the BDP 2100.

(A H M Mustafa Kamal, FCA, MP)

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

Message

It gives me immense pleasure to learn that the General Economics Division (GED) of Bangladesh Planning Commission is going to publish 26 Baseline Studies in six (6) volumes which have been used as the inputs for preparing the country's first long term Plan i.e. Bangladesh Delta Plan (BDP) 2100. The Baseline Studies of BDP 2100 are the culmination of both quantitative and qualitative benchmark information for relevant subject areas of the plan and identified critical areas for future intervention. I believe, GED of Bangladesh Planning Commission has pursued with various eminent professionals, scientists, researchers, academia etc. at national and international levels for conducting these Baseline studies.

I know that BDP 2100 is the long term plan for the country to realize sustainable and a commonly agreed upon strategy with specific short, medium and long term interventions involving all relevant stakeholders for an optimum level of water safety and food security as well as sustained economic growth of Bangladesh and a framework for its implementation.

I congratulate the GED for taking up this bold initiative. I would like to thank the authors and also the reviewers who have contributed to prepare these Baseline Studies. Documented Baseline Studies will also be helpful for policy planners, development practitioners, researchers, academicians, professionals and even students as well. I also expect that the Baseline Studies will be useful for the officials of GED to prepare necessary policy briefs and write-ups they often prepare. I believe that not only GED but also other relevant officials will be immensely benefited with these Baseline Studies for upgrading and updating their knowledge and professional competences. Finally, I thank GED leadership for undertaking this endeavor for publishing Baseline Studies of the BDP 2100 for much wider use.

I wish all the best and all out success.

M. A. Mannan, MP

Shamsul Alam
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Prefatory Comments

Bangladesh is one of the largest deltas of the world and its rivers and floodplains support life, livelihood and economy. The country is defined by the delta, with almost a third of the country lying less than 5 (five) metres above sea level, on the contrary however, coastal zone, the low-lying area, is highly vulnerable, especially to cyclones and storm surges. In addition, salt-water intrusion, floods, sea level rise intensify the vulnerability of the community of the areas. These problems are likely to become even worse due to climate change adverse impact.

Many more challenges lie ahead for Bangladesh, the most important being pressure on land use, environmental protection, governance, globalization and macro-economic development. Given the ambition to be a developed country by 2041, addressing the expected impacts of climate change, there is a need for an integrated approach to future land and water management in relation to water safety, agricultural growth and food security. The recent and future anthropogenic changes in the hydrological cycle due to e.g. climate change, construction of dams and barrages in the upstream countries in combination with increasing water demand are expected to make future water governance and management even more challenging.

With a view to meeting the above challenges, the Government of Bangladesh (GoB) requested the Government of the Netherlands (GoN) to assist for formulation of adaptive, multi-sectoral, comprehensive and holistic Delta Plan taking lessons from Dutch experiences. The GoN agreed to provide the necessary support through its Embassy in Dhaka. In accordance with the decision of the Government, the General Economics Division (GED) of the Planning Commission, Ministry of Planning was assigned to lead the formulation of Bangladesh Delta Plan 2100, as the GED is mandated for medium and long term planning at the national level.

Bangladesh Delta Plan 2100 has been conceived as a techno-economic, long-term, holistic, water centric, strategic plan. As such, formulation of strategies in the short (budgeting), medium and long term is the most significant part in the planning process. The long term strategies will help to fulfil the Delta Vision, whereas the short and medium term strategies will help achieve benefits within the country's 5 year planning horizon as well as contribute to achieving SDG's and other national policy goals. An interactive planning process has been followed comprising three major steps: i) Conducting Baseline Studies; ii) Formulation of Adaptive strategies; and iii) Development of the Delta Management Framework. These steps were supported by country wide consultation processes which eventually led to the outcome of an Investment and Implementation Plan.

The project has prepared 26 Baseline Studies on known delta problems, reviewing existing policies and governance challenges in the sector of water resources, land, environment, disaster, agriculture, fisheries, livestock, transportation, finance, governance, knowledge generation etc. The studies followed the basic steps of reviewing the current policy situation, assessing the status of individual sectors, identification of drivers or pressures, conducting integrated analysis for the right interpretation of problems, challenges and knowledge gaps. For starting an integrated analysis with stakeholders it was essential to create an overview of already established and agreed-upon policies as well as to rank priorities for further investigation, research and discussion. The key elements in the approach were (a) knowing the present state, problems, impacts, challenges and current responses or interventions; (b) consideration of uncertainties of social and natural systems and knowledge gaps; (c) the evaluation of drivers, trends or events in the interaction between the delta and society.

These Baseline Reports have been clustered into Six Volumes on the basis of thematic issues and topics.

Volume 1: Water Resources Management consists of seven Baseline Reports: 1. Sixty Years of Water Resources Development in Bangladesh: Lessons Learnt; 2. River System Management; 3. Water Resources; 4. Groundwater; 5. Coast and Polder Issues; 6. Water Supply and Sanitation; 7. Part A- Sediment Management and Part B- Meghna Estuary Study;

Volume 2: Disaster and Environmental Management consists of four Baseline Reports: 8. Climate Change; 9. Disaster Management; 10. Environmental Pollution; 11. Ecological Setting;

Volume 3: Land Use and Infrastructure Development consist of three Baseline Reports: 12. Land Resources Management; 13. Urbanization and Settlement; 14. Sustainable Transportation and Infrastructure;

Volume 4: Agriculture, Food Security and Nutrition consists of four Baseline Reports: 15. Agriculture and Food Security; 16. Fisheries; 17. Livestock; 18. Forests and Biodiversity;

Volume 5: Socio-Economic Aspects of the Bangladesh Delta consist of three Baseline Reports: 19. Population Growth and Management; 20. Socio-Economic and Demographic Condition; 21. Socio-Economic Characteristics of Chittagong Hill Tracts;

Volume 6: Governance and Institutional Development consists of five Baseline Reports: 22. Institutional Framework and Arrangements; 23. Information and Knowledge Management; 24. Regional Cooperation; 25. Financial Mechanisms & Arrangements in the Water Sector in Bangladesh; and 26. Private Sector Engagement in Deltas.

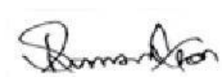
Volume 2: Disaster and Environmental Management

Climate Change: Climate Change is one of the most important themes under the Delta Plan as it would affect almost everything, and as such the topic deserves priority. Moreover, the Delta Plan is a long term plan spanning over hundred years, and it is almost impossible to ignore the impact of climate change, especially during the latter part of the current century. The cluster also contains disaster management, environmental pollution and ecological setting, the other three topics, which are integrally connected with climate change. Disaster is directly related with climate change, the effect of which is the worst in case of disaster and natural calamities like cyclone, storm-surge, flood, salinity intrusion. Climate change can potentially have a negative impact on water safety, food security and sustainable economic growth, the three issues aimed to be improved by the Bangladesh Delta Plan. To reduce climate change vulnerability of the country it is important that information on climate change are documented and shared, so that the Delta Plan can include a strategy to adapt to future climate change. The baseline study tried to review the information available on historic and future climate change in Bangladesh and to outline a method for the development of climate change scenarios for the Bangladesh Delta Plan. Both global and regional climate change scenarios indicate that the historic trends are likely to continue into the future. Temperature will continue to rise and total annual rainfall is likely to increase in the future. The overall impact is an increase in disaster and calamities, disturbing ecological balance and causing environmental pollution.

Disaster Management: The World Risk Report released in 2012 identified Bangladesh to be the 5th most disaster prone country among 173 countries in the world. The main hazards in Bangladesh are: flood, cyclone, storm surge, water logging, salinity intrusion, river bank erosion, etc. The nature and types of the disasters vary geographically within the country. About 230 natural disasters occurred in the country between 1980 and 2010, causing death to 0.19 million people, livelihood loss of $ 320 million and economic loss of $550 million. In terms of death, the cyclonic storm is the most devastating disaster that caused 87% of the total deaths. In terms of livelihood and economy, the flood is the worst disaster that caused losses to 75% of the total affected people. Climate change and (relative) sea level rise are likely to exacerbate the impacts of natural hazards on lives, livelihood and properties in future. In the past, the approach of combating hazards/disasters was mostly limited to providing relief and very inadequate rehabilitation. Since early last decade, Bangladesh got a paradigm shift from conventional relief distribution to a holistic disaster risk reduction approach at all levels and times of disaster events (before, during and after). Now disaster issues got priorities in development planning. It is, therefore, important to make sure that the disaster management is comprehensive and all-hazards focused comprising disaster risk reduction and emergency response.

Environmental Pollution: Environmental Pollution is closely related with the process of overall economic development. The restoration of polluted rivers, prevention and mitigation of environmental pollution, and safeguarding the environmental quality are the challenging issues in integrated development planning. The environmental pollution especially water, air, and soil pollution are hardly addressed in the country’s development strategies and plans. Environmental degradation is affecting economic growth. Lack of proper implementation and monitoring of environmental rules hinder the achievement of environmental goals. There is a good initiative of enforcing installation of an effluent treatment plants (ETP) in industries but effective operation and monitoring of these ETPs are still far away. Only the mega cities like Dhaka, Chittagong, Khulna, and Rajshahi have limited waste management and waste water treatment facilities. Pollutions of river water near the mega cities are in worst situations due to lack of proper implication of policies, monitoring, and public awareness. Industrial effluent, oil and lube spillage, faecal pollution and agricultural inputs are the major water related issues. Pollution caused by the ship breaking industries in the coastal areas, especially at Chittagong coast, is becoming a major threat near the port areas. Ocean going ships are causing pollution in Passur and Karnaphuli Rivers and their adjacent coast. Ship wrecks, and sunken bulk carriers also threaten the ecosystem, including the Sundarbans.

Ecological Setting: The ecosystem plays an important role in the ecology, economy and livelihood of Bangladesh. However, ecosystem habitats, wetlands biodiversity in Bangladesh have long been facing serious degradation and loss due to many natural and anthropogenic factors. Besides natural causes, factors like overexploitation of resources, lack of awareness, human encroachment, conflicts over natural resource management, pollution, and absence of effective enforcement of laws, are some of the most important factors for the decline in ecosystem habitat and biodiversity of the country. The baseline report on ecological setting covers the state of biological environment like ecosystem types with its resources, bio-ecological zones, current situations of ecosystem management and past initiatives, problems, gaps, ecosystem services, existing policies and regulations, driving forces, strategy and issues for ecosystem conservation, problems and issues of ecosystem, and possible solutions and future plan which relate to the Bangladesh Delta. The report has also presented the strategy development and implementation arrangement regarding the management of ecosystem conservation in future.



(Shamsul Alam)

Acknowledgements

The Bangladesh Delta Plan 2100 has been prepared by the General Economics Division (GED) of the Bangladesh Planning Commission and is supported by the Government of the Netherlands. At the behest of the Hon'ble Prime Minister of the People's Republic of Bangladesh, Sheikh Hasina, a Memorandum of Understanding (MoU) was signed between Bangladesh and the Netherlands to cooperate on Bangladesh Delta Plan 2100. During a meeting in The Hague, Prime Minister Sheikh Hasina of the People's Republic of Bangladesh and Prime Minister Mark Rutte of the Netherlands renewed their support to the preparation and implementation of Bangladesh Delta Plan 2100.

Hon'ble Minister Mr. AHM Mustafa Kamal, M.P., Ministry of Planning, always encouraged the formulation of the project and contributed to the formulation of the plan passionately. Mr. Abdul Mannan, M.P., State Minister, Ministry of Planning and Ministry of Finance, gave valuable time and guidance.

We acknowledge the guidance and timely direction provided by the National Steering Committee (NSC) headed by Mr. Md Abul Kalam Azad, Principal Secretary of the Hon'ble Prime Minister and Dr. Kamal Abdul Naser Chowdhury, Principal Secretary of the Hon'ble Prime Minister and Mr. Md. Nojibur Rahman, Principal Secretary of the Hon'ble Prime Minister in consecutive terms for their contributions to successful completion of the Plan.

We are also grateful to the valuable contribution of the Panel of Experts headed by Dr Jamilur Reza Choudhury for their review of the Plan contents, and the important suggestions to improve those. The reviewers' contribution to the Baseline Reports are also acknowledged for their valuable comments and suggestions for improvement.

The International Economics Wing of the General Economics Division (GED), Bangladesh Planning Commission, coordinated all the reports under the broad and extensive guidance of Dr. Shamsul Alam, Member (Senior Secretary), GED, so that, the Plan could meet the quality standard. Mr. Naquib Bin Mahbub, Division Chief; Mr. Md. Mafidul Islam, Joint Chief; Dr. Md. Mizanur Rahman, Ex. Project Director; Mr. Mohd. Enamul Haque, Deputy Chief and Project Director, Dr. Md. Taibur Rahman, Senior Assistant Chief; Mr. Md. Murtuza Zulkar Nain Noman, Senior Assistant Chief, Mr. Mohammad Asaduzzaman Sarker, Senior Assistant Chief and Mirza Md. Mohiuddin, Assistant Chief provided constant support in the process of preparation of the plan.

The Embassy of the Kingdom of the Netherlands, in addition, regularly arranged funds and meetings. Ms. Martine van Hoogstraten, Head Development Cooperation, Mr. Carel de Groot, and Mr. Peter de Vries, First Secretary, Mr. ATM Khaleduzzaman, Senior Advisor, Water Management of EKN, always extended their valuable support to the activities related to the BDP 2100 project.

Prof. Dr. Jaap de Heer, Team Leader, Mr. Giasuddin Ahmed Choudhury, Deputy Team Leader of the project were always available to guide, advice and assist the studies. They extended impeccable efforts for coordination among the consultants, authors, reviewers and the GED. We thank the involved other experts from the consultancy teams: Mr. Stephan van den Biezen, Dr. Maminul Haq Sarker, Yeusuf Ahmed, Shaker Bin Shams, William John Oliemans, Anwar Zahid, Zahirul Haque Khan, Fred de Brujn, Ismat Ara Parvin and Tanvir Ahmed.

Last but not the least, many officials from the Ministry of Planning, Ministry of Water Resources and other ministries of the government graced with their presence to project-related meetings and discussions. Also many stakeholders attended the Delta Seminars/Workshops throughout the country.

We from GED gratefully acknowledge the efforts by all concerned.

June 2018

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Abbreviations

AR4	Fourth assessment report of IPCC
AR5	Fifth assessment report of IPCC
ADP	Annual Development Programme
ADPC	Asian Disaster Preparedness Centre
AQC	Air Quality Cell
AQI	Air Quality Index
AQM	Air Quality Monitoring
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BDP	Bangladesh Delta Plan 2100
BMD	Bangladesh Meteorological Department
BWDB	Bangladesh Water Development Board
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BDP	Bangladesh Delta Plan
BDRCS	Bangladesh Red Crescent Society
BDT	Bangladesh Taka
BMD	Bangladesh Meteorological Department
BNBC	Bangladesh National Building Code
BPC	Bangladesh Planning Commission
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
3R	Reduce, Reuse, Recycle
BBS	Bangladesh Bureau of Statistics
BCCTF	Bangladesh Climate Change Trust Fund
BOD	Biological Oxygen Demand
BRT	Bus Rapid Transit
BWDB	Bangladesh Water Development Board
CCA	Climate Change Adaptation
CCC	Chittagong City Corporation
CCDMC	City Corporation Disaster Management Committee
CCTF	Climate Change Trust Fund
CCTFP	Climate Change Trust Fund Project
CC	Climate Change
CDO	Collection of command line operators
CDA	Chittagong Development Authority
CDMP	Comprehensive Disaster Management Programme
CFAB	Climate Forecast Applications in Bangladesh
CI	Corrugated Iron
CPP	Cyclone Preparedness Programme
CRA	Community Risk Assessment
CMIP5	Coupled model inter-comparison project phase 5
CAMS	Continuous Air Monitoring Station
CASE	Clean Air and Sustainable Environment

CBO	Community Based Organization
CC	City Corporation
CDA	Chittagong Development Authority
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CFC	Cloro Fluro Carbon
CNG	Compressed Natural Gas
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
DC	Deputy Commissioner
DDM	Department of Disaster Management
DDMC	District Disaster Management Committee
DG	Director General
DHI	Danish Hydraulic Institute
DM	Disaster Management
DMA	Disaster Management Act
DMC	Disaster Management Committee
DMB	Disaster Management Bureau (erstwhile name of DDM)
DM&RD	Disaster Management and Relief Division
DNA	Damage and Need Assessment
DoE	Department of Environment
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DoE	Department of Environment
DO	Dissolved Oxygen
DoE	Department of Environment
DPHE	Department of Public Health and Engineering
ESM	Earth system model
ESPA	Ecosystem services and poverty alleviation (project)
FYP	Five Year Plan
ECMWF	European Centre for Medium-Range Weather Forecasts
ECNEC	Executive Committee of National Economic Council
EGPP	Employment Generation Programme for the Poorest
EPWAPDA	East Pakistan Water and Power Development Board
ERM	Emergency Response Management
ERRRP	Earthquake Risk Reduction and Recovery Programme
ECA	Environment Conservation Act
EIA	Environmental Impact Assessment
EPZ	Export Processing Zone
EQS	Environmental Quality Standard
FF	Flood Forecasting
FFWC	Flood Forecasting and Warning Centre
FFWS	Flood Forecasting and Warning System
GBM	Ganges, Brahmaputra and Meghna

GCM	General Circulation Model
GDP	Gross domestic product
GoB	Government of Bangladesh
GED	General Economics Division
GO	Government Organisation
GIS	Geographical Information System
GoB	Government of Bangladesh
GSB	Geological Survey of Bangladesh
HFA	Hygo Framework for Action
IDL	Interactive data language
IPCC	Intergovernmental Panel on Climate Change
JTWC	Joint typhoon warning centre
KMPH	Kilo Meter Per Hour
LGED	Local Government Engineering Department
LGED	Local Government and Engineering Department
LGI	Local Government Institutions
LLP	Low Lift Pump
IWM	Institute of Water Modelling
MoEF	Ministry of Environment and Forest
MDG	Millennium Development Goal
MoDMR	Ministry of Disaster Management and Relief
MPO	Master Plan Organisation
MOEF	Ministry of Environment and Forest
MRVA	Multi-hazard Risk and Vulnerability Assessment
MSL	Mean Sea Level
NDVI	Normalised Difference Vegetation Index
NGO	Non-Government Organisation
NPDM	National Plan for Disaster Management
NPDRR	National Platform for Disaster Risk Reduction
NSDS	National Sustainable Development Strategy
Precis Centre	Providing Regional Climates for Impacts Studies, regional climate model from the Hadley
PDMC	Pourashava Disaster Management Committee
PGA	Post Ground Acceleration
PIO	Project Implementation Officer
PPT	parts per thousand
PWD	Public Works Department
RCP	Representative Concentration Pathways
RCM	Regional climate models
RAJUK	Rajdhani Unnoyon Kartripakho (Capital Development Authority)
RCC	Reinforced Cement Concrete
SLR	Sea level rise
SMRC	SAARC Meteorological Research Centre
SPARRSO	Space Research and Remote Sensing Organization

SRES	Special report on emission scenarios of IPCC
SST	Sea surface temperature
SA	Spectral Acceleration
SAARC	South Asian Association of Regional Cooperation
SDMC	SAARC Disaster Management Centre
SFA	SAARC Framework for Action
SFYP	Sixth Five Year Plan
SOD	Standing Orders on Disasters
SOS	Save Our Soul
SPI	Standardised Precipitation Index
SWSMP	Surface Water Simulation Modelling Programme
TAG	Technical Advisory Group
UDMC	Union Disaster Management Committee
UN	United Nations
UNDP	United Nations Development Programmes
UNFCC	United Nations Framework Convention for Climate Change
UNGA	United Nations General Assembly
USD	United States Dollar
UZDMC	Upazila Disaster Management Committee
VIC	Variable Infiltration Capacity, macro-scale hydrological model
Wageningen	UR Wageningen University and Research Centre
WARPO	Water Resources Planning Organization
WB	World Bank
WGI	Working Group I of IPCC
WARPO	Water Resources Planning Organisation
WMO	World Meteorological Organisation

BASELINE STUDY: 08

Climate Change

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Executive Summary: Study 08

The aim of the Bangladesh Delta Plan is to improve water safety, food security and to increase sustainable economic growth. Climate change can potentially have a negative impact on all these three issues. To reduce climate change vulnerability of the country it is important that information on climate change (observed and modelled) are documented and shared, so that the delta plan can include a strategy to adapt to future climate change. This Climate Change Baseline Study – one of a total of 19 baseline studies made - aims to review the information available on historic and future climate change in Bangladesh and to outline a method for the development of climate change scenarios for the Bangladesh Delta Plan.

The study was conducted in close cooperation with various experts from across the country. They provided valuable inputs in order to formulate the state-of-the-art technology on climate and climate change. The Sixth Five Year Plan (6^{th}FYP), including reference to the BCCSAP, provides the basic policy setting on climate change. Adaptation to climate change is taken up in other baseline studies as integrated part of the analysis (e.g. water resources, food security). Based on the contributions of both climate change experts and the other baseline studies, the current need for climate and climate change related information for the development of the Bangladesh delta plan are formulated.

Recent climate change was analysed using the meteorological data of 35 stations as obtained from the Bangladesh Meteorological Department (BMD) for the period of 1948 to 2011 (63 years). It is observed that averaged across the country, minimum temperatures have increased by 0.85 °C over the last 60 years. Minimum temperatures have increased most during the winter and the least during the monsoon. Maximum temperatures have increased by 0.5 °C over the last 60 years. Rainfall in Bangladesh is highly variable and changes from year to year. This makes it difficult to detect long term trends. However over the 60 years of data analysed (1948-2011), there is a clear increase of 10% in total annual rainfall. Most of the increase took place during the first part of the analysed period and after 1985, rainfall has been more or less stable. Rainfall especially increased (20%) during the pre-monsoon period from March till May. Rainfall also increased during the monsoon. During the post monsoon and dry season rainfall has hardly changed. Changes in temperature and rainfall are not only caused by global warming but can also be affected by local land use change.

Both global and regional climate change scenarios indicate that the historic trends are likely to continue into the future. Temperature will continue to rise and total annual rainfall is likely to increase in the future. Future climate change was analysed as presented in IPCC AR5, and further analysis was carried out using an ensemble of five General Circulation Models (GCM), making spatial information available across the entire country. For the Bangladesh Delta Plan, information is needed regarding the water situation and related impacts, i.e. when is there too much, too little, or too dirty water. In discussions with experts, 12 meteorological indicators were identified and analysed. A climate atlas with interactive maps was created as an output to communicate the results. These analyses can be used as an input for the scenario development.

The analyses of future climate change scenarios indicate that averaged across the five climate models rainfall can increase up to 800 mm in the northwest of the country and by 300 mm in southeast. While total rainfall increases, the number of rain-days is remaining more or less the same. This indicates that the increase in total rainfall will be the result of more intense rainfall events and intensity of rainfall events will increase throughout the country. The increase in rainfall is especially projected for the monsoon season. During the dry season the scenarios are highly uncertain. However the longest period of consecutive dry days is projected to increase which is likely to result in higher drought risks.

Cyclones can have a devastating impact on Bangladesh both in human and economic terms. Changes in cyclone frequency, paths and intensity can therefore have a large impact on the country. The analyses of historic changes on cyclones showed that the number of cyclones is decreasing but the intensity is increasing. For the future, this trend is

likely to continue. Cyclone intensity will probably increase. The impact of climate change on cyclone frequency remains unclear but most analyses show no change or a slight reduction.

The latest IPCC (2013) report indicates a historic sea level rise of about 2.0 mm/year. The local observations in Bangladesh tend to be higher and are between 3 and 8 mm/year. Most of the local observations are relative sea level rise, including subsidence and tectonic effects. Future sea level rise scenarios presented in the IPCC are between 20 and 100 cm for the coming century. Internationally, these numbers are considered by some scientists to be too conservative and they believe increased instability of the Greenland ice sheet could especially increase the sea level by more than 1 meter. For the sea level rise scenarios we suggest to use the most recent global scenarios developed by Hinkel et al. (2014) which include improved uncertainty analyses of melting of global land ice (including Greenland). According to this study for 2100, sea level rise is projected to be between 37 to 75 cm for the RCP4.5 and 55 to 123 cm for RCP8.5. Analyses of regional sea level rise for Bangladesh show that the sea level rise in Bangladesh is slightly higher than the global average mean. However the differences between the global and regional scenarios are small in most cases, and less than 5% with a maximum of 10% higher.

For the use of future climate change impact studies a set of twelve indicators and 8 climatic variables were developed. For each indicator and variable 10 data sets are available; 5 climate models and two RCPs (4.5 and 8.5). Further work is required to include the climate change scenarios into the delta scenarios that will be developed for the Bangladesh Delta Plan. For example the impact of climate change with regard to future changes in upstream water availability, future agricultural water demand, future flood risk and salt intrusion need to be analysed through an improved climate change impact assessment. In addition there is a need to make climate change knowledge and information accessible and useful at the local scale. This is needed for the design of appropriate adaptation measures.

In conclusion the future trends for climate change in Bangladesh are becoming more robust. Both analyses of historical trends and future scenarios based on regional and global climate models indicate that temperatures will be higher and the pre-monsoon and monsoon rainfall will increase. Rainfall intensity will also increase in future. Also for cyclones both historic observations and model analyses indicate that cyclones will become more intense in future. For the dry season there is no trend in rainfall changes and also the future scenarios are inconsistent. However an analysis of meteorological drought indicators shows that drought frequency and severity is likely to increase in the future.

While future trends are becoming clear there is need for more quantified spatial specific information, especially on future changes in extremes. This information is needed for improved flood and drought risk analyses. Therefore we propose to do a climate change downscaling analysis of the future climate scenarios for Bangladesh. The output of this downscaling exercise is necessary for future water availability, food security and flood risk analyses.

1. Introduction

Bangladesh is rapidly developing towards a middle incomecountry; showing a consistent GDP growth and progress towards MDG goals (6th Five Year Plan, GoB, 2011). In order to address longer term development, land and water management related spatial planning is undertaken, which can assist prioritizing investments and make them benefiting the people of Bangladesh now and in the future.

Bangladesh is widely seen as one of the most vulnerable countries to climate change. A combination of sea level rise, changes in monsoon rainfall and more extreme events will have large scale impacts on the country. Climate change is likely to increase flood and drought risks, increase monsoon river flows and salt water intrusion in the southwest. As a result climate change will have large impacts on water management and water related sectors. Climate change will not only have an impact on the environment but will also have serious consequences on overall development in Bangladesh. A recent report by Asian Development Bank (ADB) estimated that without further action climate change would cause total economic losses of on average 9.4% of total GDP (Ahmed and Suphachalasai, 2014),which in a worst case scenario, could go up to 23% (ibid). As a resultclimate change is one of the major drivers of change when considering longer term development in the Bangladesh delta.

Considerable work has been done on studying climate change in Bangladesh over the last decades and currently, much more information is available on temperature trends, rainfall, sea level rise, cyclone tracks compared to 5 to 10 years ago. Howeverthe knowledge is scattered over a wide range of different publications, from scientific journal papers, to ADB and WB reports and government publications. There is need for a good review of the available knowledge. In addition a process is needed to generateconsensus on the most appropriate climate scenarios to be used for the Bangladesh Delta Plan. This will help o include climate change into development planning and adapting to future change.

For the Bangladesh Delta Plan a detailed understanding of the impacts of climate change is necessary. For example how will climate change affect future flood risks, water availability and salt water intrusion? To be able to deal with uncertainties and to analyse the impacts of climate change consistently throughout the Bangladesh Delta Plan there is a need to develop climate change scenarios. The scenarios can be used for impact analyses, adaptation planning and for visualization to improve the understanding of possible future climate change impacts.

1.1. Scope of the Report

This report focuses on two objectives. The first objective is to provide an overview and review of the available information on recent and future climate change in Bangladesh. The second objective is to provide the first ideas and analyses of the climate change scenarios to be used for the development of the Bangladesh Delta Plan. Reference is made to Annex 1 for the TOR of the climate change baseline study.

The current report addresses these two objectives. It has been prepared within a limited period of time (September – November 2014), preceded by a Quick Scan assessment (May – July 2014). To collect and discuss the information and the climate change scenarios, consultations were held with experts in the field of climate change, team members within the formulation team and of GED, the focal points, and a wider group of people involved in climate change research in Bangladesh, amongst others the Gobeshona Platform.

After an introduction on the climatology of Bangladesh presenting the current climate (Chapter 2), the report presents a review and analyses of recent climate change as well as the currently available information on future climate change (Chapters 3 and 4 respectively). Consultation with various groups on the climate change information and knowledge needed for the Bangladesh Delta Plan was made and is reported in Chapter 5. Further the report describes the methods used for developing future climate change scenarios (Chapter 6), and the initial results of the scenarios (Chapter 7), and the use of such scenarios in climate change impact studies. The report concludes with an overview of knowledge gaps identified and suggestions for further development of climate change and delta scenarios, taking into consideration that the development of the Bangladesh Delta Plan is a process of continuously bringing the latest scientific insights and data into the planning and implementation process. In Chapter 8 and 9, analyses of future cyclonic storm events and SLR have been included, and in Chapters 10 and 11, scenarios for the delta have been elaborated. Chapter 12 includes an analysis of climate change in the 6th Five Year Plan and the baseline is concluded in Chapter 13.

2. General Climatology of Bangladesh

Bangladesh is situated in the heart of the South Asian monsoon region. With the Bay of Bengal and the vast Indian Ocean to the south and large mountain ranges— Himalayan Mountains and ArakanRanges to the north and east respectively—the country receives very high annual precipitation, most of which is concentrated during the monsoon season (June-September). There are four climatic seasons in Bangladesh:

Winter	December-February
Pre-monsoon	March-May
Monsoon	June-September
Post-monsoon	October-November

Climatology of temperature and precipitation of Bangladesh has been developed using the observed data from 35 different meteorological stations with maximum data range of 1948-2011 (**Figure 1**). The stations Sylhet, Srimangal, Sitakundu, Chittagong and Rangamati are situated in the hilly areas of eastern Bangladesh. The stations Chuadanga has started in 1989 and Mongla and Syedpur in 1991. The coverage of stations is much better in the coastal zone compared to other parts of the country.

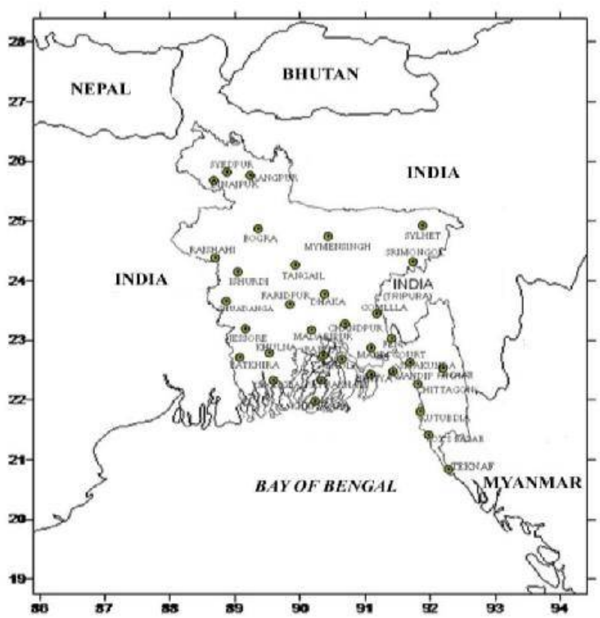


Figure 1: 35 BMD meteorological stations of Bangladesh

2.1. Temperature and precipitation climatology

Long term mean of country-average monthly minimum temperature ranges from 12.5 ^{0}C in January, in winter to above 25 ^{0}C in summer(**Figure 2**). The maximum temperature ranges from 25 ^{0}C in winter,with a peak in summer, in April (33.5 ^{0}C). A secondary peak is observed in September (31.6 ^{0}C).

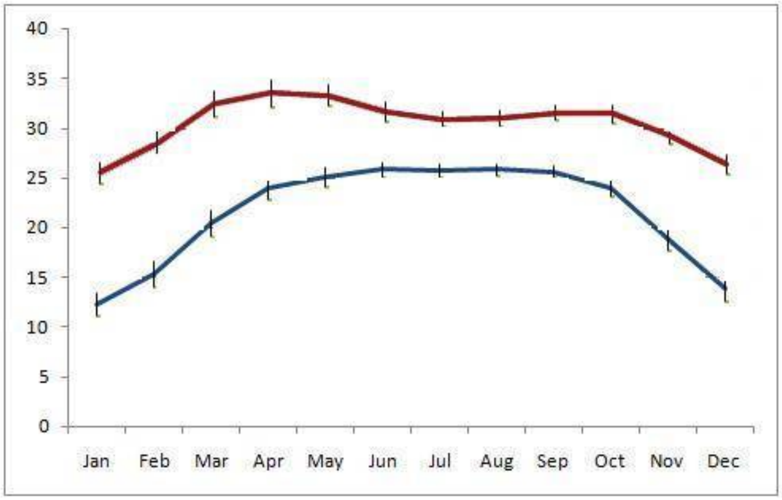


Figure 2: Climatology of Annual Distribution of Average Minimum and Maximum Temperature of 35 different meteorological stations across Bangladesh

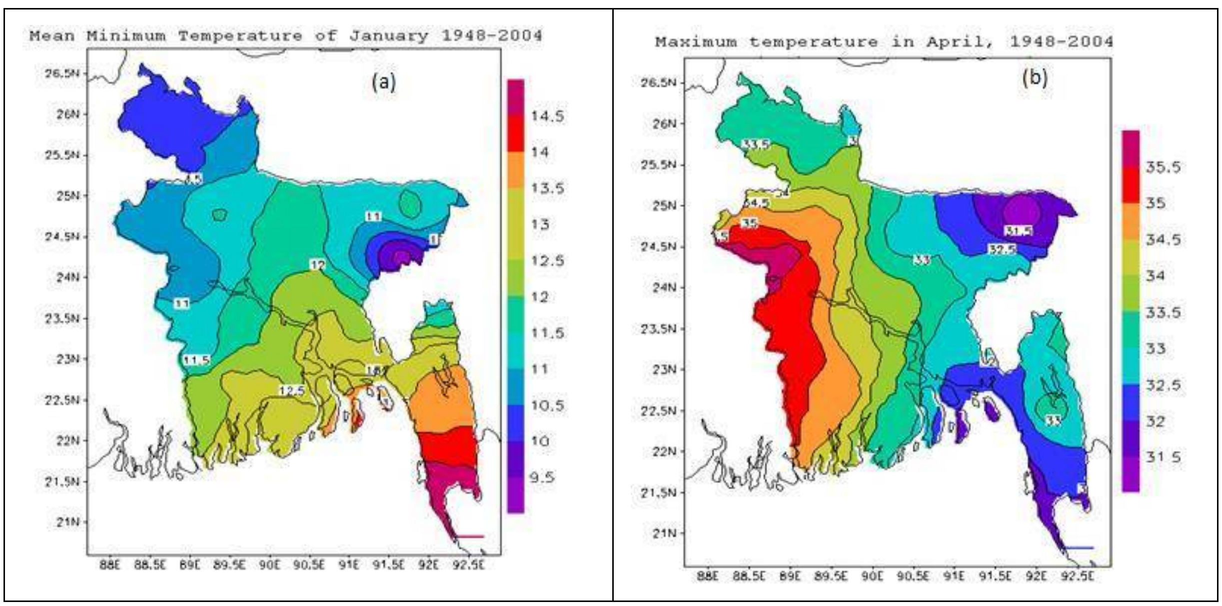


Figure 3 (a,b): Geographical distribution of climatology of the minimum and maximum temperature in(a) January and (b) April

Note: Data used are from 1948-2004 of 34 meteorological stations of Bangladesh

The spatial distribution of temperature shows that the coastal zone is relatively warmer in the winter and the thermal gradient is positive towards south [**Figure 3(a)**]. The temperature is very high in the central western part of the country which extends up to the western coastal zone, whereas the eastern coastal zone has a slightly milder temperature **[Figure 3(b)].** The maximum temperature in April is relatively low in the northeastern and southeastern part of the country. In the coastal area the temperature increases from east to west in the summer.

Figure4shows the annual pattern of long term mean of monthly precipitation. This shows that very high precipitation occurs in the monsoon season and low precipitation in the winter season. Bangladesh receives on an average 2425 mm of precipitation/year, with a standard deviation of around 286 mm. The seasonal distribution shows that most of the precipitation occurs in the monsoon season (June-September) amounting to 1750 mm which is 72% of the total annual precipitation. The pre-monsoon season receives about 17% of the annual precipitation. The post-monsoon season occupies 9.1% of the annual precipitation **(Figure5)**. The winter is relatively dry and receives only 1.5% of the annual precipitation.

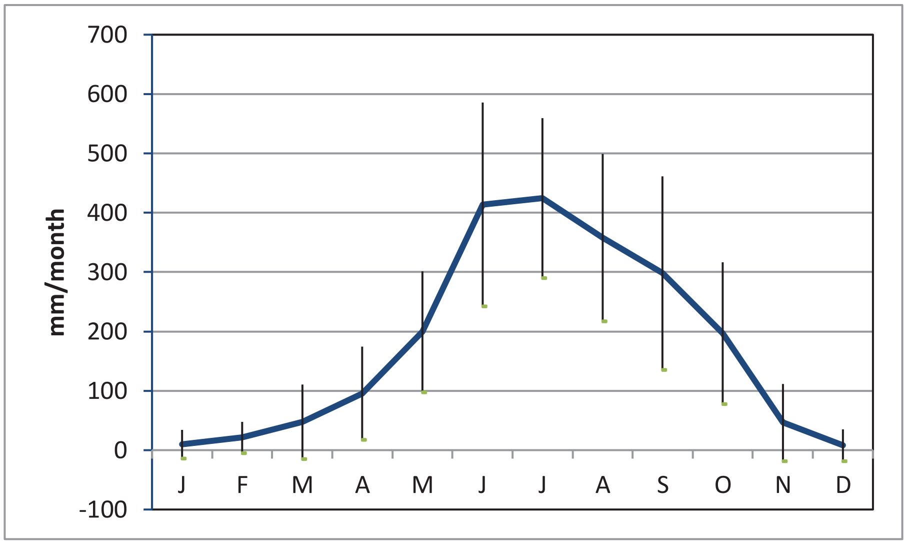


Figure 4: Annual distribution of climatology ofthe country mean precipitation based on 1948-2004 data

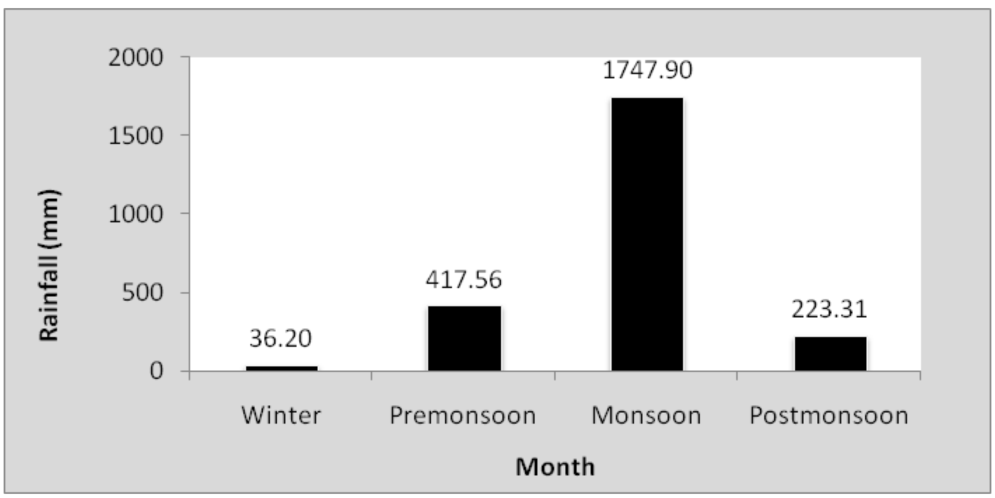


Figure 5: Distribution of country average seasonal precipitation of Bangladesh

The geographical variation of annual and monsoon precipitation is large in Bangladesh **[Figure 6 (a,b)].**The wettest parts of the country are the north-east and south-east where monsoon precipitation is around 2000-2800 mm and the total annual precipitation between 3000 and 4000 mm. Relatively low precipitation is obtained in central-western Bangladesh which is oriented in the north–south direction. The low precipitation area bulges towards central Bangladesh. The distribution pattern is more or less similar for both annual and monsoon. The geographic distribution of annual precipitation shows that the coastal zone experiences around 1800-4000 mm of precipitation, but it is relatively higher over the southeastern coastal zone and gradually decreases towards the west. The deficit and excess precipitation from normal becomes critical causing droughts and floods. Low pre-monsoon and monsoon precipitation and high temperature in these seasons have caused the western part of delta to become highly drought prone. Excessive precipitation over Bangladesh and in the upper catchment of the Ganges Brahmaputra and Meghna (GBM) river system causes devastating floods. The floods of 1974, 1988, 1998 and 2007 are worth mentioning. Further reference is made to the baseline studies on water resources and disaster management.

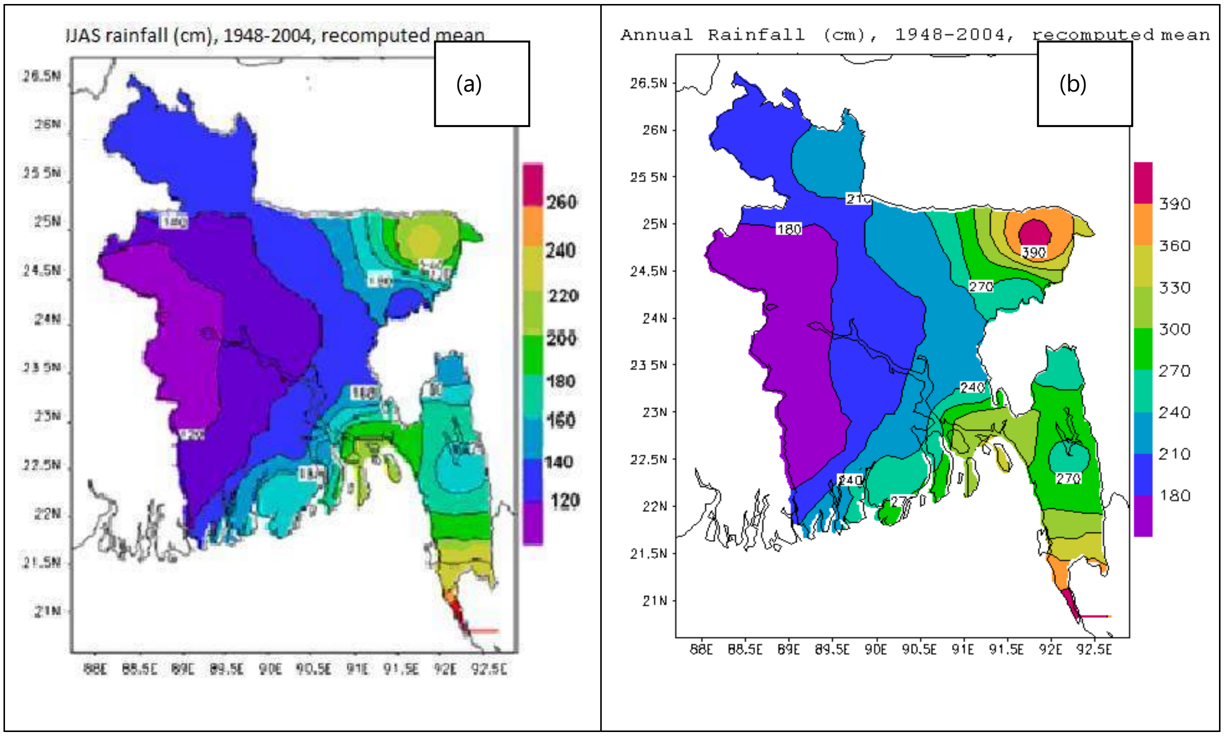


Figure 6: (a, b): Distribution of monsoon precipitation (a), and annual precipitation (b) in cm

Note: Climatology has been derived using the available data of 34 BMD meteorological stations from 1948-2004

The monsoon precipitation mechanism of Bangladesh is associated mainly with the convective activities in the semi-permanent monsoon trough that runs from west to east parallel to Himalayan foothills. The monsoon depressions form in the head of the Bay and move towards the land. Land depressions are also formed in the monsoon trough when the trough occupies more northerly position compared to normal. These depressions produce heavy precipitation. About 92% of the catchments of the great rivers of Ganges, Brahmaputra and Meghna (GBM) originating in the Himalayan mountains lie outside Bangladesh and precipitation produced over these catchments ultimately drains through Bangladesh, which contains 8% of catchments. The tropical cyclones frequently develop in the pre- and post-monsoon seasons, which cause heavy precipitation and is associated with strong winds and high storm surges.

The pre-monsoon precipitation over Bangladesh is mainly caused by the thunderstorm activities associated with the passage of subtropical westerly troughs in the middle and upper troposphere. In the lower troposphere, the warm moisture laden air flows northwards to the lands and meets the dry and relatively cool air masses in the northern Bangladesh and adjacent areas in the Himalayan foothills occasionally causing low level pseudo-frontal system conducive for convective activities. Besides, warm moist air in the low level and cold air in the high level provides favourable conditions for convections causing thunderstorms, squall lines and tornadoes. In this season, the tropical depressions and tropical cyclones are also found to occur in the Bay of Bengal and hit the coasts. These calamities make their way to inland causing heavy precipitation over Bangladesh and the adjacent territories of India and Myanmar.

The winter precipitation occurs from the activities of subtropical westerly disturbances. These disturbances usually have northerly positions well beyond Bangladesh's latitude, and sometime extend towards south, when the country gets some precipitation. Because of lack of moisture in the atmosphere, precipitation is scanty during this season. However, the tropical cyclones occasionally form over the Bay of Bengal in the month of December and may have landfall over Bangladesh and cause heavy precipitation and causes huge damage due to wind action and high storm surges.

The months May-October are responsible for 90% of the annual precipitation. Considering this the country average mean monthly number of rain days has been estimated for these six months which includes 4 monsoon months and 2 peripheral months using the data of 30 stations from 1948-2011 or as available. Here, the country average and standard deviation of the mean monthly number of rain days has been calculated and shown in **Figure7**. It is seen that the month of July has the highest number of rain days and August occupies the second highest. The vertical lines indicate the standard deviation. It is seen that on an average the remains under rain condition from 16.5 to 21.9 rain days during the monsoon months with standard deviation which varies between 2 to 2.2 days. The month of May has around 12.2 and October 8.3 rain days respectively with standard deviation of 3.0 and 2.6 days.

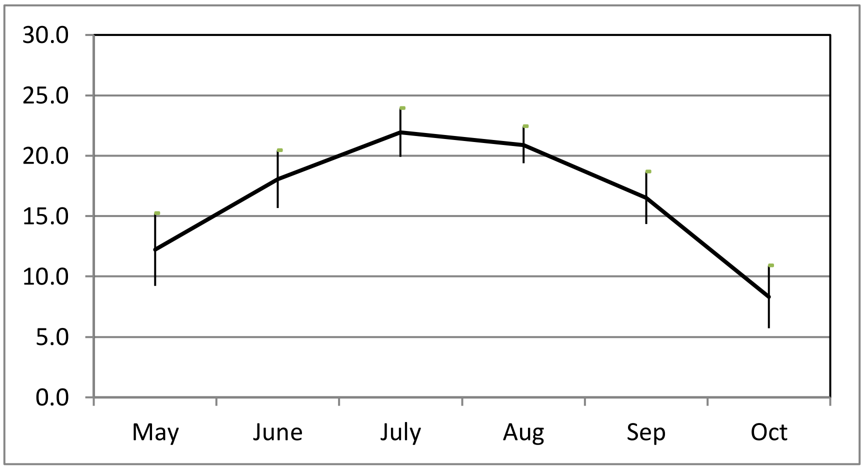


Figure7: Country averages and standard deviation of mean monthly number of rain days

Note: Data usedfor 1948-2011, May-October or as available. The vertical lines indicate standard deviation

2.2. Tropical cyclones and cyclones in Bangladesh

The tropical cyclones are the worst form of meteorological disasters. Tropical cyclones are low pressure systems that form in the tropical warm ocean with sea surface temperature (SST) higher than 26.5^{0}C with sufficiently warm layer of the ocean from the surface. The depth of the warm boundary layer is determined by the depth of 26^{0}C isotherm from the sea surface, which should be higher than 50 m. The higher the depth the higher is the tropical cyclone potential. The Bay of Bengal basin is one of the active zones for tropical cyclone formation where SST is always above 27^{0}C during the cyclone seasons. The cyclones being formed over the Bay of Bengal move to inland and cause loss of human and animal lives, and damages to infrastructure, environment, ecology, resources, and livelihoods due to rampaging impacts of wind and storm surge actions. In 2007, the tropical cyclone Sidr caused financial loss of US$1.7 billion according to an estimate of GoB (2008).

The use of reliable dataset maintained by Joint Typhoon Warning Centre (JTWC) on tropical cyclone formation, track and development has been made to accumulate and organize the latest information of tropical cyclones of the Bay of Bengal for the period of 36 years (1978-2013). The monthly statistics of tropical cyclone frequency has been produced and presented in **Table1** and **Figure8.** Here, a tropical cyclone classification which maintains most of the features of TC classification in Northern Indian Ocean as well as the Atlantic Ocean Saffir Simpson classification[1] has been used. It is seen that the months April-June and September-December are the tropical cyclone seasons for the Bay of Bengal. The months September-December is the primary cyclone season when 86 cyclones (66.7% of total) were formed and months April-June are the secondary season when 35 tropical cyclones (28% of total) were formed during the 36 years of observation. The months October-November are the months with highest frequency of occurrence of intense tropical cyclone.

Table 1: Frequency of different tropical cyclone categories formed in the Bay of Bengal during the period 1978-2013

Tropical Cyclone category (Maximum sustainable wind (km/hour)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Annual mean
CS (62-88)	5	0	1	0	3	6	1	0	5	15	6	8	50	1.4
SCS (89-118)	1	0	0	2	9	5	0	0	2	10	12	5	46	1.3
SCS–H (119-152)	0	0	0	0	1	0	0	0	0	0	6	4	11	0.3
ISCS-H(153-188)	0	0	0	0	1	0	0	0	0	0	3	2	6	0.2
VSCS-H(189-220)	0	0	0	1	4	0	0	0	0	1	3	0	9	0.3
SuC (221-251)	0	0	0	0	2	0	0	0	0	1	0	0	3	0.1
Cat-5 SuC (vmax>251)	0	0	0	1	0	0	0	0	0	2	1	0	4	0.1
All	**6**	**0**	**1**	**4**	**20**	**11**	**1**	**0**	**7**	**29**	**31**	**19**	**129**	**3.6**

CS- Cyclonic Storm, SCS-Severe Cyclonic Storm, SCS-H- Severe Cyclonic Storm with Hurricane Intensity, ISCS-H: Intense Severe Cyclonic Storm with Hurricane speed, VSCS-H:Very Severe Cyclonic Storm and: SuC: Super Cyclone

1/ Atlantic Ocean Saffir Simpson classification: **Saffir–Simpson hurricane scale** (**SSHS**), classifies hurricanes – Western Hemisphere tropical cyclones that exceed the intensities of tropical depressions, and tropical storms – into five categories distinguished by the intensities of their sustained winds. To be classified as a hurricane, a tropical cyclone must have maximum sustained winds of at least 74 mph (33 m/s; 64 kn; 119 km/h) (Category 1). The highest classification in the scale, Category 5, is reserved for storms with winds exceeding 156 mph (70 m/s; 136 kn; 251 km/h).The classifications can provide some indication of the potential damage and flooding a hurricane will cause upon landfall.

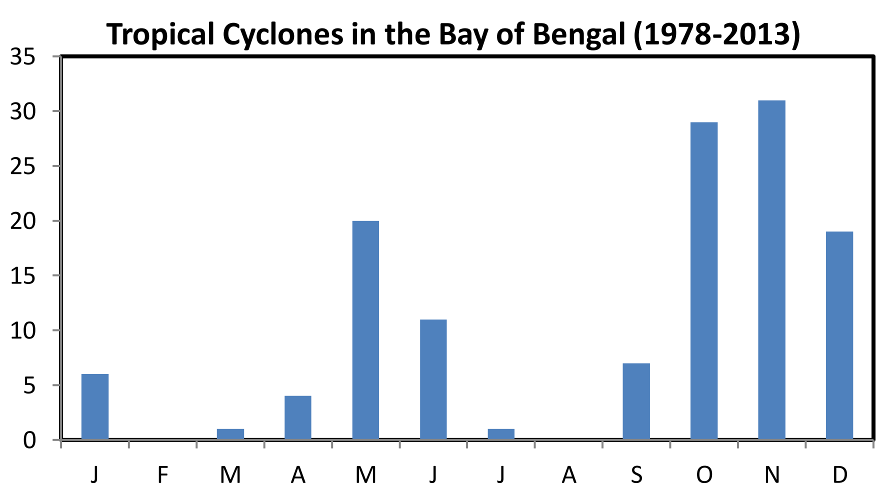


Figure 8: Distribution of monthly average tropical cyclone frequency over Bay of Bengal

During the period of 1978-2013 a total of 129 tropical cyclones were formed showing annual mean occurrence of 3.6 tropical cyclones. Bangladesh was hit by 32 tropical cyclones constituting about 25% of the total number of cyclones in the Bay of Bengal formed during that period.

Bangladesh Cyclones

There is a reliable dataset for tropical cyclones which hit Bangladesh since 1961. A total of 61 tropical cyclones hit Bangladesh and its close neighbouring territories during the period 1961-2013. This result is an update of the analyses by Quadir and Iqbal (2008). The update has been accomplished by using JTWC Best Track tropical cyclone data. According to the current statistics, an average of 1.15 tropical cyclones hit Bangladesh per year. The distribution of land-falling cyclones over different regions of Bangladesh coast is shown in **Table2**. It is seen that Noakhali and Chittagong including eastern part of Meghna estuary was hit by about 26% of the cyclones of Bangladesh and the south-eastern coast of Cox's Bazar, Teknaf and adjacent areas by 29.5%. The south-central and south-western coastal zones were hit by 16 and 28% respectively. The tracks of the cyclones hitting Bangladesh for the period 1991-2013 are shown in Figure-9. It is evident from these 23 year's tracks that the tropical cyclones hit the Meghna estuary and south-eastern coast mostly in the month of May (pre-monsoon) and the central and western coast in the months from October-November(post-monsoon).

Table 2: Distribution of Land-falling Cyclones to Different Coastal Regions during 1961-2013

Sl. No.	Coastal Region	Number of tropical cyclones hit the coast	% of the total number of tropical cyclones
1	Sundarban coast (Satkhira, Khulna and Bagerhat) Central coast (Borguna, Potuakhali, Pirozpur, Barisal, Bhola	17	27.9
2	Central coast (Borguna, Potuakhali, Pirozpur, Barisal, Bhola	10	16.4
3	Meghna estuary, east central coast (Eastern Bhola, Noakhali and Chittagong)	16	26.2
4	Southeastern coast (Southern Chittagong, Cox's Bazar and Teknaf	18	29.5
Total		**61**	100

Out of 61 tropical cyclones, 30 (39.1%) belong to range of speed of 62-118 km/hr, 13 (21.3%) to 119-152 and 7 (11.5%) to153-188 km/hr, 6 (9.8%) to speed 189-220 km/hr, 3 (5%) for 221-251 km/hr and 2 (3.3%) to above 251 km (**Table3**). A few tracks of tropical cyclones hitting the coast of Bangladesh in the period 1991-2013 have been prepared and plotted by the Consultancy Team in **Figure 9**. On average Bangladesh gets 1.16 cyclones a year for the period 1961-2013. The tropical cyclones with wind speed of 62-118 have the return period of 1.8 years and those with 119-152 km/year have the return period of around 4 years and with speed of 153-188 km/hour have return period of around 8 years. The cyclones with speed of 189-220 have the return period of 8.8 years, and with speed of 221-251 km/hr have 17.7 and those greater than 251 km/year have the return period of around 26.5 years.

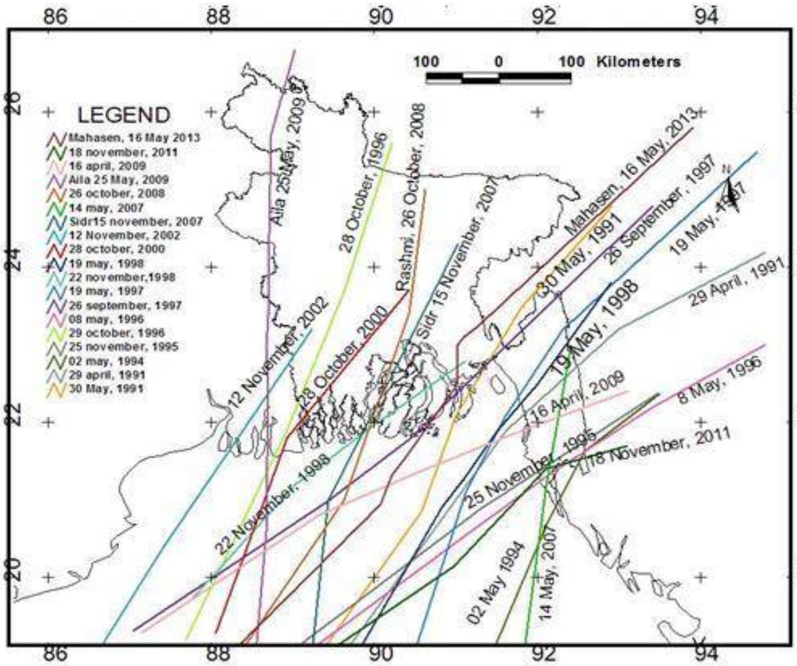


Figure 9: A few tracks of tropical cyclones hitting Bangladesh coast for the period 1991-2013

Note: Cyclone tracks prepared by Consultancy Team

Table 3: Frequency and probability of Landfall of Cyclones with Return Period

(Data used 1961-2013, Source: Consultancy Team)

Range of wind speed (km/hour)	Frequency	Annual Mean	Percentage	Return period (year)
62-88	19	0.36	31.1	2.8
89-118	11	0.21	18.0	4.8
119-152	13	0.25	21.3	4.1
153-188	7	0.13	11.5	7.6
189-220	6	0.11	9.8	8.8
221-251	3	0.06	5.0	17.7
>251	2	0.04	3.3	26.5
Total	61	1.16	100	N/A

2.3. Storm Surges

The strong winds of tropical cyclones at the surface level frictionally interact with the ocean water and generate high water waves called storm surges. The strong pressure drop inside the tropical cyclones enhances the height of these surges. Most of the damages due to tropical cyclones are caused by storm surge flooding over the coastal zone. The storm surge height is influenced by the coastline configuration, bathymetry of the coastal sea and direction of the cyclone track relative to the coastline. The funnel shape of the Meghna estuary is responsible for high storm surges over and around that area. The tidal height above and below the mean sea level further modifies the absolute surge height as $S_h = S \pm h_t$, where S_h is total surge and S is the surge due to tropical cyclone and h_t is the tidal height above or below the tidal level. Thus if the cyclone passes through the coast at high tide the surge will be higher. The extreme shallowness of the topography makes the western and central coasts highly vulnerable to storm surge inundations. **Table 4** shows the distribution of storm surge heights as a function of wind speed for the Bangladesh coast (World Bank 2011).

Available literature indicates a range of 1.5 to 10.0 m high storm surges for severe cyclones during 1960-2012. Heights in excess of 10m may also occur. Surges can be even more devastating if the cyclones make landfall during high tide. In general, it has been observed that the frequency of a wave (surge plus tide) along the Bangladesh coast with a height of about 10m is approximately once in 20 years, and the frequency of a wave with a height of about 7m is approximately once in 5 years (MCSP, 1993).

Table 4: Tropical Storm Surges and Limit to Coastal Inundation with Maximum Wind Speed with some adjustment

Maximum Wind Speed (Km/hour)	Storm Surge Height (m)	Limit to Coastal Inundation (km)
85	1.5	1.0
115	2.5	1.2
135	3.0	1.5
165	3.5	2.0
195	4.8	4.0
235	6.5	5.0
260	7.8	5.5

Source: World Bank, 2011

3. Recent Climate Change

Bangladesh has experienced climate change and severe impacts on several environmental, ecological, economic, social and other development processes of the Bangladesh delta, which needs to be thoroughly investigated. It is believed that the climate change is mainly related to global warming due to excess anthropogenic greenhouse gas emission caused by burning of the fossil fuel, landuse change such as forestry, agriculture, organic wastes (solid and liquid) and enteric fermentation. In the present study, the recent climate change information has been discussed based on information available in published sources and some updated knowledge has been generated based on the analysis of long-term historical data of some important climatic parameters.

Observational records show an increase of annual mean surface temperatures of about 0.6—0.8°C during the past 100 years over the north-eastern region of India, which borders Bangladesh (Hingane (1985). Observations of 32 years of monthly maximum and minimum temperatures over Bangladesh by Choudhury et al. (1997) shows increase of temperature in most of the selected stations by around 0.11-0.33°C during the observational period varying over the seasons. The study has shown slight increases in precipitation. Karmaker et al. (2000) using data of 1961-1990 has shown that the annual minimum, maximum and mean temperature increased with trends of 0.0066, 0.007 and 0.0034°C/year. The annual precipitation has been found to increase at a range 4-5 mm/year. The study by Quadir et al. (2004) has shown that Bangladesh and the adjacent areas experienced warming with maximum at Dhaka (0.037 °C/year) during the period of 1961-1990.

Study by Singhvi et al. (2010) using the data from 1961-2004 indicated that the country average minimum and maximum temperature shows increasing trends at the rate of 0.0094 and 0.007°C/year respectively. However, the investigations for individual seasons show that the changes vary over the seasons with seasonal trends varying between 0.007 to 0.013°C for minimum temperature and 0.018 and 0.023 °C for maximum temperature of monsoon and post-monsoon. The winter shows very insignificant negative trend and pre-monsoon shows decreasing trend of maximum temperature (-0.01°C/year). The precipitation trends exhibits an increase for all seasons. The increase of precipitation is high over the western, central and northern Bangladesh (Shahid, 2010). Brammer (2014) showed strong inter-annual variability of annual precipitation and indicated that the variability is linked with El Nino and La Nina to some extent. The time series plot of Calcutta close to southwestern border of Bangladesh shows high inter-annual variability. The plot shows high frequency occurrence of negative anomalies from the 1940s up to the middle of 1960s and then increasingly higher frequency of positive anomalies are observed showing increase of extreme rainfall events.

Recent climate change has been performed using the up-to-date meteorological data of 34 stations of Bangladesh with maximum time coverage of 1948-2011 (64 years). The data of minimum and maximum temperature and precipitation used in the study have been collected from the Bangladesh Meteorological Department (BMD). Some preliminary data quality check has been made for this time bound study, but more rigorous data checking and repairing is needed for future work.

The area weighted seasonal and annual country average of the considered parameters is derived by averaging the gridded data within the territory of Bangladesh for the period 1948-2011 for subsequent trend analysis.

3.1. Recent temperature changes

The country average of minimum, maximum and mean temperature for the period 1948-2011 has been subjected to least square time regression analysis to estimate the trends for country average temperature. Student's T-test based on R2 values has been used to determine the confidence levels at 90%, 95% and 99% levels ($p<0.1$, $p<0.05$ and $P<0.01$ respectively are considered as thresholds).

The analysis shows that the annual mean minimum temperature increased at a rate of 0.014°C/year and maximum temperature at a rate of 0.008°C/year during the period of 64 years from 1948-2011 **(Figure 10 (a,b)** and **Table 5)**. The mean temperature has increased at a rate of 0.001°C/year **(Figure 11** and **Table 5)**. The mean temperature thus increased by 0.64°C during the period of 1948-2011.

During the winter and pre-monsoon seasons the minimum temperature has increased more than the maximum temperature. The changes in winter temperature are significant while the trend for maximum temperature is not significant. However, for the monsoon and post-monsoon season the maximum temperature has increased more than for the minimum temperature. Trends in both minimum and maximum temperature are highly significant**(Figure 12)**.

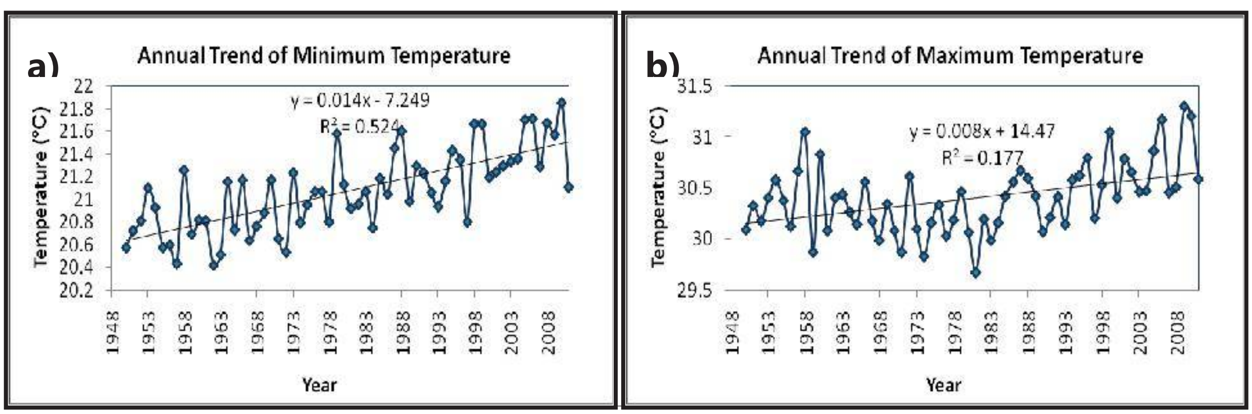


Figure 10: (a,b): Time series plots of annual mean minimum (a) and maximum (b) temperature

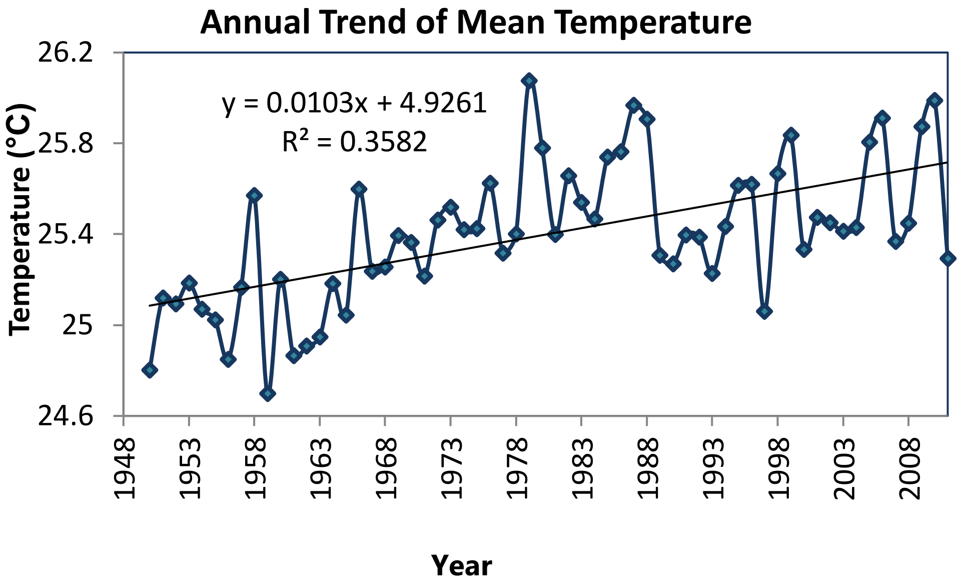


Figure 11: Time series plot of annual mean temperature (1948-2011).

Note: The thin straight line is the least square best fit line showing the trend of mean temperature

Table 5: Seasonal and annual trends and corresponding p-values of minimum and maximum temperature during the period 1948-2011

Seasons	Trends (ºC/year)and p-values					
	Tmin	**P**	**Tmax**	**P<**	**Tmean**	**P**
Annual	0.014	<0.001	0.008	0.001	0.010	<0.001
Winter	0.021	<0.001	0.000	n.s.	0.013	<0.002
Pre-monsoon	0.014	<0.002	-0.004	n.s.	-0.001	n.s.
Monsoon	0.008	<0.001	0.015	0.001	0.011	<0.001
Post-monsoon	0.016	0.001	0.024	0.001	0.016	0.001

Note: 'p-values' indicate the probability of rejection of Null Hypothesis.

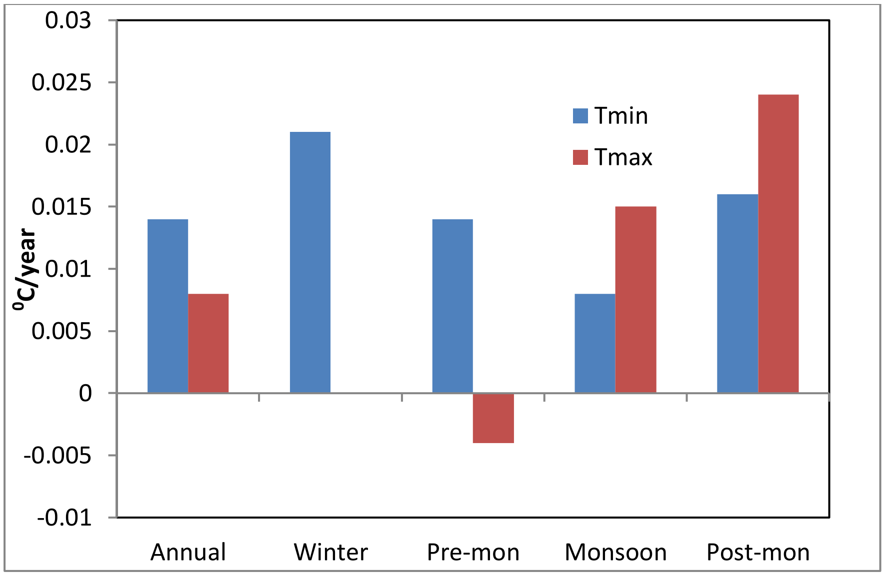


Figure 12: Bar chart showing seasonal and annual trends of minimum and maximum temperature.

The mean temperature trends have been estimated by Shahid (2010) for 17 individual stations uniformly distributed over the country and having more than 50 years of records. The geographic distribution of the trends of mean temperature is shown in **Figure 13**. The trends of 0.012-0.030^{0}C/decade are observed in the central, north-central, south-central and south eastern part of the country. The central Bangladesh (Dhaka and Faridpur) shows very high warming rate at around 0.03^{0}C/decade. Northern, north-eastern and south-western part of the country show insignificant increasing trends. The analysis of the observed daily minimum temperature at the 10th percentile show that the number of cold nights has decreased and the 90th percentile shows that the number of warm nights has increased (Tank, et al., 2006; UK Met Office, 2011).

The above analysis gives indication of clear signal of warming trends during the last 5-6 decades. However, the warming is not uniformly distributed over the country and at some areas the weak decreasing trends are also observed. According to Brammer (2014), daily temperature higher than 40°C has decreased over the western part of the country. A daily temperature higher than 40°C is characteristic for the months of April and early May for those areas. This statement is true for these months. The results of trend analysis of the current study show an increase of minimum temperature and a decrease of maximum temperature in the pre-monsoon season, when the winter rice extends over large part of the country. This supports Brammer's interpretation. The results of monsoon and post-monsoon seasons show significant trends in minimum and maximum temperature. The latter (maximum temperature) trends are stronger than the former (minimum temperature) trends.

Though Bangladesh contribution (roughly 0.19%) of anthropogenic GHGs is very negligible compared to global contribution, the significant warming over Bangladesh is mainly related with global warming and to some extent on local factors like land-use change, such as, expansion of the irrigated rice cultivation during February-April and rapid urbanization. The local factors may enhance or reduce the warming due to environmental changes caused by land-use change. The seasonal variation of trends may have some links with seasonal pattern of land-use. High trends of temperature in big cities may have some links with urbanization factor in addition to global warming.

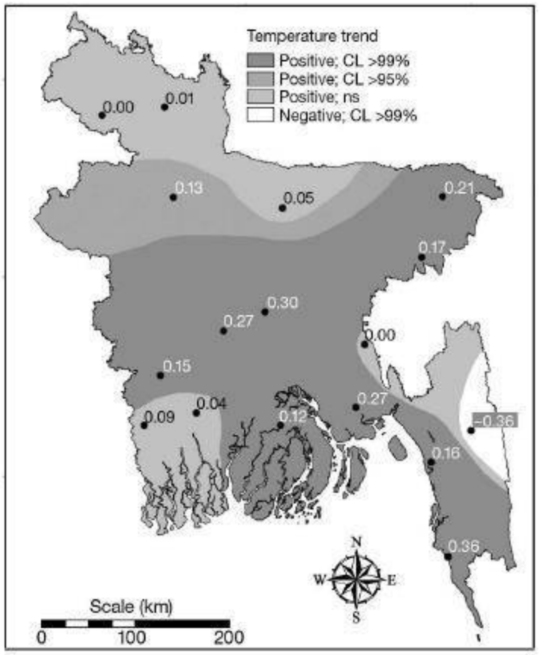


Figure 13: Trends of mean temperature (^{0}C/decade) of Bangladesh with maximum time span from 1958-2007 [Shahid, 2010]

3.2. Recent changes in precipitation

The trend analysis of the country average precipitation using the annual and seasonal data of 1948-2011 has been performed. The time series for the annual precipitation has been plotted in **Figure 14** (thin blue line), while the thick red lines show the plots of time series obtained using 11 year moving average. The straight line (black) is the best-fit regression line. The time series of the seasonal precipitation are plotted in **Figure 15 (a-d).** The high frequency inter-annual variation is prominent in the precipitation process, which suppresses the low frequency variation including the secular trends. Smoothing the time series using 11 year moving average has substantially eliminated the high frequency modes. This has enabled to visualise the existence of the longer period variation and the long term trends of precipitation. The quantitative trend analysis has been performed using the time regression analysis of the smoothed data. The straight line indicates the best-fit regression line indicating the trends of seasonal precipitation.

The slopes of the trends for individual season's and annual are shown in **Table 6.** The results show that winter, pre-monsoon, monsoon and post-monsoon precipitation has statistically significant increasing trends with trend values of 0.2, 1.31, 2.05, and0.47 mm/year. The annual precipitation trend is about 4.0mm/year. The precipitation trends obtained in this study are comparable with those provided by Shahid (2010)**(Figure 16).** The change during the past 50 years has been estimated. This indicates that the country average precipitation has increased by 29.2%, 12.2%, 6.3% and 11.4% for winter, pre-monsoon, monsoon and post-monsoon seasons. The increase in annual precipitation was 8.6% during this period. The substantial increase of pre-monsoon precipitation may be inferred as early onset of monsoon activity. An up to date study on monsoon onset is needed for confirming such interpretation. Such an increase of pre-monsoon precipitation has made the country more vulnerable to early flooding in the month of May. The increase of monsoon precipitation during the past 50 years and the increase of the same in the adjacent region of sub-Himalayan west Bengal, Sikkim and gangetic west Bengal as reported by Jain et al. (2012) have increased the vulnerability of the country to severe floods. The unprecedented floods of 1974, 1987, 1988 and 1998 and severe floods of 2004 and 2007 may be cited as examples of over past 3 decades which is related with increased precipitation over Bangladesh and in the upper catchments.

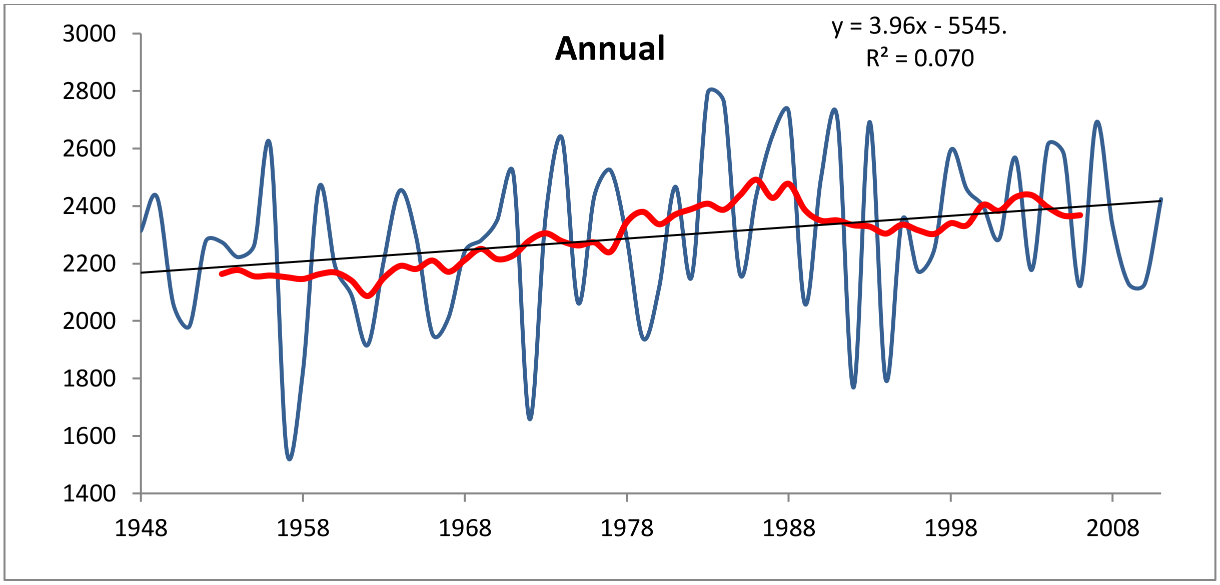
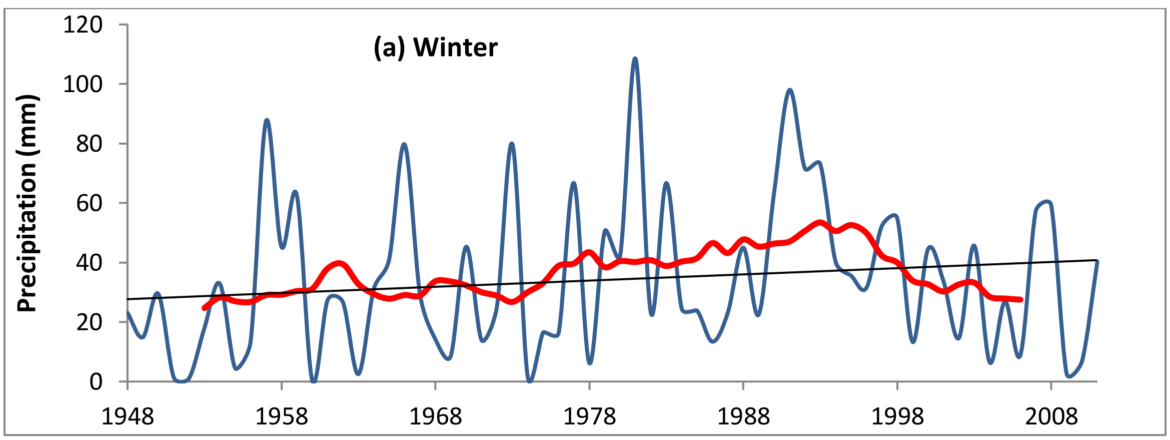
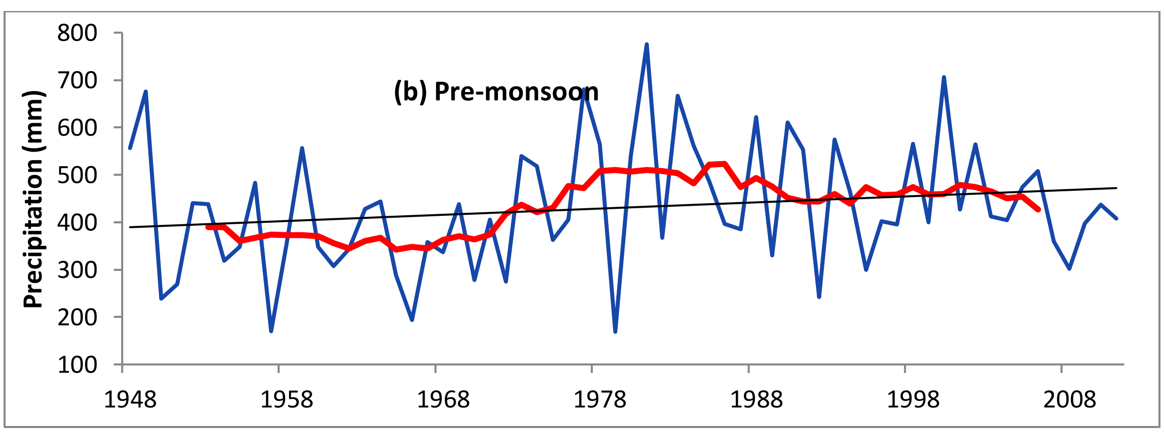


Figure 14: Time series plots of country average annual precipitation (mm) and linear trend. The thick red line indicates 11 year moving average





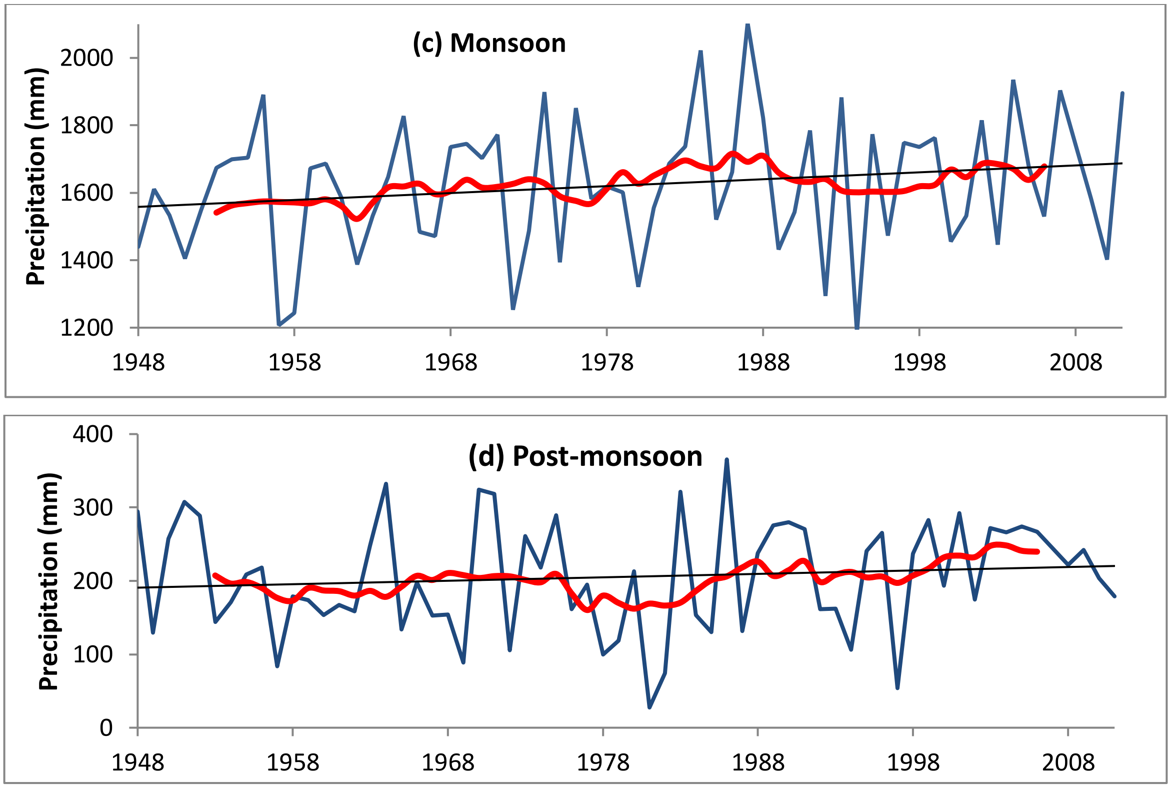


Figure 15: Time series plots of country average seasonal precipitation in mm (thin blue lines) and 11 year moving average (thick red lines)

Note: The straight line indicates the best-fit regression line indicating the trends of seasonal precipitation

Table 6: Seasonal and Annual trends of country average precipitation in Bangladesh for the period 1950-2011

Season	**Trend value (mm/year)**	**% increase of precipitation in 50 years**	**Probability p**
Winter	0.20	29.21	n.s.
Pre- monsoon	1.31	12.16	<0.01
Monsoon	2.05	6.32	<0.01
Post-monsoon	0.47	11.43	<0.05
Annual	3.96	8.64	<0.001

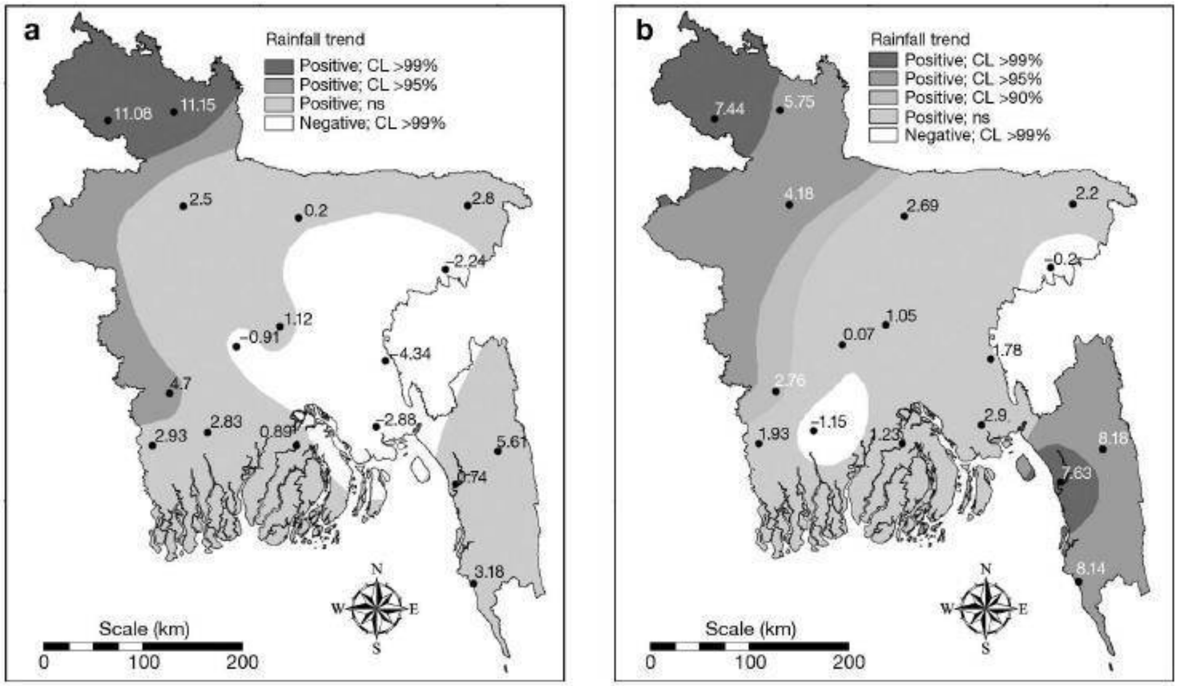


Figure 16: Trends of Precipitation (mm/year) for (a) monsoon and (b) pre-monsoon (b) [Shahid, 2010]

In the monsoon season, Bangladesh precipitation shows increasing trends over most part of the country **(Figure 17).** The only exceptions are the central, east-central and south-central part round lower Meghna basin of the country, where negative trends of around -1 to -4 mm/year were observed. The reason of these decreasing trends may be linked with some changes of the frequency and tracks of monsoon depression. This hypothesis needs verification through independent study.

In the south-eastern zone, the trends range from 0.7-5.7 mm/year, in the south-western coastal zone the trends have values 0.9-4.7 mm/year and in the north-central and north-eastern part the trends vary from 2.5-2.8 except for Mymensingh where the trend is negligible. Largest values of trends of monsoon precipitation at around 11 mm/year are observed in north-western Bangladesh.

In the pre-monsoon season, precipitation has increased all over Bangladesh with dominant trends lying in the range 2.0-7.4 mm/year. The highest increase (4-7.4 mm/year) is observed in the north-western and south-eastern Bangladesh. The moderate increasing trends are observed in the north-western part of the country which exhibits higher risks of flash flood in the month of May.

The annual precipitation shows increasing trends all over Bangladesh with exceptions of Srimangal where small and insignificant negative trend has been found. South-eastern hill station Rangamati shows trends of around 11 mm/year and the south-western coastal zone exhibits moderate increasing trends of around 7 mm/year. The central and northern to north-eastern Bangladesh shows dominant trends of 4-8 mm/year. The highest trends of 6.5-16.5 mm/year are observed in north-western Bangladesh.

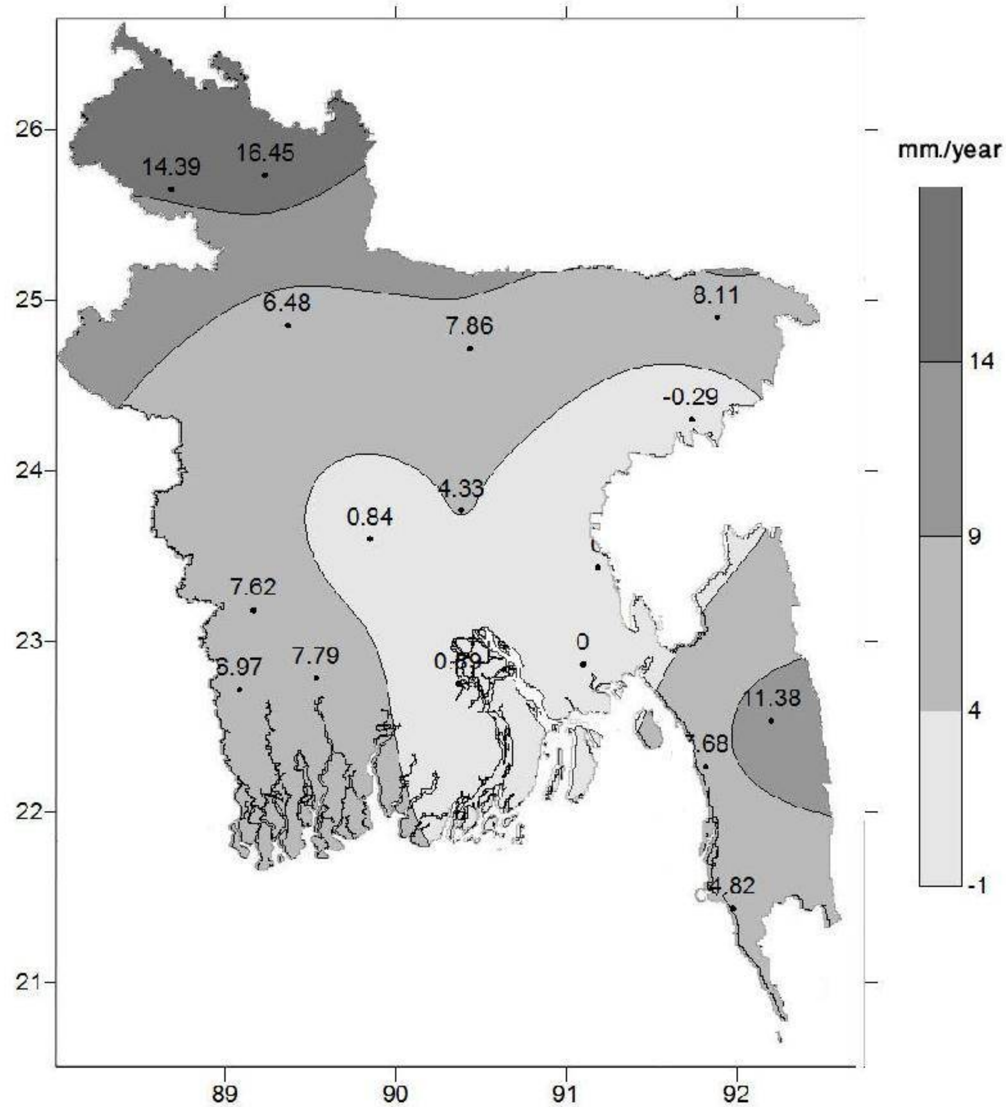


Figure 17: Geographical distribution of Trends of monsoon precipitation (mm/year) of Bangladesh with maximum time span from 1958-2007 [redrawn after Shahid, 2010]

The observed precipitation analysis indicates that the frequency of extreme precipitation days with daily precipitation more than 10 mm, 20 mm and 50 mm are all increasing. It also shows that precipitation above 95th and 99th percentile exhibits increasing trends (SMRC, 2008).

It is of interest to the agricultural scientists and planners to have analysis of the monthly total number of rain days. On this consideration, the number of rain days for the individual months from May-October for the maximum period of 1948-2011 or as available has been estimated using daily rainfall data for 30 meteorological stations of Bangladesh. The time series plot of country average mean total rainfall days for the six months May-October has been shown in **Figure 18**where the trend has been shown. The plot indicates high inter-annual fluctuation with period 3-5 years. The figure shows an increasing trend of 0.172 days/year. The smoothed line obtained through 11 year moving window (thick line in the figure) clearly demonstrates the increasing trend. In addition to the existence of the trends, a long term variation of scale 40-45 years is also visible. According to the trend analysis, the number of rain days has increased by 11 days during the past 64 years for the rainy months May-October.

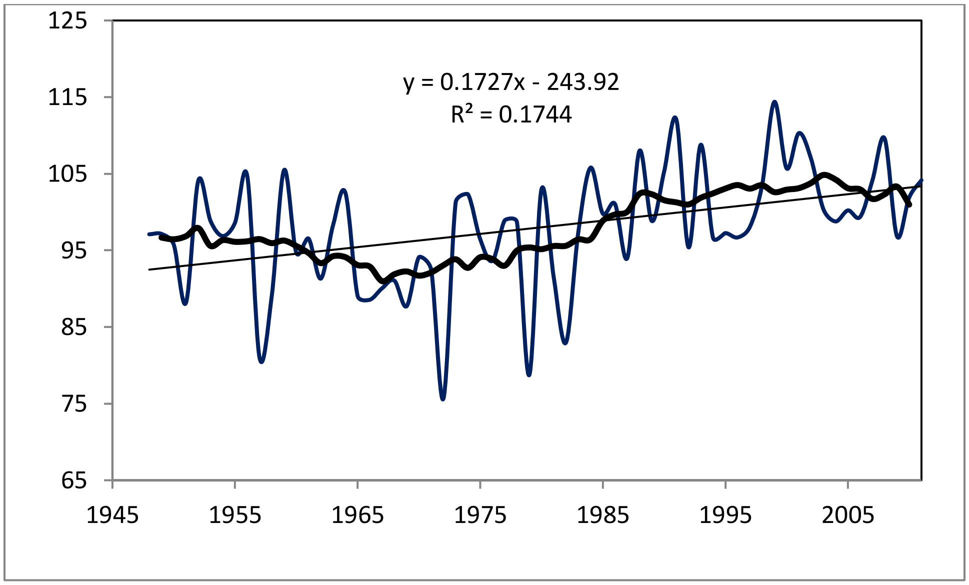


Figure 18: Temporal distribution of total number of country average rain days for the months May-October

Note: The thick line denotes smoothed line obtained by 11 year moving average.

The station-wise trends have been estimated for the individual months of May-October. The geographical distribution of the trends of rain days has been shown in **Figure 19**. The figure indicates dominant increase of rain days for the months May, June, July and September. The month of August and October also demonstrate increasing trend over 70-75% of the areas of Bangladesh.

3.3. Inter-annual variability of Bangladesh precipitation

The precipitation of Bangladesh is highly variable from year to year. It is well known that Indian Monsoon has strong link with ENSO activity, but the correlation with 21 year sliding window shows that the correlation have reduced drastically since the middle of 1980s exhibiting a weakening of the link (Kumar, Balaji and Cane, 1999). For Bangladesh Country average precipitation, the correlation is moderate for winter and post-monsoon rainfall with SOI and MEI. The correlation with 11 year moving window indicates large temporal variation of correlation with approximate period of around 20 years; the correlation has drastically reduced (Saha et al., 2015). However, it is found that most of the extreme droughts of pre-monsoon, monsoon and post-monsoon seasons occur in the El Nino situation.

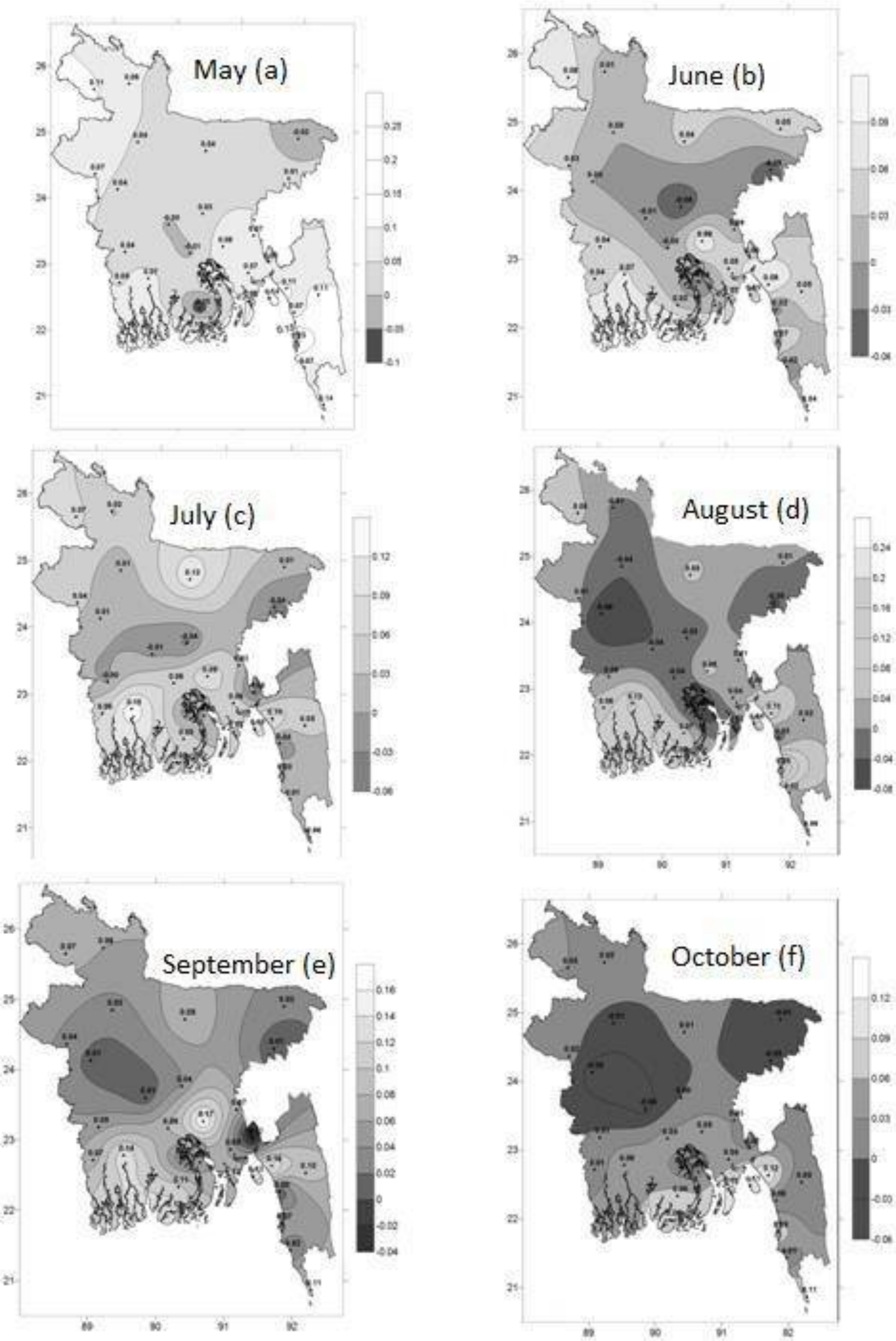


Figure 19: Geographical distribution of the trends of rain days for the months May-October

For Bangladesh, an investigation has been made recently using the seasonal data of Bangladesh rainfall against the corresponding SOI for the period 1951-2010 (60 years). It has been found that there is no one to one correlation. For Bangladesh Country average precipitation, the correlation is moderate for winter and post-monsoon rainfall with SOI and MEI. The correlation with 11 year moving window indicates large temporal variation of correlation with approximate period of around 20 years; however, the correlation has drastically reduced since the middle of 1980s

(Saha et al., 2015). However, it is found that most of the extreme droughts of pre-monsoon, monsoon and post-monsoon seasons occur in the El Nino situation.

3.4. Recent change in sea level

Sea level rise (SLR) is a secondary effect of global warming caused by the volumetric expansion of sea water and the addition of liquid water to the sea due to the melting of the polar and mountain glaciers. For low-lying countries like Bangladesh the coastal zones are highly vulnerable to sea level rise. Studies by Khan et al. (1999) and SMRC (2003) have reported increasing trends in Relative Sea Level Rise (RSLR) using tidal observation data of 1978-1998 (**Table 7**). The RSLR is integrated results of sea level rise due to global warming and geological subsidence in the coastal zone. The RSLR was found to be 4 mm/year at Hiron point (western coast), 6 mm/year at Char Changa (Meghna Estuary) and 7.8 at Cox's Bazar (East Coast) during the period of 1977-1998. The study of CEGIS (2011) has shown that the sea level rise is 5.5 mm/year at Hiron Point, 7.5 mm/year at Maheshkhali, 5.1 mm/year at Cox's Bazar and 7 mm/ year at Sandwip. The differential nature of the observed sea level rise is related with subsidence of the delta.

Table 7: Observed Relative Sea Level Rise (RSLR) during the Period 1978-1998

Stations	Latitude	Longitude	RSLR (mm/year)	SLR (IPCC AR5)
Western Sundarban Coast (Hazra, 2002) (1985-1998)	-	-	3.24	2.0 mm/year* 3.0 mm/year**
Hiron Point(1978-1998)	21°48′ N	89°28′E	4	
Char Changa (1978-1998)	22°08′ N	91°06′E	6	
Cox's Bazar (1978-1998)	21°26′ N	91°59′E	7.8	
CEGIS (2011) 1991-2010				
Hiron Point (1977-2002)			5.5	
Sandwip (1977-2002)			7.0	
Maheshkhali (1968-2002)			7.5	
Cox's Bazar 1977-2002)			5.1	

* Valid for the period 1980-2000 and ** valid for the period 1991-2010

3.5. Recent tropical cyclones

All tropical cyclones can be subdivided into Cyclonic Storms (CS) with maximum sustained wind speed (MSWS) = 62-87 km/hour and Severe Cyclonic Storms (SCS) with MSWS >87 km/hour. Singh et al. (2001) have shown that the tropical cyclones of November indicate increasing trends. The trends and variability of tropical cyclone in the Bay of Bengal have been studied by Singhvi et al. (2010) using the data of 1877-2004. The tropical cyclone frequency data from IMD archives were used. It has been found that the tropical cyclones of all categories have shown large scale variations with slight decreasing trends (-0.017 cyclones/year). The tropical cyclone frequency was very low in the 1990s and in the earlier half of 2000s. The cyclonic storms (CS) having maximum sustainable wind speed (MSWS) of 62-87 km/hour show decreasing trend (-0.024 cyclones/year) with almost simultaneous increase of the frequency of severe cyclonic storms (SCS) (MSWS higher than 87 km/hour). The trend of the frequency of SCS is0.007cyclone/year (**Figure20 [a-c]**)

Variability of tropical cyclones of Bay of Bengal in recent decades has been studied using the Best Track Data of tropical cyclones obtained from Joint Typhoon Warning Centre (JTWC) archives. The data shows the wind speed, pressure drop and position at 6 hours interval. For the Bay of Bengal the complete dataset is found to begin from 1978 and ends in 2013. Time series for the tropical cyclones in the Bay of Bengal have been generated for different levels of winds. **Figure21**shows the 5-year moving average of the time series of annual frequency of tropical cyclones with MSWS between 62-118 km/hour, which shows that the tropical cyclones in recent decades are increasing at a rate of 0.013 cyclones/year. The temporal distribution of 5-year moving average of the annual frequency of tropical cyclones with speed higher than 152 km/hour shows that intensive cyclones are increasing during the period 1948-2013 with a significant trend of 0.016 cyclone/year**(Figure22)**.

The Maximum Sustained Wind Speed (MSWS) has been plotted against time to see how the wind speed is behaving with time. This depicts that the speed of the strong winds has increased in the recent years **(Figure 23).** Then from these data the decadal frequency of tropical cyclones with wind speed of 218 and above have been calculated and plotted in **Figure 24**, which clearly depicts that the frequency of very intensive tropical cyclones have increased.

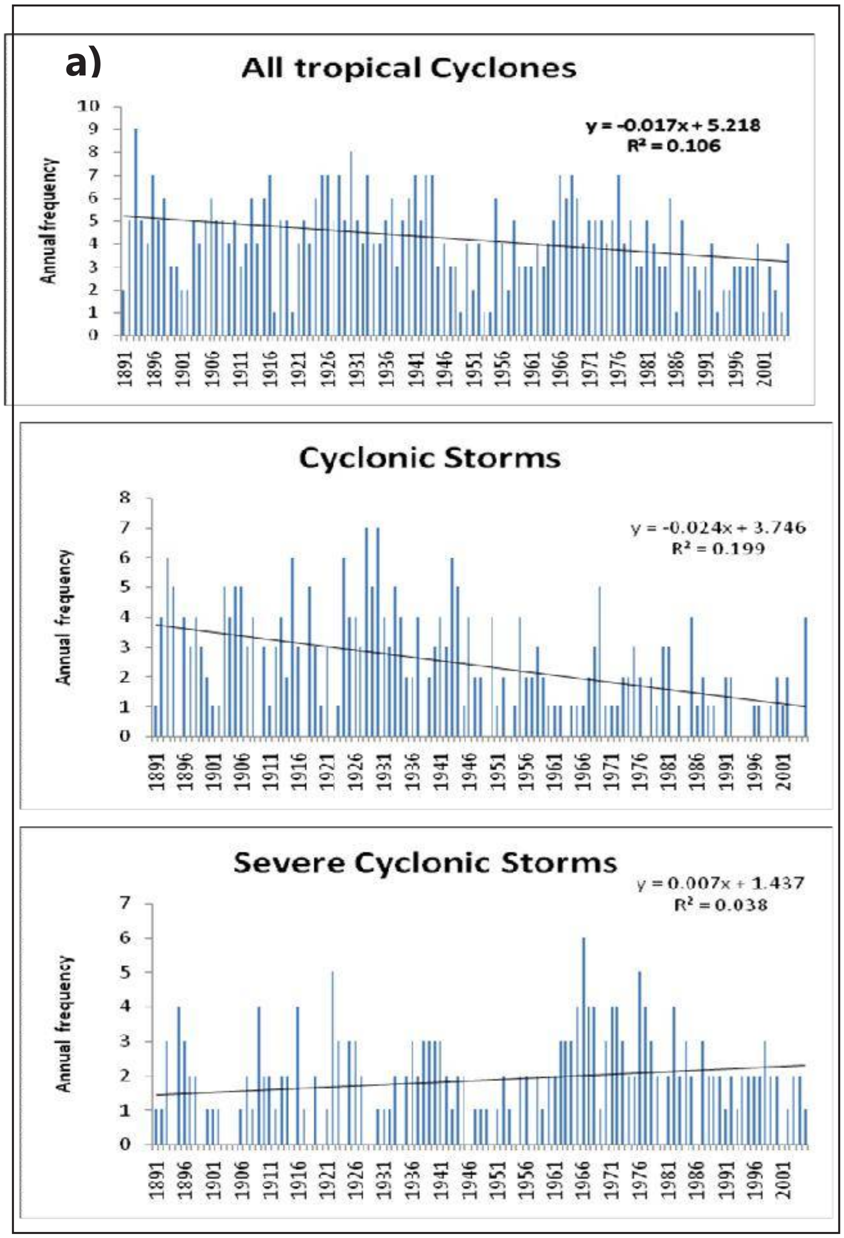


Figure 20: Annual frequency of all tropical cyclones, reproducedafter Singhvi et al,2010

Note: Trend analysis done by Consulting Team

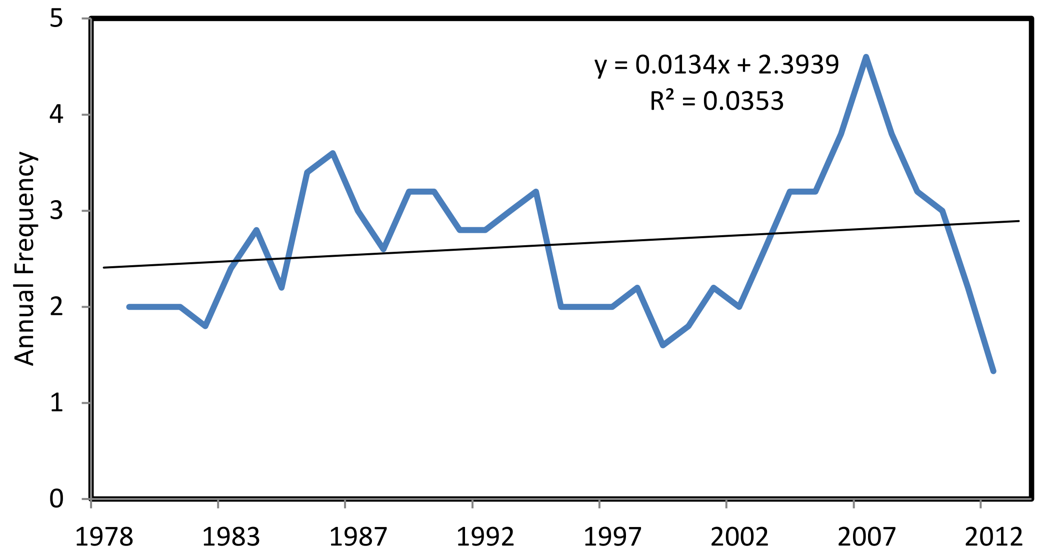


Figure 21: Five year moving average of weak tropical cyclones with MSWS of 62-118 km/hour

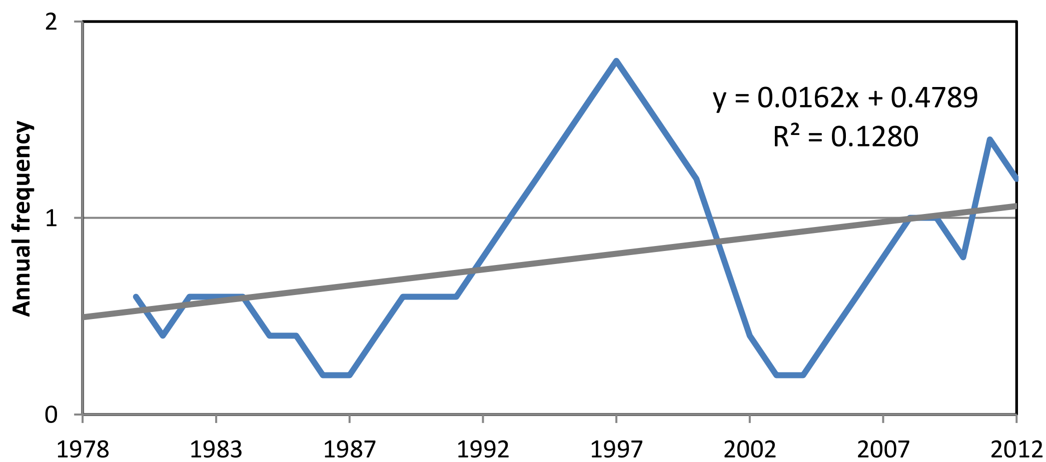


Figure 22: Five year moving average of tropical cyclones with MSWS higher than 152 km/hour

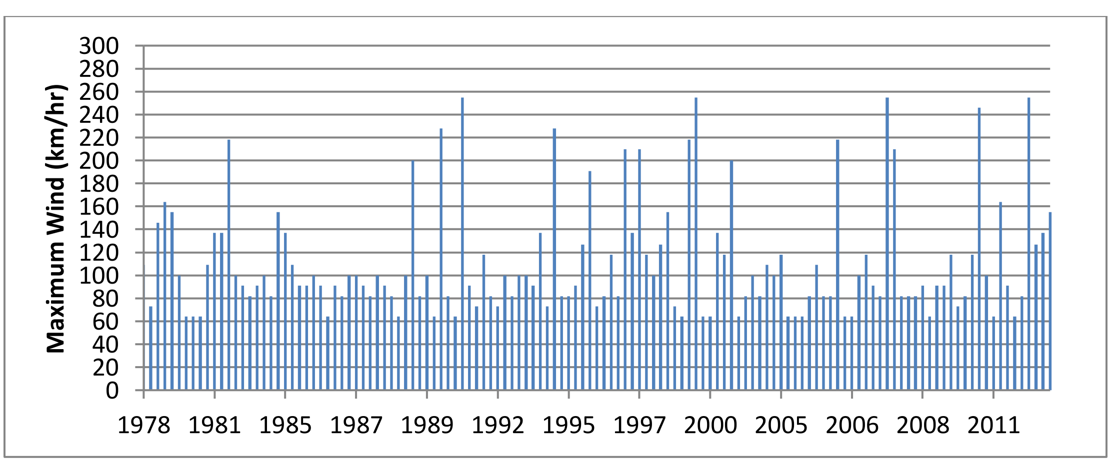


Figure 23: Variation of tropical cyclones' MSWS during the period 1978-2013

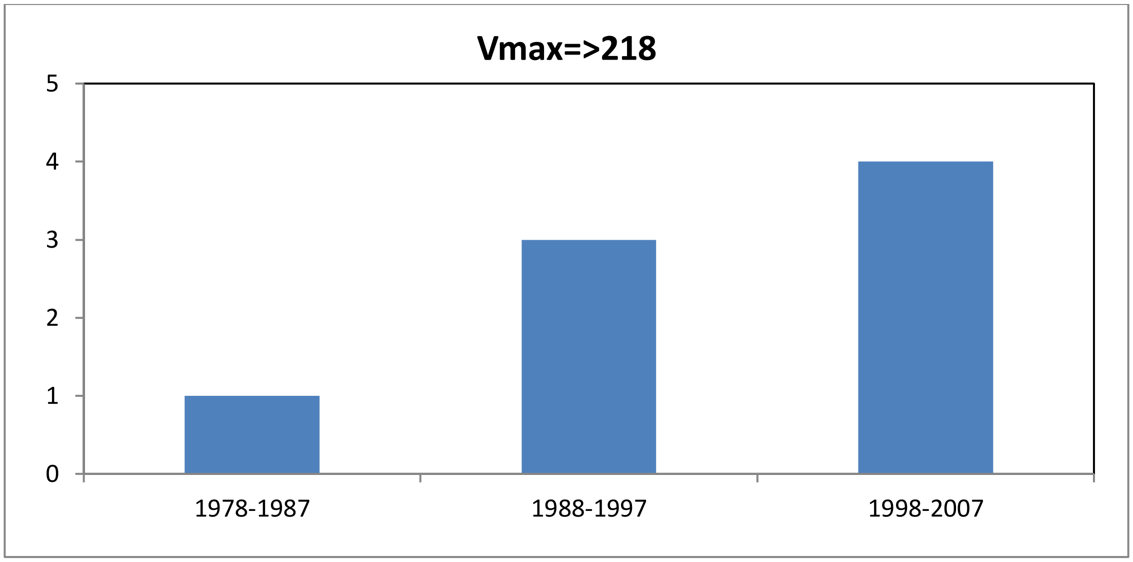


Figure 24: Frequency of high intensity cyclones (MSWS> 218 km/hr) in the Bay of Bengal over the last three decades

4. Currently Available Information on Future Climate Change

4.1. Bangladesh and IPCC AR5

Similar to the analyses mentioned in Section 3.1, the last IPCC report (2013) concluded that it is very likely that mean annual temperature has increased over the past century over most of the Asia region, but there are areas of the interior and at high latitudes where the monitoring coverage is insufficient for the assessment of trends (ref.IPCC 2013, Chapter 2, Figure 24-2). New analyses continue to support the AR4 and SRES conclusions that it is likely that the numbers of cold days and nights have decreased and the numbers of warm days and nights have increased across most of Asia since about 1950, and heat wave frequency has increased since the middle of the 20th century in large parts of Asia (ref.IPCC 2013,Section 2.6.1).

Rainfall variability in Bangladesh is extremely high. There is a large difference in rainfall between the different regions of the country and large difference between seasons. Also the inter-annual differences are large. This large variability makes it difficult to find significant trends in historical rainfall records. Studies focussing on recent changes in rainfall over Bangladesh and the Indian subcontinent show small reductions in total rainfall (IPCC 2013). This is probably partly caused by air pollution (aerosol and black carbon) (IPCC 2013). Several studies have shown increases in the frequency of extreme events (Kumar et al. 2013; IPCC 2013, WG1, Ch 14).

The IPCC has developed an Atlas (Collins et al. 2013) which summarizes the changes in climate projected by the different global climate model runs which have been done for the last IPCC report.
The figures presented and discussed below originate from that report.

The models used for the IPCC report estimate of a future temperature change of between 2 and 4 degrees depending on the time period and the emission scenarios **(Figure 25)**.The figure shows the time series of temperature change relative to 1986-2005 averaged over land grid points of South Asia in December-February (left) and June-August (right). The thin lines indicate one ensemble member per model and the thick lines the CMIP5 multi-model mean. One the right of each graph a box-plot of the distribution for the 20 year mean changes for 2081-2100 for the four RCP scenarios[4]. (IPCC 2013 - Annex 1 of IPCC Working Group 1 report).

The difference between the climate models used however is significant and warming could only be 1 degree for low emission scenarios and up to 7-8 degrees for the highest emission scenario. Warming in Bangladesh is slightly less than the global average due to its location near the ocean and also the tropics generally warm up less compared to land in the higher latitudes **(Figures 26 and 27)**.

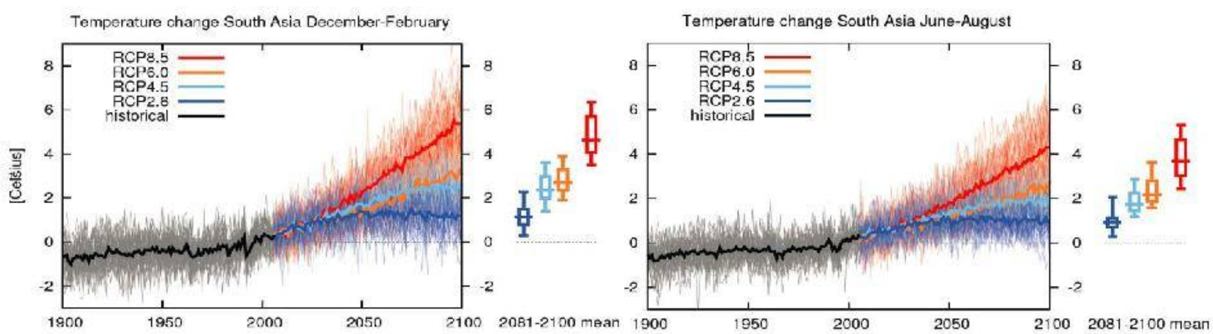


Figure 25: Time series of temperature change relative to 1986-2005 averaged over land grid points in South Asia in December-February (left) and in June-August (right)

The maps are showing the changes in temperature during the winter months (Dec-Feb) for 2016-2035, 2046-2065 and 2081-2100 relative to 1986-2005. Maps show the 25th, 50th and 75th percentile of the distribution of the CMIP5 ensemble. The maps only show the RCP4.5 scenario (IPCC 2013; Annex 1 of IPCC Working Group 1 report).

It should be noted that according to the models, temperatures will increase more in the winter compared to the summer period.

[4]**RCPs: Representative Concentration Pathways** (RCPs) are four greenhouse gas **concentration** (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014. It supersedes Special Report on Emissions Scenarios (SRES) projections published in 2000. The pathways are used for climate modelling and research. They describe four possible climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come. The four RCPs, RCP2.6, RCP4.5, RCP6, and RCP8.5, are named after a possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 Watts/m^2, respectively).

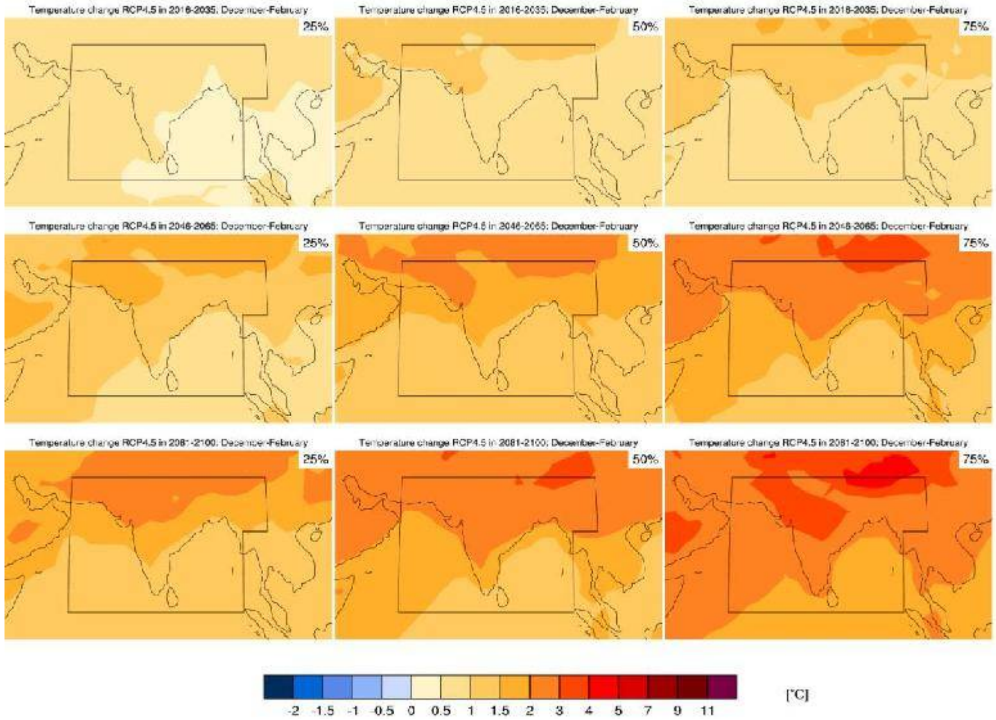


Figure 26: Maps showing changes in temperature in the winter months (Dec-Feb) for 2016-2035, 2046-2065 and 2081-2100 relative to 1986-2005

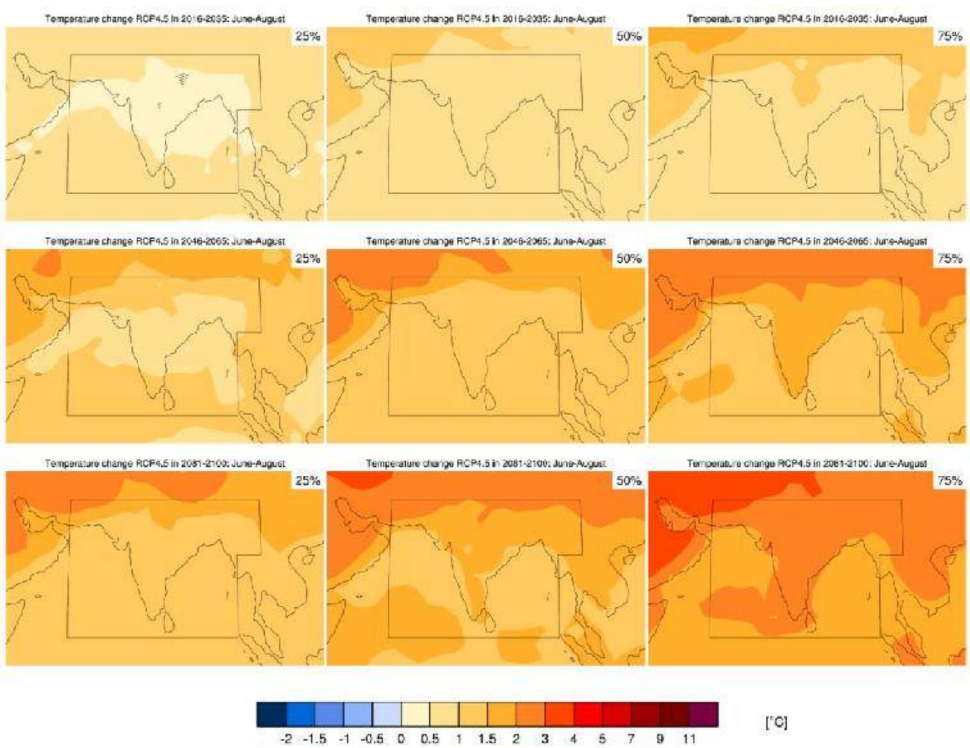


Figure 27: Maps showing changes in temperature the summer months (June-August) for 2016-2035, 2046-2065 and 2081-2100 relative to 1986-2005

The rainfall in Bangladesh is strongly influenced by the Indian Monsoon. The climate models show a very consistent and clear signal in terms of changes in Monsoon rainfall. All the climate models show an increase in both average and extreme precipitations for the Indian summer monsoon (IPCC 2013, Chapter 14.3). There is also a tendency of a longer duration of the monsoon with especially an earlier onset. This is also consistent with the observation of increased rainfall during the pre-monsoon period. While the monsoon rainfall is increasing, the strength of the monsoon circulation is decreasing **(Figure 28)**. The figure shows the impact of human activities on the monsoon rainfall. Due to warming of the atmosphere the ocean water vapour transport from the sea to the land is increasing. This increases the potential for extreme rainfall events. Global warming related changes in the circulation will result in a weaker monsoon circulation. Also aerosols (air pollution) and land use change can affect the land-sea temperature difference which affects the monsoon patterns (IPCC, 2013).

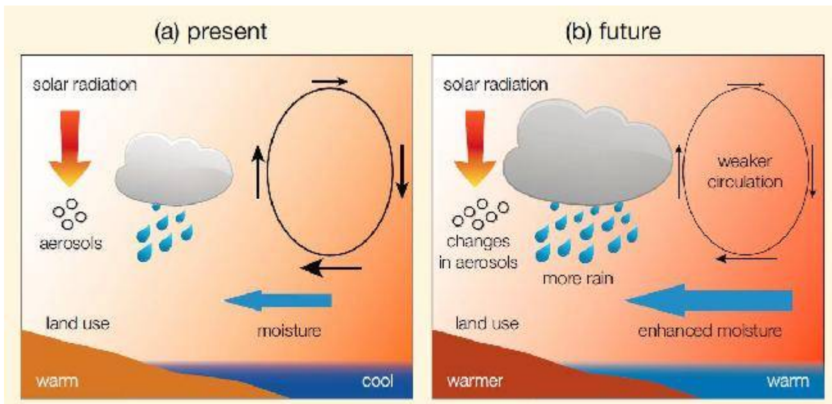


Figure 28: Impact of human activities on the monsoon rainfall

Due to increased monsoon rainfall, the annual average rainfall in Bangladesh is more likely to increase than decrease **(Figure 29).**For the RCP4.5 scenarios the average increase in rainfall is 10% to 20% by the end of the century. For RCP 8.5 scenarios this is slightly higher. Global climate models also show an increase in the frequency of extreme precipitation for RCP 6.0 and 8.5. Changes in dry season rainfall are much more uncertain. Some climate models indicate reduced rainfall during the dry season while others show an increase.

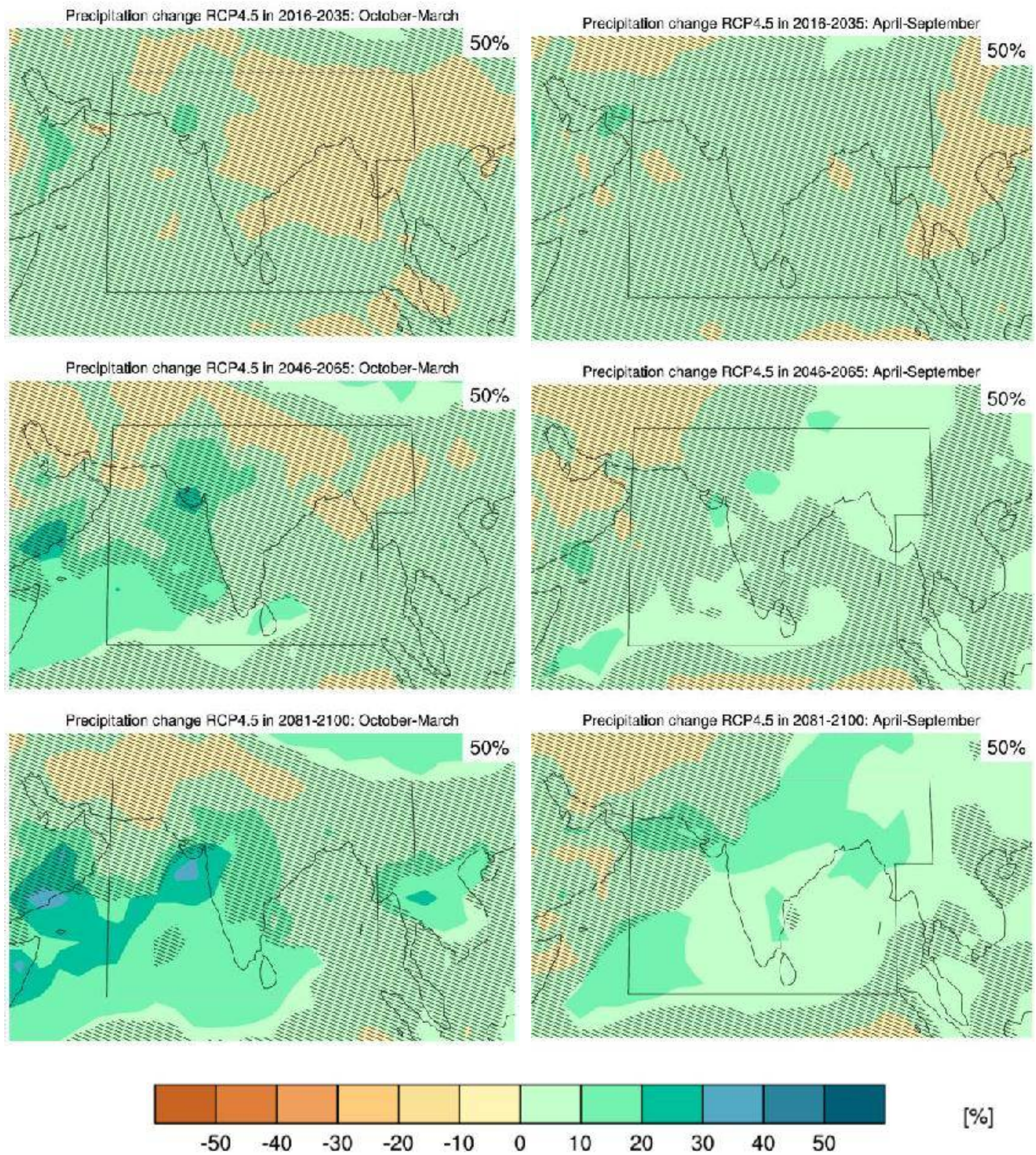


Figure 29: Maps showing changes in median rainfall for 2016-2035, 2046-2065 and 2081-2100 relative to 1986-2005

Note:The left panels show changes for October – March and the right panels for April – September

4.2. Review of papers and reports on Future Climate Change and Bangladesh

An elaborate review and compilation on the history of climate change scenarios developed for Bangladesh up to 2004 was constructed by Ahmed (2006). The early works on future climate change scenario for Bangladesh were performed in the late 1980s using speculation based on expert judgment and came up with scenarios of surface warming of 0.3 to 0.5^{0}C by 2050 (Mahtab, 1989). It was also speculated that the rainfall would increase by 5-20%. For sea level rise, 100 cm was speculated for 2050 which includes the subsidence of 10 cm. Similarly, the 2°C and 4°C change in average temperature were speculated for defining 'moderate' and 'severe' climate change scenarios, respectively with increase of peak monsoon rainfall by 18% and 33% respectively (BCAS-RA-Approach, 1994).

Several attempts have been made to develop scenarios for Bangladesh climate change due to anthropogenic GHG emissions for the future since early 1990s, using the results of Global Climate Models (GCMs) for selected storyline of development related to future GHG emissions. The BUP-CEARS-CRU (1994) study reported a 0.5^0C to 2.0^0C rise in temperature by the year 2030 under 'business as usual' scenario of IPCC. The same modelling exercise estimated 10 to 15% rise in average monsoon rainfall by the year 2030. The study did not provide a projection in relation to sea level rise, however, it described the complicacy involving both sedimentation and subsidence in addition to the climatic sea level rise.

An ADB study in 1994 used results from four GCMs: CSIRO9, Canadian Climate Centre Model (CCCM), Geophysical Fluid Dynamics Laboratory equilibrium model (GFDL) and UKMOH, anddevelopment scenario IS92a of IPCC was considered for development of climate change scenarios for Bangladesh. It was reported that, for 2010 the temperature would rise by 0.3C and for 2070, the corresponding rise would be 1.5^0C. The four models used for developing scenarios all provided different results for monsoon rainfall. The high-estimating GFDL model (GFDLH) projected 59% higher rainfall in South Asian monsoon and 16% lower rainfall in dry season. The projection from CCC model, however, shows an increase of monsoon rainfall by 20% and decrease of dry season rainfall by 6%. Both models considered a doubling of CO_2 concentration in the atmosphere (therefore, time independent). A time-dependent modelling with a CO_2 concentration of 400 and 640 ppm for 2010 and 2070 respectively showed that monsoon rainfall will increase by 5% in 2010 and 5-30% in 2070. No change of dry season rainfall has been projected by 2010, while the projection for 2070 varies between -10 to +10 %.

The development of climate scenarios for Bangladesh was attempted by Ahmed et al. (1996), Asaduzzaman *et al*. (1997) and Huq *et al*. (1998) under 'Climate Change Country Studies Programme' using a number of GCMs namely, CCCM, GFDL and 1% transient model of GFDL (i.e., GF01).

Observed climate data of the CLIM database were used for validation of the modelling results. It was found that GFDL 1% transient model represented the long term climate normal the best and was considered for development of a time based climate change scenario (Ahmed et al., 1996). The following table **(Table 8)**summarizes the climate change scenarios developed by Ahmed and Alam (1998).

Table 8: Climate Change scenarios using the GFD01 transient model [Prepared after Ahmed and Alam (1998)]

Projection years	Temperature (^{0}C)			Precipitation (%)		
	Winter	Monsoon	Average	Winter	Monsoon	Average
2030	1.3	0.7	1.3	50.0	11.2	5.6
2075	2.1	1.7	2.6	-100.0	26.8	15.6

The results of modelling future climate, obtained by Mirza (1997) using a number of GCMs, showed that by 2030 the rise of monsoon temperature would be 0.7^0C with corresponding rise of winter temperature of 1.3^0C. These results have been used by the studies of WB(2000) and the Initial National Communication (INC, 2002). The corresponding rise of rainfall was projected as 11% for monsoon followed by a decrease of 3% for the winter. For the year 2050, the rise of temperature was projected to be 1.1 ^{o}C and 1.8 ^{o}C for monsoon and winter respectively. The rainfall was projected to be 28% and -37% respectively. Mirza (2002) considered an ensemble of GCMs, instead of validating outputs of any specific model for observed values of Bangladesh, and projected an ensemble scenario. In another modelling exercise, Mirza (2005) considered three 'temperature change scenarios' with 2^oC, 4^oC, and 6^oC changes in average temperature and then computed its response in relation to changes in rainfall over the South Asian subcontinent, particularly over Bangladesh. There have been huge variations in output results, varying from 0.8% to 13.5% increase in mean annual rainfall for the Ganges basin and -0.03% to 6.4% change for the same for the Brahmaputra basin for a 2^oC temperature change scenario. There would be increasing mean annual rainfall in both the basins with increasing global warming, as reported by Mirza (2005). The UKTR model suggested as high as 63.3% increase inmean annual rainfall over the Ganges basin associated with a change in surface average temperatureof 6^oC. The corresponding change in Brahmaputra basin would be much less (Mirza, 2005).

Agrawala *et al*. (2003) have selected 11 GCMs out of 17 GCMs after validation with observed dataset for Bangladesh. The results generated using these 11 GCMs are shown in **Table 9**. It is important to note that the models have been run with the IPCC B2 SRES scenario.

Table 9: GCM projections for changes in temperature and precipitation for Bangladesh (Agarwala et al. 2003)

Year	Temperature change (standard deviation)			Precipitation change (%)		
	Annual	DJF	JJA	Annual	DJF	JJA
Baseline average				2278 mm	33.7 mm	1343.7 mm
2030	1.0 (0.11)	1.1(0.18	0.8(0.16)	+3.8 (2.30)	-1.2(12.56)	+4.7(3.17)
2050	1.4 (0.16)	1.6(0.26)	1.1(0.23)	+5.6(3.33)	-1.7(18.15)	+6.8(4.58)
2100	2.4(0.28)	2.7(0.46)	1.9(0.40)	+9.7(5.80)	-3.0(31.60)	+11.8(7.97)

Table 10: Climate Scenarios used for the NAPA (2005)

Year	Temperature change (^{o}C)			Rainfall Change (%)			Sea Level Rise (cm)
	Annual	DJF	JJA	Annual	DJF	JJA	
2030	1.0	1.1	0.8	5	-2	6	14
2050	1.4	1.6	1.1	6	-5	8	32
2100	2.4	2.7	1.9	10	-10	12	88

For the preparation of the National Action Plan on Adaptation (NAPA), in 2005, the scenarios as derived by Agarwala were used, with some adjustment**(Table 10).** Also projections of Sea Level Rise were provided. Choudhury et al. (2005) have developed a scenario for north central Bangladesh for studying the socioeconomic and physical perspectives of water related vulnerability to climate change. The results are shown in **Table 11**, which followed more practical approach for generating seasonal scenarios. The results indicate strong increase of precipitation in winter and pre-monsoon seasons.

Table 11: Future Climate Change Scenarios based on HadRM2 model results

Years	Temperature				
	Winter	Pre-monsoon	Monsoon	Post-monsoon	Annual
2020	1.7	0.8	1.4	1.8	1.4
2050	3.4	1.5	2.9	3.6	2.8
	Precipitation				
2020	30.4	26.6	4.2	5.3	9.1
2050	70.4	70.3	9.7	11.3	22.7

The scenarios for the GBM catchment and Bangladesh territory using two story lines A2 and B1 of the GHG scenarios have been developed using the results of IPCC AR4 by Tanner et al. (2007). 10 GCM results behaving well in simulating monsoon precipitation were used in this scenario development. Here the uncertainty of the scenarios have been well taken care of and are shown in **Table 12**and**Table 13**. The sea level rise has been depicted as 2-20 cm in 202 and 4-39 cm in 2050.

Table 12: Scenario of Temperature over the GBM basins and Bangladesh developed by Tanner et al. (2007)

Absolute temperature change (°C)	2020s			2050s		
GBM Basin – A2	**Annual**	**DJF**	**JJA**	**Annual**	**DJF**	**JJA**
Cool	0.9	0.7	0.4	1.4	1.8	0.8
Average	*1.2*	*1.4*	*1.0*	*2.4*	*2.8*	*2.0*
Warm	1.5	2.0	1.5	3.1	3.6	2.9
GBM Basin - B1						
Cool	0.8	0.9	0.5	1.3	1.4	0.6
Average	*1.2*	*1.4*	*1.0*	*1.9*	*2.3*	*1.6*
Warm	1.5	2.4	1.5	2.5	3.0	2.4
Bangladesh - A2						
Cool	0.6	0.0	0.2	1.3	1.5	1.0
Average	*0.9*	*1.0*	*0.9*	*2.0*	*2.4*	*1.8*
Warm	1.4	1.8	1.3	2.6	3.7	2.3
Bangladesh – B1						
Cool	0.5	0.7	0.1	1.0	1.1	0.9
Average	*1.0*	*1.2*	*0.9*	*1.6*	*1.9*	*1.4*
Warm	1.3	2.2	1.6	2.1	2.9	1.9

Table 13: Scenario of Bangladesh precipitation (Tanner et al. 2007)

BangladeshA2 precipitation (%)	2020s			2050		
	Annual	Winter	Monsoon	Annual	Winter	Monsoon
Dry	-9	-24	-11	-14	-70	-11
Average	0	+3	+1	+2	-3	+2
Wet	+9	+46	+13	+62	+62	+24
Bangladesh B1						
Dry	-10	-60	-9	-57	-57	-9
Average	+2	0	+4	-4	-4	+7
Wet	+7	+62	+16	+27	+27	+28
Sea Level Rise (SLR) (cm)	2-20			4-39		

4.3. Regional Climate modelling for Bangladesh and Indian subcontinent

The information global climate models provide is a very coarse spatial resolution and often shows significant biases especially for precipitation (Jacob and Van der Hurk 2009). To overcome this deficiency there is a need to downscale and/or bias-correct the global climate model. Dynamical downscaling uses regional climate models of higher resolution which are nested within global climate models (Giorgi 2006). In this approach Large scale phenomena are inherited from the global climate model and additional detail is provided by Regional climate model. The RCM allows for more detailed modelling of the land used, topography and improved spatial simulation of physical processes (Kumar et al 2013).

4.3.1. HighNoon

Within the EU project HighNoon (www.eu-highnoon.org) three different regional climate models were used in combination with two global climate models (Kumar et al. 2013). The results of this study showed that the regional models were better able to simulate the historic climate compared to global climate models. The simulated change a climate was dominated by the signal of the global model with the regional model providing additional detailed information. For Bangladesh the results showed that rainfall is likely to increase between 10 and 20% by the end of the century using the A1b emission scenarios. In this study only the A1b scenarios was used. For mid-century the scenarios are unclear. On average the models show little change in rainfall. A detailed analysis by Wiltshire (et al 2010) show that for Western Bangladesh the rainfall is decreasing and for Eastern Bangladesh the rainfall is increasing. It is not described what has caused these changes.

4.3.2. Impact2C

Within the EU FP7 project "Impact2C" (impact of 2^0C increase in global temperature) different regional climate models were used to analyse changes in the regional climate change under a 2 degree warming for the Ganges and Brahmaputra Basins. Three different Regional Climate Models,RCM,were used for the analyses. Each regional climate was forced at the edges of the region by a different Global Climate model. The following RCM-GCM combinationwere used: Arpege 52-CNRM, SMHI-RCA4 – ECEarth, and BCCR-WRF331-NorESM. Each model combination was run for a historical period (1971-2005) and using three different emission scenarios RCP2.6, 4.5 and 8.5. Some initial analyses are done and the data are available at Wageningen UR for further analyses. The initial results show that there will be an increase in the length of monsoon season by about 5 to 10 days under two degree warming (figure 3.1). Two degree warming is likely to be reached by 2050. Results also show that rainfall intensity is more likely to increase than decrease. The probability density function (pdf) analysed for the Dhaka region clearly show the possible range of climate change **(Figure 30).** The majority of the pdf in the upper right corner indicate the most likely change is a longer monsoon season and increased rainfall intensity. The rainfall intensity could increase by up to 3 mm/day.However parts of the pdf are also in the area with lower rainfall intensity and it is thus also possible that climate change will reduce rainfall intensity**(Figure 31).** The analysis also shows the high uncertainty in the changes in the length of the monsoon season. Some models indicate a shorter monsoon while others show an increase in the length of the monsoon season.

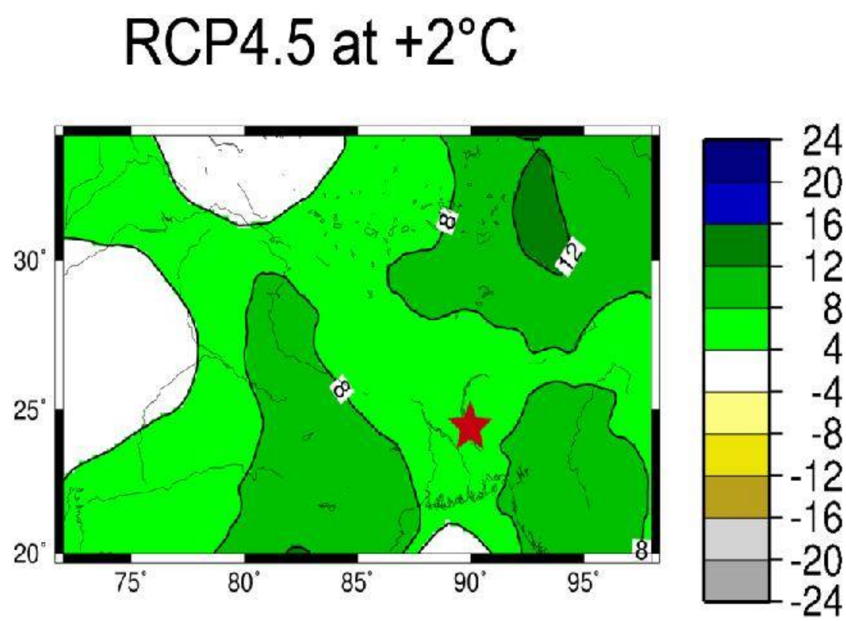


Figure 30: Changes in the duration for the monsoon at two degree warming

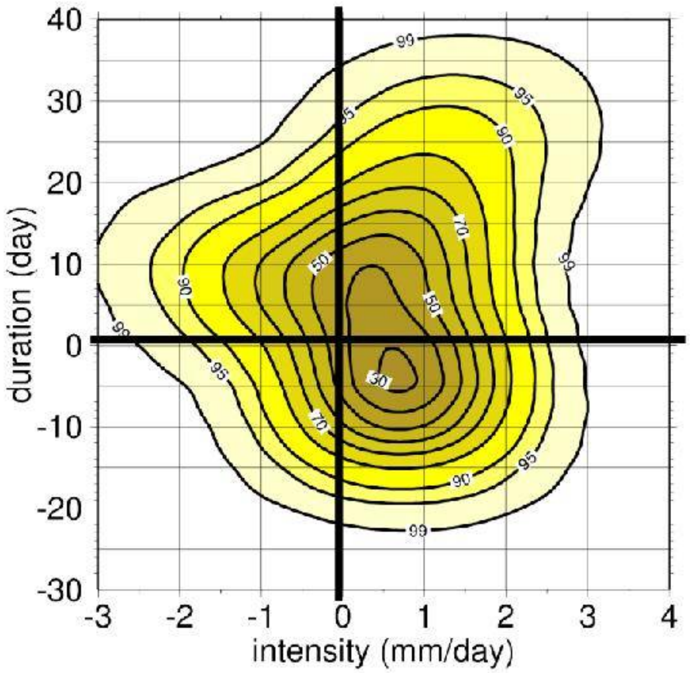


Figure 31: Bivariate probability density function (pdf) for changes in the monsoon duration and rainfall under 20C warming for RCP4.5 for Dhaka(Note: The contours indicate cumulative probability in %)

4.3.3. Regional climate modelling using PRECIS In earlier chapters the chronology of climate scenarios developed using the GCM results for the GBM region and Bangladesh territory has been discussed. However, for more effective planning of adaptation to climate change, especially in water and agriculture sectors, projections with higher spatial resolution are needed. These can be obtained through a downscaling process by running regional models which are initialized with GCM outputs. Providing Regional Climates for Impacts Studies (PRECIS) model developed by Hadley Centre is one of those which produce the downscaled climate scenarios with high spatial resolution. The first work was done by Islam (2009), in which dealt with calibration of the downscaled modelling outputs from PRECIS for the period 1961-1990 against observations and developed calibration coefficients for adjusting the model projections. The calibrated results were then compared with observation for the period 2001-2006. This shows that in some years over-estimation and in other years under-estimation is simulated by PRECIS, with a net over-estimation of 4.5% during the year 2000-2006 .The projection for the period from 2010-2020 is found to be -1% to +5.3%. The maximum temperature is found to increase by 0.45^{0}C and minimum temperature by 0.15 ^{0}C during this period. The study of DoE (CCC, 2008) generated scenarios for Bangladesh for precipitation and temperature for 2030, 2050 and 2070 using ECHAM4 SRES A2 emission scenario. This shows that the precipitation will increase at 4%, 2.3% and 6.7 % in 2030, 2050 and 2070 respectively with reference to the observed baseline period.**Figure32** shows the spatial distribution of future scenarios of Tmax for 2030, 2050 and 2070, while **Figure 33** shows the spatial distribution of future scenarios of precipitation for 2031, 2051 and 2071.

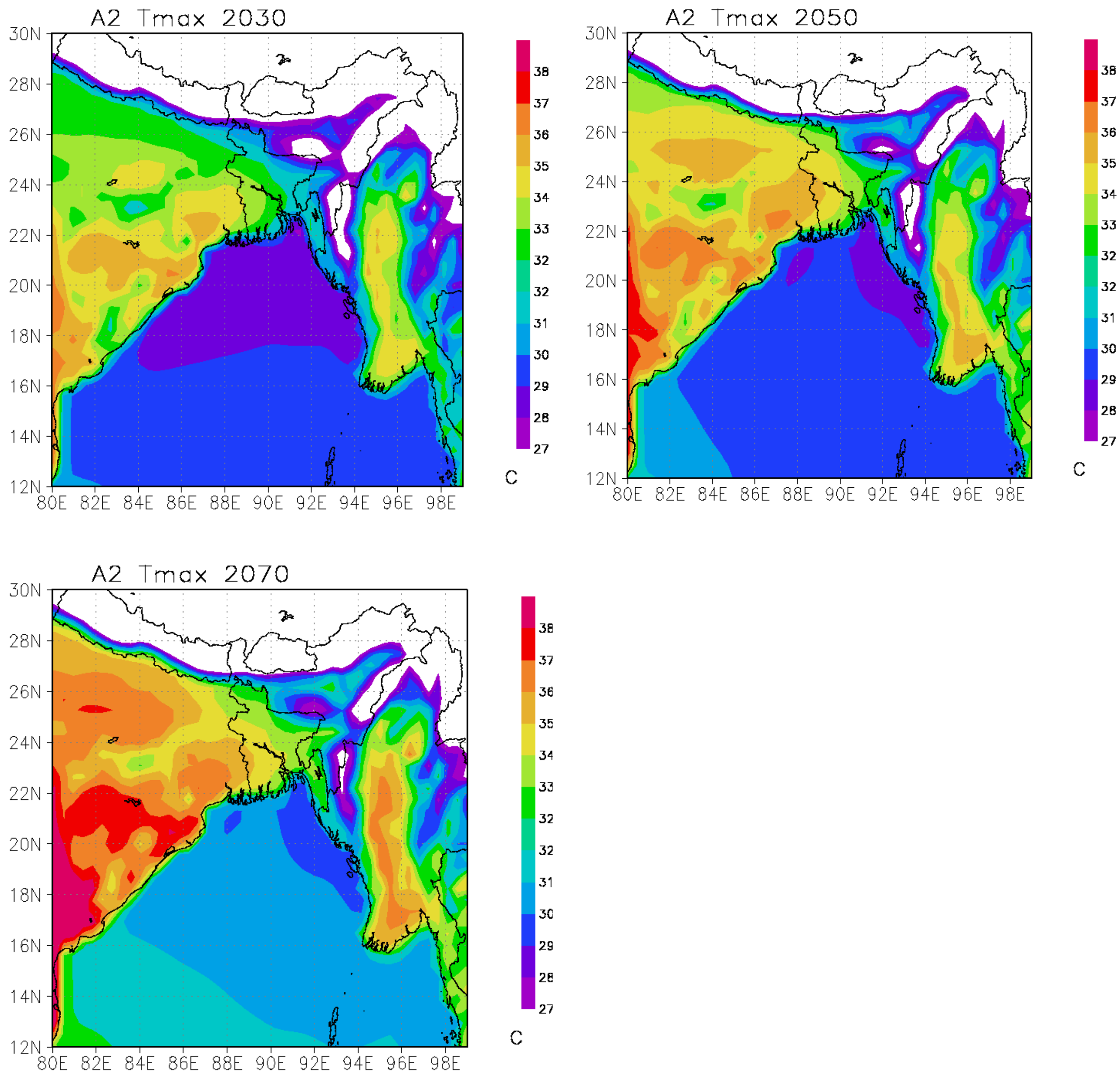


Figure 32: The spatial distribution of Tmax for the years 2030, 2050 and 2070 down-scaled using PRECIS model

Note: The PRECIS model was run for 50x50 km grid size (CCC, 2008)

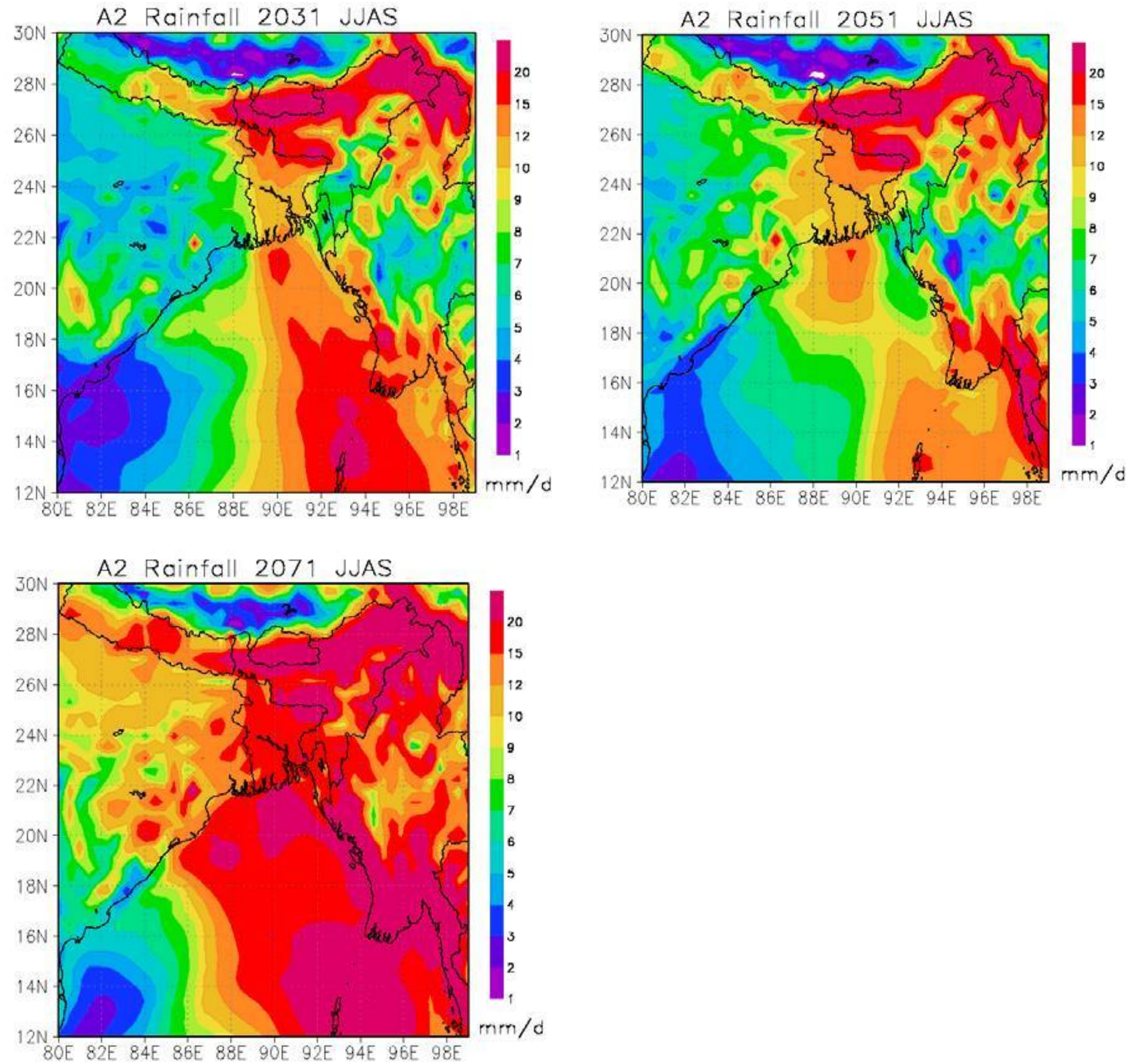


Figure 33: The spatial distribution of precipitation in 2031, 2051 and 2071 down-scaled using PRECIS model.

Note: The PRECIS model was run for 50x50 km grid size (CCC, 2008)

The work does not specify which GCM results are used for the initializing the PRECIS model. Experimentation with multi model GCM results using the calibration with observed data will provide more reliable results.

URL http://teacher.buet.ac.bd/akmsaifulislam/climate/ (last accessed Jan 2015)' provides the future projections of mean temperature and precipitation climate of Bangladesh using PRECIS models relative to selected meteorological stations of Bangladesh as shown in **Figure 34**. The scenario has been developed using SRES A1B GHG scenarios To look at the data it is required to get into the web page and click on the location of the station to see the dataset. For example the station Mymensingh is clicked and then the projection data are obtained. It is not described which GCMs have been used.

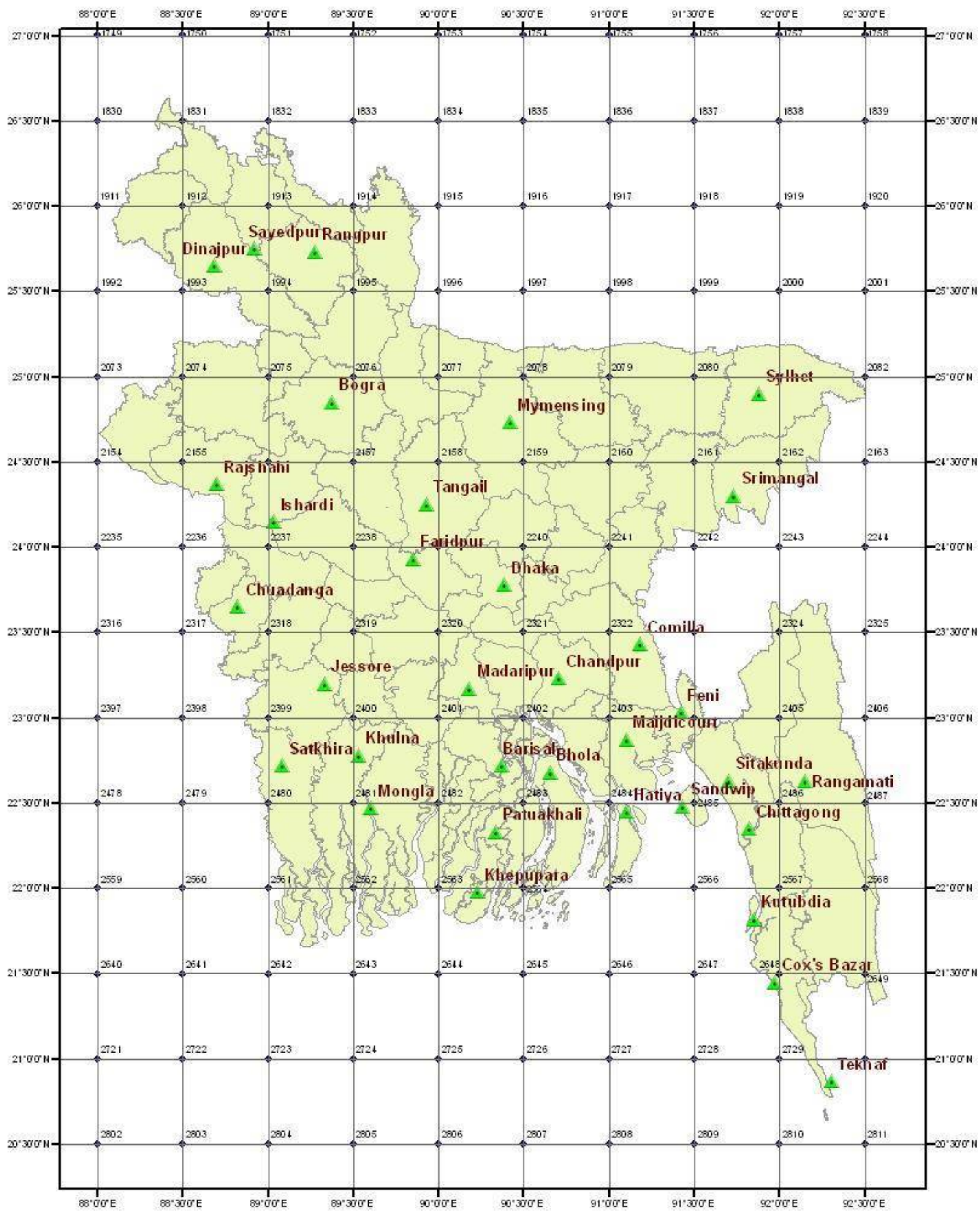


Figure 34: Map of Bangladesh showing the locations of BMD stations

Note: This map is available in the link – http://teacher.buet.ac.bd/akmsaifulislam/climate,when the location of a station is double clicked the projection data become visible.

5. Climate Change Information needed for the Bangladesh Delta Plan

While the earlier chapters discussed an overview of the available knowledge on current climate, and current and future climate change, this chapter focuses on stakeholders, policies and projects, in order to identify where the currently available knowledge on climate change is generated and used, and what additional knowledge or mechanism may be required for the Bangladesh Delta Plan.

5.1. Climate Change related Stakeholders, Policies and Projects

From Government side, coordination on all aspects of climate change is done by the Ministry of Environment and Forests, the Climate Change Cell and the Department of Environment (DoE).

Coordination of the government funds for climate change is done under the Climate Change Trust Fund (BCCT) (http://www.bcct.gov.bd/), while the donor funds are brought together under the climate change resilience fund, CCRF, are coordinated by World Bank.

Stakeholders can be grouped on their interest for climate change and climate change science, climate change mitigation and climate change adaptation. Also there is a group of people interested in the subject of 'loss and damage'. For the purpose of this study, the focus is on climate change and climate change science.

Major stakeholders on climate change science in government and knowledge institutes are:

- Ministry of Environment and Forests, Department of Environment, Climate Change Cell
- Climate Change Trust Fund / Climate Change Resilience Fund
- Bangladesh Meteorological Department (BMD)
- Bangladesh Space Research and Remote Sensing Organization (SPARRSO)
- Bangladesh Water Development Board (BWDB)
- Bangladesh Water Resources Planning Organization (WARPO)
- CEGIS
- IWM
- BUET
- DUET (new MSc on climate change schedule to start in 2015)
- Jahanginagar University
- Khulna University
- BCAS
- World Bank
- ICCCAD
- Gobeshona Platform on climate change research in Bangladesh (www.gobeshona.net)

AsapartoftheglobalobligationundertheUnitedNationsFrameworkConventiononClimateChange(UNFCCC),theGovernmentofBangladeshhassubmitted a First National Communication (INC) in 2002 and the SecondNationalCommunication (SNC) in 2012to UNFCCC / the Conference of Parties (COP) in accordance with article-4, paragraph-3 of the Convention. SNC has provided a comprehensive review of climate change related policies, plans and strategies up to 2012 in addition to the major contents on national circumstances, GHG inventory, GHG mitigation and climate change adaptation.

With regard to national government policies, the two major policy documents on climate change are the NAPA and the Bangladesh Climate Change Strategy and Action Plan. In 2014 a new document was developed, the National Action Plan (NAP).

5.1.1. NAPA, 2005

The National Adaptation Programme of Action (NAPA, 2005) has been prepared by the Ministry of Environment and Forest (MOEF), Government of the People's Republic of Bangladesh in 2005 as a response to the decision of the Seventh Session of the Conference of the Parties (COP7) of the United Nations Framework Convention on Climate Change (UNFCCC). NAPA has identified a number of areas where the climate change and extreme climate events would have severe impacts. Most damaging effects of climate change are floods, tropical cyclones, salinity intrusion, and droughts that are found to drastically affect crop productivity almost every year. Climate change induced challenges are: (a) scarcity of fresh water due to less rain and higher evapotranspiration in the dry season, (b) drainage congestion due to higher water levels in the confluence with the rise of sea level, (c) river bank erosion, (d) frequent floods and prolonged and widespread drought, (e) wider salinity in the surface, ground and soil in the coastal zone. It was found that the population living in the coastal area is more vulnerable than the population in other areas. The agricultural sector will face significant yield reduction. Thus food-grain self-sufficiency will be at risk in future.

The strategic goals and objectives of future coping mechanisms are to reduce adverse effects of climate change including climate variability and extreme events, and promote sustainable development. Future coping strategies and mechanisms are suggested based on existing process and practices keeping main essence of adaptation science which is a process to adjust with adverse situation of climate change. NAPA prioritized 15 studies for funding for development of coping mechanism for climate change adaptation and reducing disaster vulnerability. The list of priority areas are shown below:

- Reduction of climate change hazards through coastal afforestation with community participation.
- Providing drinking water to coastal communities to combat enhanced salinity due to sea level rise. Providing drinking water to coastal communities to combat enhanced salinity due to sea level rise.
- Capacity building for integrating Climate Change in planning, designing of infrastructure, conflict management and land-water zoning for water management institutions.
- Climate change and adaptation information dissemination to vulnerable community for emergency preparedness measures and raising awareness on enhanced climatic disasters.
- Construction of flood shelter, and information and assistance centre to cope with enhanced recurrent floods in major floodplains.
- Construction of flood shelter, and information and assistance centre to cope with enhanced recurrent floods in major floodplains.
- Mainstreaming adaptation to climate change into policies and programmes in different sectors (focusing on disaster management, water, agriculture, health and industry)
- Inclusion of climate change issues in curriculum at secondary and tertiary educational institution.
- Enhancing resilience of urban infrastructure and industries to impacts of climate change
- Development of eco-specific adaptive knowledge (including indigenous knowledge) on adaptation to climate variability to enhance adaptive capacity for future climate change
- Promotion of research on drought, flood and saline tolerant varieties of crops to facilitate adaptation in future.
- Promoting adaptation to coastal crop agriculture to combat increased salinity.
- Adaptation to agriculture systems in areas prone to enhanced flash flooding–North East and Central Region.
- Adaptation to fisheries in areas prone to enhanced flooding in North East and Central Region through adaptive and diversified fish culture practices.

- Promoting adaptation to coastal fisheries through culture of salt tolerant fish special in coastal areas of Bangladesh
- Exploring options for insurance to cope with enhanced climatic disasters.

5.1.2. BCCSAP, 2009

As one of the first countries in the world, Bangladesh took action to formulate a climate change strategy following COP 13 in Bali, 2007. The Bangladesh Climate Change Strategy and Action Plan (BCCSAP) was first formulated in 2008 and further revised in 2009. The BCCSAP was formulated upon wide-ranging consultation within the Government as well as between the government and the civil society, development practitioners as well as development partners and the private sector. The document outlines the core policy, strategy, and action thrusts to come up with mechanism to respond to and address the risks related to climate change and occurrences of extreme events in the country. The BCCSAP is an integral part of the Government's over-all development strategy to adapt the climate change impacts in a sustainable manner.

The BCCSAP 2009 provides background issues related to physical and climatic contexts, core socio-economic realities and policies in the country and the rationale of the vision of future development in the climate change sector. The document provides an overview of the vulnerability to different natural hazards and climate change impacts (**Figure 35**). The report further provides a set of programmes under six priority action pillars of the BCCSAP. It is a set of 10-year programme (2009-2018) for capacity building and achieving resilience of the country to meet the challenges of climate change over the next 20-25 years. The needs of the poor and vulnerable, including women and children, will be mainstreamed in all activities under the Action Plan.

Under BCCSAP six thematic areas were identified, namely

(1) food security, social protection and health
(2) comprehensive disaster management
(3) infrastructure
(4) research and knowledge management
(5) mitigation and low-carbon development
(6) capacity building and institutional strengthening

Implementation of BCCSAP has been entrusted to the Climate Change Trust (government funds) and the Climate Change Resilience Fund (donor funding).

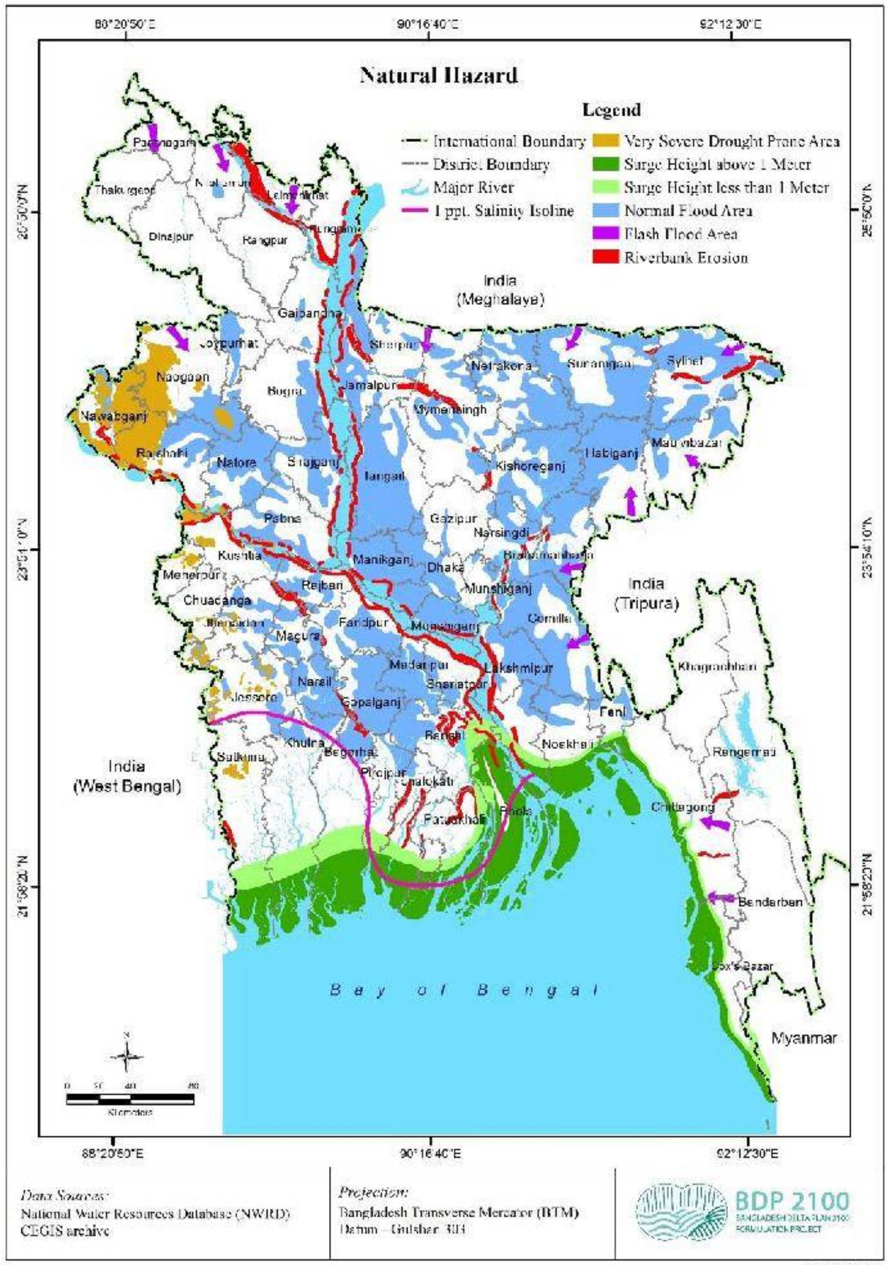


Figure 35: Vulnerability to different natural hazards (source CEGIS; in: BCCSAP, 2009)

5.1.3. Climate change in the 6th Five Year Plan

In the 6th Five Year Plan, a section has been included addressing climate change. Both NAPA and BCCSAP are used as cornerstones of the government's efforts to address climate change. This will be discussed further in Chapter 12. Bangladesh is developing the 7th Five Year Plan which is likely to address climate change issues for more rigorous climate research, institutionalization of climate change and materialize priority options for climate change adaptation and disaster risk reduction.

5.1.4. NAP (2014)

In 2014, a team was formed to formulate the National Action Plan, a road map to implement adaptation and mitigation action.The formulation of the NAP is considered important in order to ensure climate funding from international level (note that climate funding is not addressed under this baseline study). A consultative process based national consensus will be forged under the NAP formulation process to develop a comprehensive coordination and implementation mechanism across sectors and actors on CCA. The NAP Roadmap will consider the most vulnerable issues regarding highlighted gender sensitivity issues that must be plugged in towards developing CCA projects in Bangladesh. International support is necessary to both enhance GOB capacities to carry out the task and to mobilize external support in the form of technically sound personnel and/or consultants to complete the task within a considerable time frame.

5.1.5. National Policies

A number of policies on environment, disaster, health, water resources, water supply and sanitation and agriculture and livestock have been developed over the years and incorporatedclimate change, impacts and adaptation. Most of the policies underscored the need for an integrated approach, mainstreaming adaptation into the planning and implementation process. The important policies which have integrated climate change and adaptation are:

- National Environmentpolicy, 1992 and 2013 Ministry of Environment and Forest
- National forestpolicy, 1994 Ministry of Environment and Forest
- Energy Policy, 1995 and 2004 Ministry of Energy and Mineral Resources
- National fisheriespolicy, 1998, Ministry of Fisheries and Livestock
- National policyforsafewatersupplyandsanitation,1998, Ministry of Local Government, Rural Development and Cooperatives
- National Agricultural Policy, 1999, Ministry ofAgriculture.
- Land Usepolicy, 2001,Ministry of Land (MoL)
- Integrated Pest Management policy, 2002, (Ministry ofAgriculture),
- National populationpolicy, 2004,Ministry of Health and Family Welfare
- Industrialpolicy, 2005, Ministry of Industries
- Coastal zonepolicy, 2005, Ministry of Water Resources
- National BiotechnologyPolicy, 2005, Ministry of Science and Information and Communication Technology
- Renewable Energy Policy of Bangladesh, 2008, Ministry of Power, Energy andMineral Resources
- Information communication and technologypolicy, 2009 , Ministry of Science, Information and Communication Technology
- Social and resettlement policyframework, 2009, Ministry of Planning
- National foodpolicy, 2006, Ministry of Food and DisasterManagement
- Tourismpolicy, 2009, Ministry of Civil Aviation and Tourism
- National healthpolicy, 2011, Ministryof HealthandFamilyWelfare
- National Agriculture Policy, 2010

5.1.6. Some of the climate change science related projects and research

There is a large variety on climate change projects in Bangladesh. CEGIS, BCAS, IWM, IWFM, BARI, BRRI, BARC have on-going research on climate change, also related to agriculture and water. Sofar, there is not a single institute which is the lead organization in Bangladesh on climate change science.

Internationally, a number of institutes are involved in climate change related research on Bangladesh, like the Hadley Centre, the Climate Institute in Potsdam, and Wageningen University and Research Centre. The collection of research findings as collected by IPCC is of importance to Bangladesh. The most recent work of IPCC (2013) has been summarized with regard to Bangladesh in this baseline study in Chapter 4. It is noted that most of the research on Bangladesh in IPCC is done by researchers from outside Bangladesh (Stott, 2014). For the purpose of strengthening climate change research in Bangladesh, the Gobeshona Platform was initiated (www.gobeshona.net). For this climate change baseline study, active interaction took place with the platform.

When focussing on climate change science and impacts some of the major research and implementation projects are listed below:

- Impact2C (BCAS, IWM, Wageningen UR)
- NICHE155, scenario development in IWRM (BUET, BAU, CEGIS, WARPO, IHE, Wageningen UR, Deltares)
- ESPA (coordinator in UK: University of Southampton, coordinator in Bangladesh: IWFM/BUET)
- CEGIS/IWM/BUET research on climate change in Bangladesh (forthcoming)
- Earth2Observe and Corfu (IWM and 26 institutions internationally)
- Climate change and food security (published in Winston Yu et al, 2010)
- Comprehensive Disaster Management Programme (CDMP-II), a collaborative initiative of the Bangladesh Ministry of Disaster Management and Relief (MoDMR) and UNDP.

5.2. Links with other relevant baseline studies and climate change impacts

During the BDP Climate Change Baseline Study, other baseline studies were consulted on their information requirements regarding climate change. In **Table 14**an overview is provided of meteorological indicators related to climate and climate change and the importance to the 8 clusters, covering all 19 studies. Though climate change is considered important in all 8 clusters, for some studies the demand is not direct, as for instance for economics and governance clusters.

Table 14: Inter linkages between climate and climate change information and baseline study clusters

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Water						x	x	x	x	x	x	x
WatSan				x	x		x	x	x	x	x	
Drn &CC	x	x	x	x			x	x	x	x		x
Spat.pl				x		x	x	x	x			x
Food sec	x	x	x	x	x	x	x	x	x	x	x	x
Envt mgt			x	x	x	x	x	x	x			x
Econ&Fin												
Govern												

Meteorological indicators

(1) Average maximum temperature (Tmax)
(2) Average minimum temperature (Tmin)
(3) Difference Tmax-Tmin
(4) Heatwaves (>5 days above normal)
(5) Number of days Tmax above threshold
(6) Average precipitation
(7) Duration and length of dry spells
(8) Duration and length of wet spells
(9) Average rain intensity
(10) Average highest one day prec.amount
(11) Average highest 5 day prec.amount
(12) Number of wet days

The data of the climate change baseline is available to the other baselines and already some exchange has taken place with the touch table team. This has resulted in an interactive mapping tool (draft version). The results of chapter 7 are used in this tool. Further verification with stakeholders is currently undertaken.

5.3. Climate Information needed for development of Bangladesh Delta Plan

The Bangladesh Delta Plan envisages an open and inclusive process for its formulation. Also for bringing together the state-of-the-art knowledge on climate change, and to formulate jointly scenarios on climate change for the BDP2100 an open approach was followed, consulting in steps an increasing number of the stakeholders as mentioned in section 5.1. During the baseline study process3 meetings were organized, one with the TA team to formulate inter-linkages, one with climate change experts to inventorize and validate climate change information, and one with the Gobeshona platform for the same. The meetings took place in September and October 2014. In December 2014 a field visit was undertaken to Khulna, to consult climate experts at Khulna University and Khulna University of Engineering and Technology (KUET). Also the mayor of Khulna and some NGOs were briefed on the climate change baseline study and information was gained from discussion. The general impression is, that it is not easy to provide location specific information on climate change and climate change impacts.

Indicators required are related to water in the delta: too much, too little, too dirty. The indicators provided have sofar proven sufficient. However, it is expected that with further integration of the baseline studies, more specific requests for data may arise (e.g. hourly versus daily rainfall, minimum and maximum temperatures, annual or seasonal analysis of precipitation). One complex question has already emerged, related to future water demand in agriculture under conditions of climate change. Complex, as both agriculture and climate are changing.

Accessibility of the data and modelling results were emphasized. In the Climate Change Baseline Study, results will come in standard format, and can be made available for interested users. It is expected that in the wider context of the Bangladesh Delta Plan an information point (server) will become available.

From the Bangladesh Delta Plan Baseline Study Climate Change, the data for the indicators as in section 5.2 will be available for the design and implementation of the Bangladesh Delta Plan, as will be the modelling outcomes, indicating future climate change (see Chapter 6). These will also be used for the development of the delta scenarios.

In general, it is noted thatfor local level adaptation, spatial data are required, while climate related measurements are often point-based. Modelling results, e.g. through downscaling, can assist providing such spatial data.Dynamic downscaling is increasingly possible, and should be explored further. More field level data and verification of modelling data at field levelare required.

It is noted that in general, urgent present day problems are being addressed, while not yet taking into account climate change insights. Future climate change information is not yet widely available and used. There is a gap between the stakeholders working on the climate change science, and the users of such data (government, NGOs etc). As the Bangladesh Delta Plan is a longer term effort, which entails to use updated knowledge also in future implementation and updates of the plan, a monitoring mechanism on climate (how to collect the data) and a distribution mechanism for climate change information is required (how to make relevant information available to specific stakeholder groups).

6. Methods for developing future climate change scenarios

Although it is very likely that increased future greenhouse gas emission will change the climate in Bangladesh, the extent and sometimes the direction of change are highly uncertain. To cover this uncertainty and to provide guidance to the Development of the Bangladesh Delta Plan it is necessary to develop scenarios for climate change. These scenarios can be used for the problem and impact analyses and to guide the development of adaptation plan and pathways.

The methods used are similar to the WorldBank Climate analyses tools (Girvetz et al. 2013; http://s3.amazonaws.com/WB_Bangladesh/index.html). However, this data set is based on the latest climate models runs performed for the 5th Assessment Report (AR5) of the IPCC (2013). As a result is also use of the latest emission pathways (RCPs). For this analysis a relatively low emission pathway (RCP4.5) was used, similar to the SRES B1 scenario and a high emission pathway (RCP8.5) higher than the SRES A2 scenario. This method has also been used to develop scenarios for Europe and East Africa (Ludwig et al. 2013).

6.1. Climate models used

This analysis is using the output of Five different Global Climate Models.

1. MPI-ESM-LR
2. IPSL-CM5A-LR
3. HADGEM2-ES
4. ECEARTH
5. CNRM-CM5

For all GCM's the historical, the RCP85 and RCP45 data were collected. The meteorological variables included in the series are: windspeed, maximum temperature, minimum temperature, mean daily temperature, surface down-welling shortwave radiation (SDSR), surface down-welling long-wave radiation (SDLR), precipitation and snowfall.

Five different climate models were selected based on a range of indicators. First all daily output was obtained for all the requested variables. In addition models for which quality has been assessed over the last 5 to 10 years were selected. All selected models, except EC-Earth, have participated in a number of previous model inter-comparisons. In addition models which covered the range of future climate projected by the whole CMIP5 ensemble were selected. The most extreme models were not included. Two relatively dry models, two relatively wet models and a middle of the road model were selected. Of these, two models have been selected which were used in many previous analyses (MPI-ESM-LR and HADGEM2-ES). The ensemble average change of the five models is very similar to the ensemble average change of the 39 CMIP5 models.

6.2. Downscaling and Bias correction

6.2.1. Standardization

After downloading the data, the series were standardized. First, series of equal length were constructed. For the historical data the series comprised data from 1stJanuary 1960 until 31stDecember 2005. The RCP4.5 and RCP8.5

comprised data from 1st January 2006 until 31st December 2100. Exceptions are the CMCC-CESM series, which started on 1st January 1961 and the IPSL-CM5A-LR series which ended on 31st December 2099. Subsequently, for those data series that did not contain leap years the calendar type was set to "proleptic gregorian" and data from February 28 was copied to February 29 to incorporate leap years. Note that the HADGEM2-ES data series have a calendar year of 360 days. Depending on the year, leapyear or non-leapyear, 5 or 6 days at the end of the year were copied and added in order to get a series of 365 or 366 days. Within a year days were reshuffled to form correct series that follow the "proleptic gregorian" calendar.

6.2.2. Interpolation

Subsequently all data series were interpolated to a 0.5 x 0.5 degree grid size that is similar to the WATCH forcing data (centre of the first grid cell: 179.75 W and 89.75 N) (Weedon et al. 2011)

6.2.3. Bias correction

The temperature, precipitation and snowfall data series were bias corrected according methods developed by Piani et al. (2010). The bias correction script (written in IDL) that was made by Piani and Haerter within the WATCH project was used. The radiation and wind speed data series were bias corrected with the method used by Haddeland et al. (2012), using a python script in combination with the CDO package. Both the bias correction methods used the Watch forcing data series (1960-1999) as a reference. The bias correction took place on a dedicated Linux server with extensive memory to accommodate the large data files.

6.3. Meteorological indicator analyses

The bias and non-bias corrected outputs of the ESM simulations can be used to calculate changes for the following indicators:

1. Average maximum temperature (Tmax)
2. Average minimum temperature (Tmin)
3. Difference between the maximum of Tmax and the minimum of Tmin (Etr)
4. Number and duration of heatwaves where a heatwave is defined as the period with 6 consecutive days temp more than 5°above normal
5. Number of days where Tmax is above threshold
6. Average precipitation
7. Duration and length of dry spells
8. Duration and length of wet spell.
9. Average rain intensity
10. Average highest one day precipitation amount
11. Average highest five day precipitation amount
12. Number of wet days

For every year in the selected period and for every GCM the above mentioned indicator is calculated. Subsequently the indicators were averaged over all GCM's and over the years for the selected periods, and the changes in these indicators relative to historical results are established. The twelve indicators above are mostly available at Wageningen UR and only need to be plotted for Bangladesh and upstream areas. Based on the data set available other indicators can be calculated as requested by stakeholders and partners.

At monthly average timescale these datasets should be similar to the data which will be createdby a WB study. However the data in Wageningen has an improved method for calculating daily extremes and the development of a spatially coherent data set (Hagemann et al. 2011). Also the use of the historical data is transparent in the Wageningen UR dataset which is the Watch Forcing Data (Weedon et al. 2011). The Watch Forcing Data is freely available and is specifically developed for hydrological and water resources models and analyses

7. Initial Results of Climate Change Scenarios

7.1. Scenarios for Bangladesh

The climate scenarios show that Bangladesh will become warmer and that rainfall intensity will increase in the future. The average rainfall is also likely to increase but the dry spells will also become longer in the future.

Both Maximum and Minimum temperatures will continue to increase during the coming century. Minimum temperatures in Bangladesh are projected to increase between 2 and 5 degrees depending on the time periods and emission scenarios **(Figure 36).** For the RCP4.5 the temperature increase will be limited to about 2 to 2.5 degrees. Under high emissions (RCP8.5), minimum temperatures will increase up to 5 degree by the end of the century. The patterns for maximum temperature are similar to the change of minimum temperature**(Figure 37)**. The maximum temperatures are increasing slightly less than the minimum temperatures. By mid-century temperatures will increase between 2 and 3 degrees. At the end of the century, with high emissions temperatures could be 4 degrees higher compared to the baseline period 1970-1999.

The scenarios show a broad scale increase in total annual rainfall for Bangladesh. Rainfall will increase the most in the North East and the least in the South West. In the North East the rainfall increases up to 800 mm/year in the South-western part the increase is less than 200 mm per year **(Figure 38).** The figure shows changes in total precipitation (mm) compared to baseline period 1970-1999. As expected, the increase in rainfall is higher by the end the century and is also higher for RCP8.5 compared to RCP4.5. The higher future rainfall is mainly caused by an increase in intensity because the number of rain days are not expected to increase. Averaged over the five climate models, there is hardly any change projected for the number of rainy days **(Figure 39)**. The figure shows changes in days with rainfall compared to baseline period 1970-1999. The rainfall intensity however is clearly increasing. For example the number of days with more than 20 mm of rain will increase by 10 to 30% resulting in 5 to 15 days more with intense rainfall **(Figure 40)**. The figure shows changes in the number of days with rainfall higher than 20 mm compared to baseline period 1970-1999. Also the maximum daily rainfall event is increasing throughout the county (data not shown).

The severity of dry spells is also increasing. The length of the longest period without rainfall is increasing in the future. Although there is large uncertainty here and the average signal only become clear towards the end of the century **(Figure 41)**. Figure shows changes in the number of days with rainfall higher than 20 mm compared to baseline period 1970-1999.

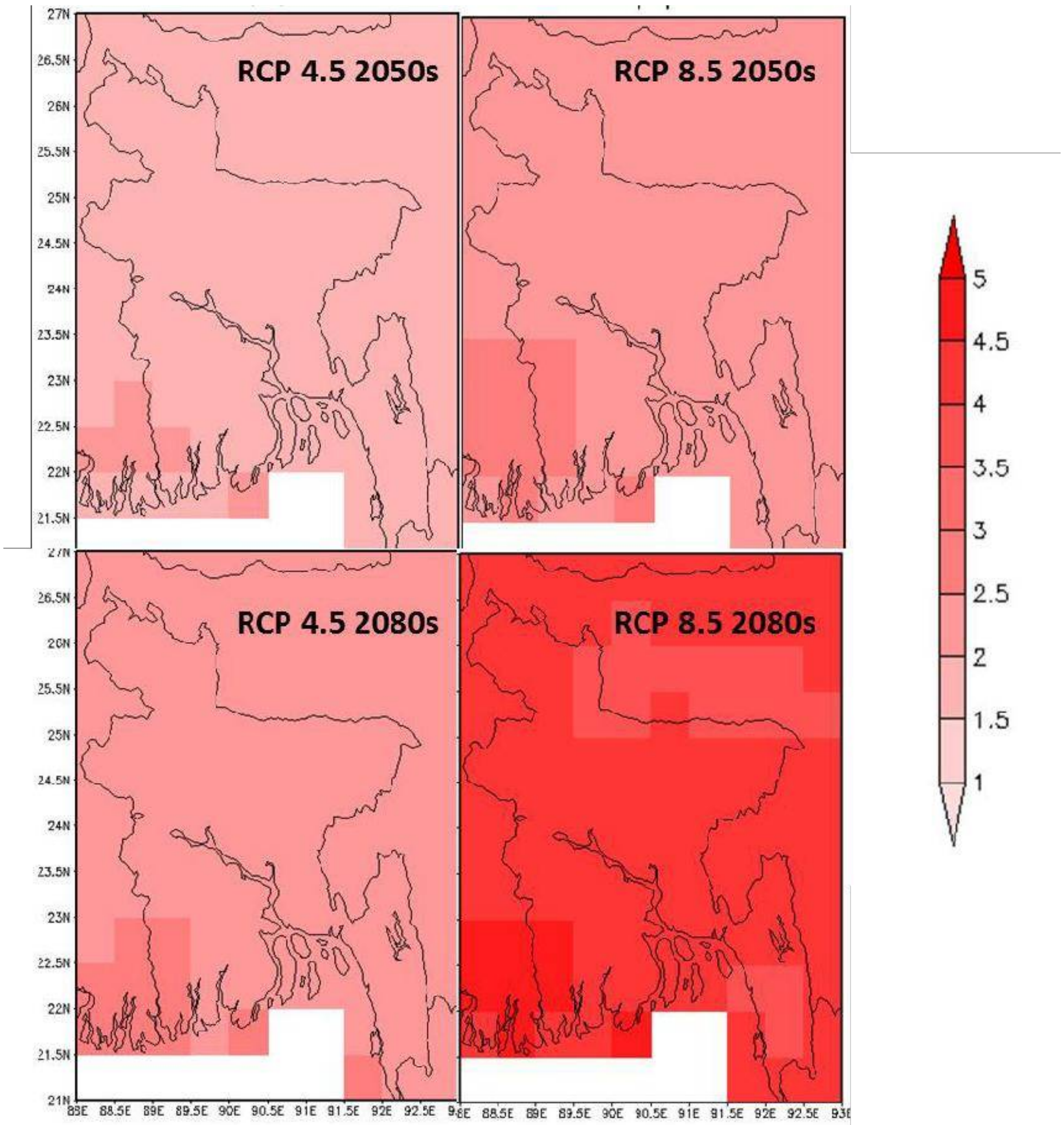


Figure 36: Average change in minimum temperature for mid-century 2050s (2036-2065) and end of the century 2080s (2070-2099) for a low (RCP4.5) and high (RCP8.5) emission scenario

Note: Figure shows changes in minimum temperature compared to baseline period 1970-1999

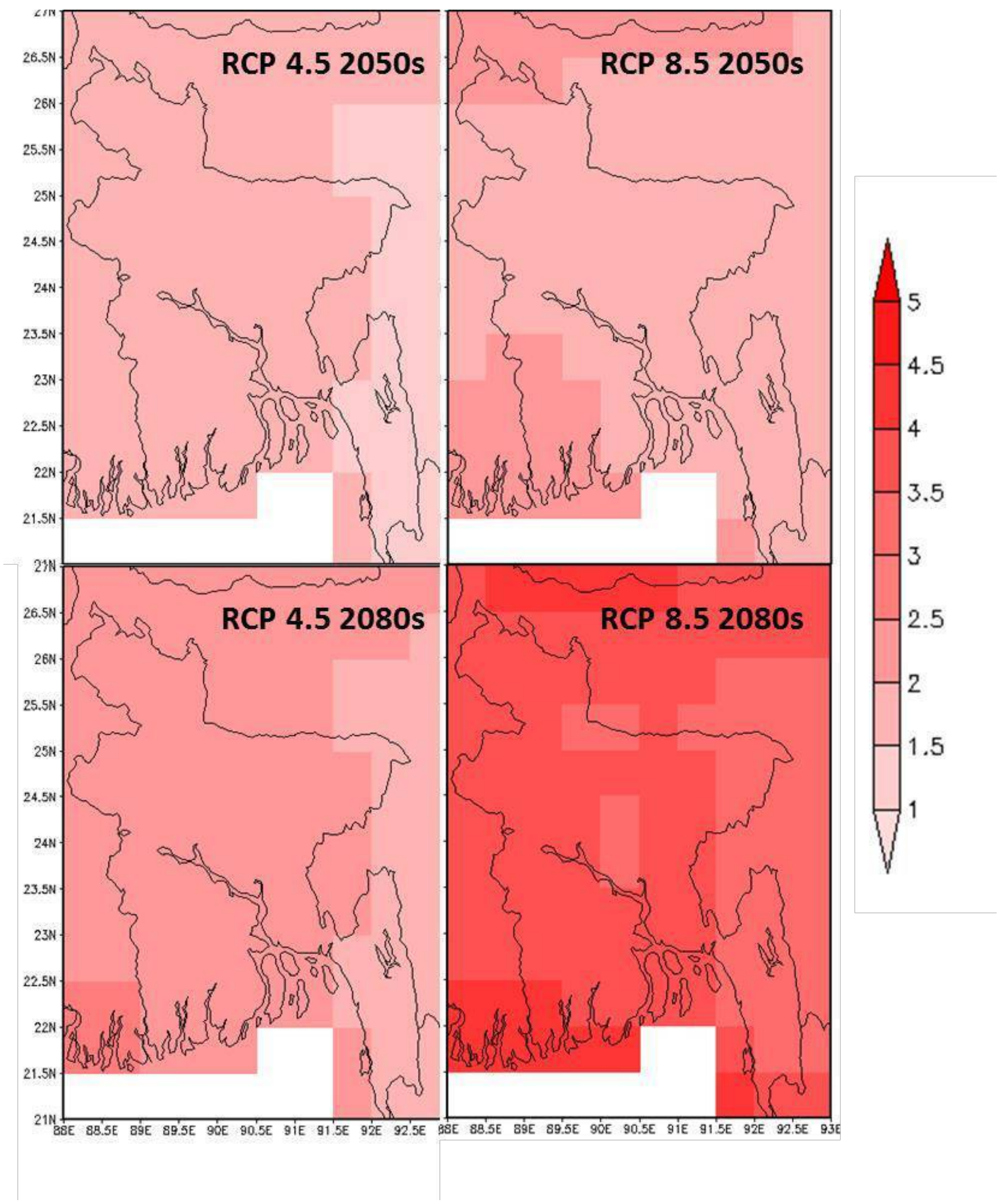


Figure 37: Average change in maximum temperature for mid-century 2050s (2036-2065) and end of the century 2080s (2070-2099) for a low (RCP4.5) and high (RCP8.5) emission scenario

Note: Figure shows changes in minimum temperature compared to baseline period 1970-1999

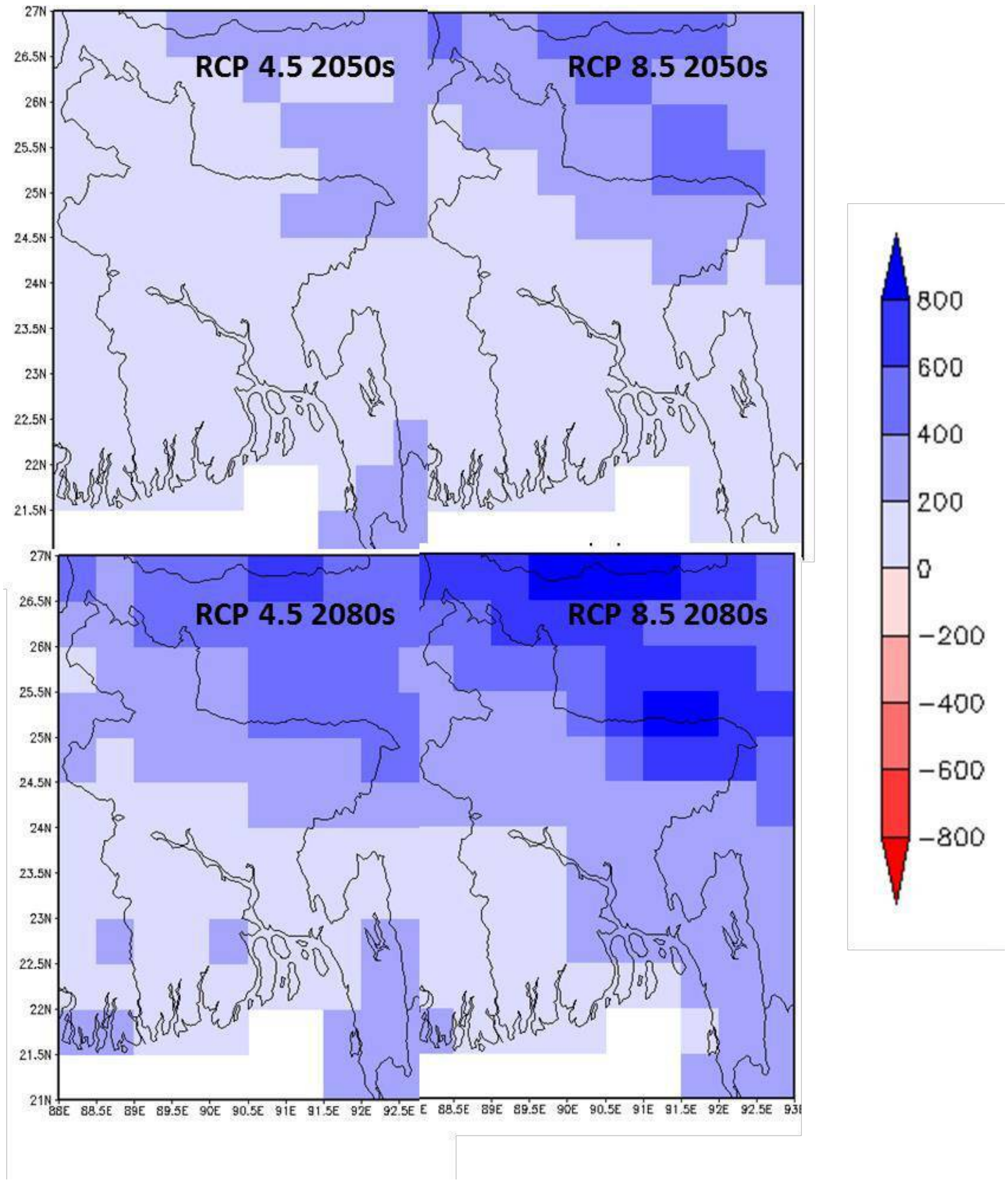


Figure 38: Average change in total annual precipitation (mm) for mid-century 2050s (2036-2065) and end of the century 2080s (2070-2099) for a low (RCP4.5) and high (RCP8.5) emission scenario

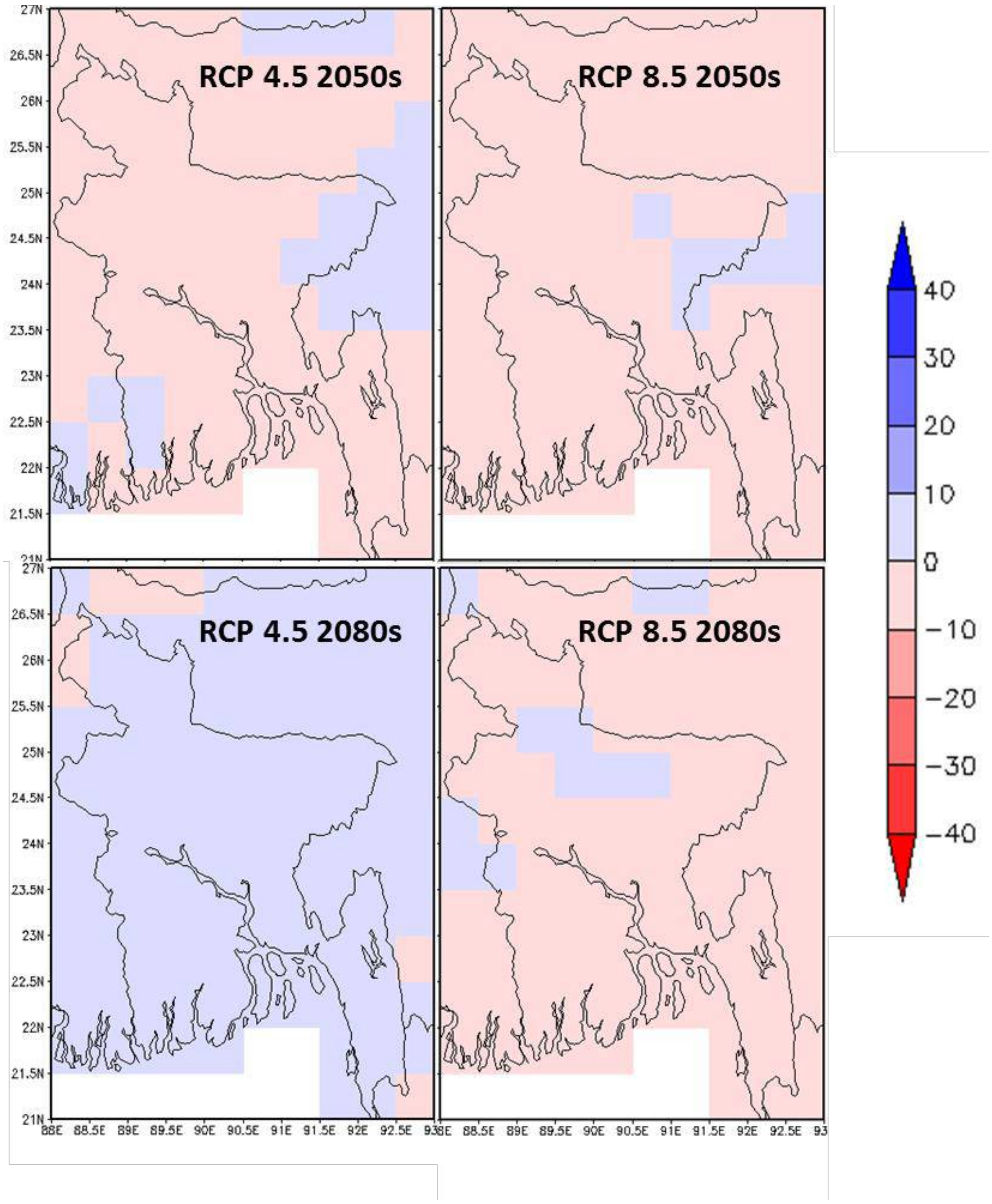


Figure 39: Average change in total number of rain days for mid-century 2050s (2036-2065) and end of the century 2080s (2070-2099) for a low (RCP4.5) and high (RCP8.5) emission scenario

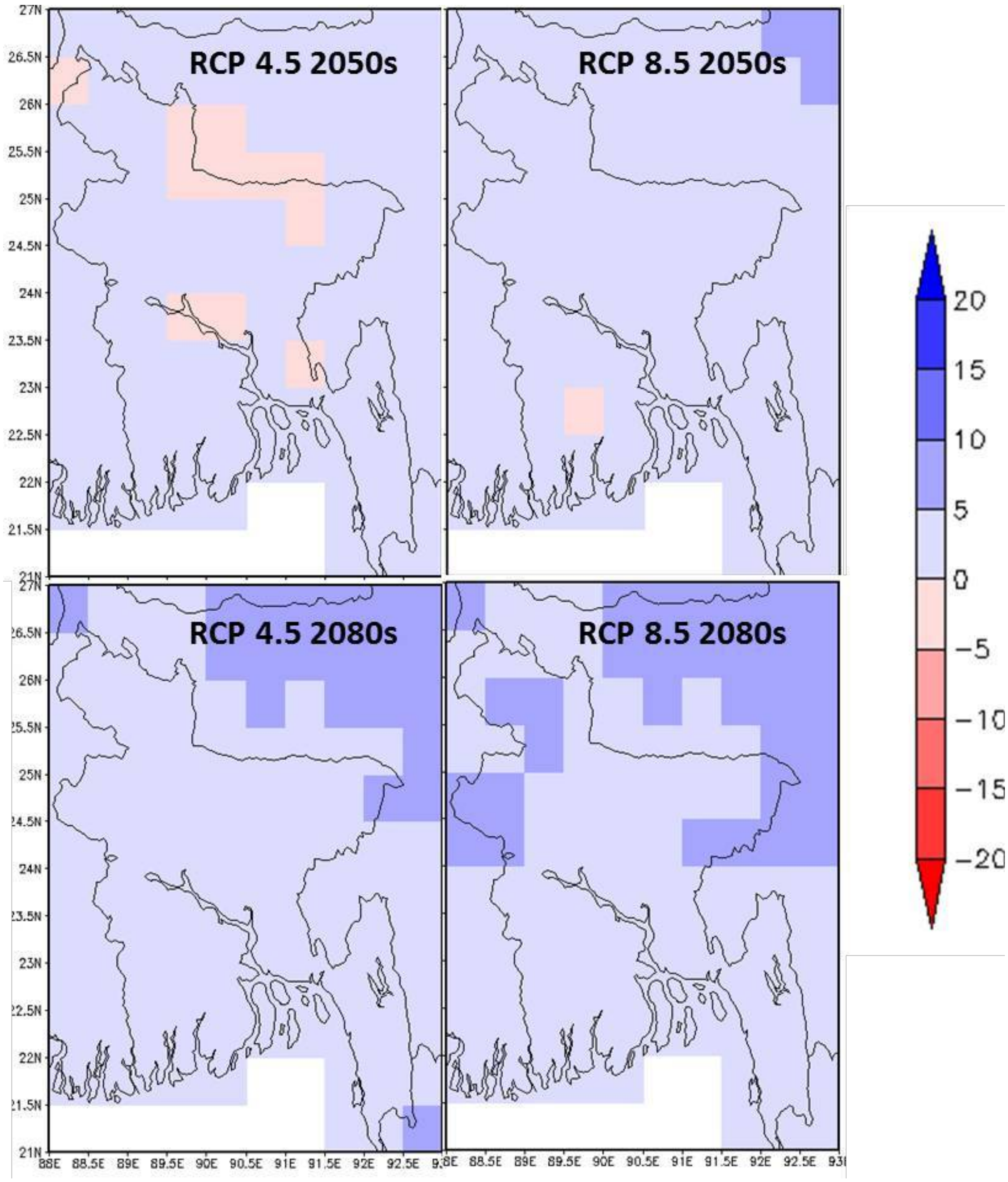


Figure 40: Average change in total number of days with more than 20 mm rainfall for mid-century 2050s (2036-2065) and end of the century 2080s (2070-2099) for a low (RCP4.5) and high (RCP8.5) emission scenario

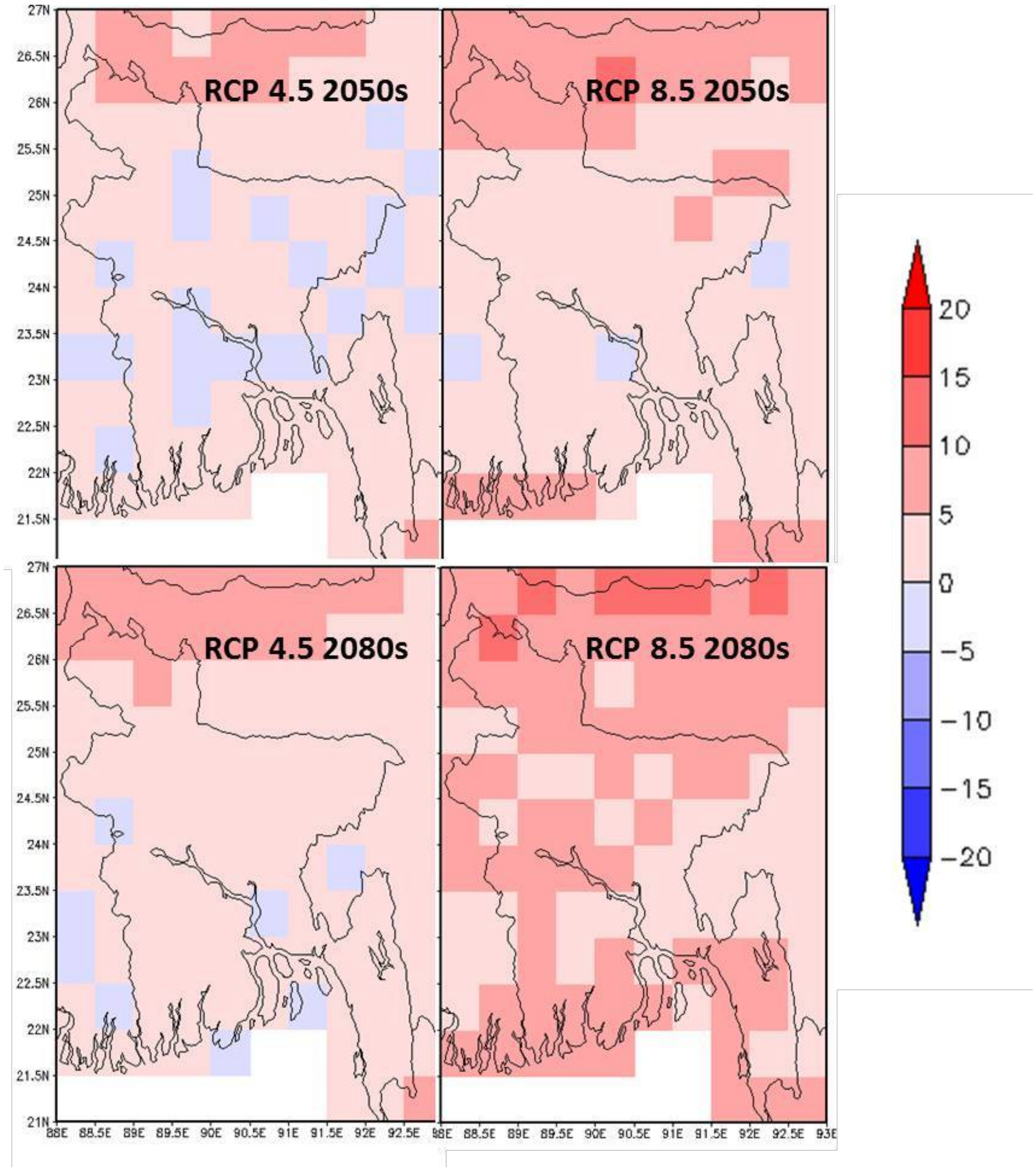


Figure 41: Changes in the average length of the largest period of consecutive dry days at the end of the century for mid-century 2050s (2036-2065) and end of the century 2080s (2070-2099) for a low (RCP4.5) and high (RCP8.5) emission scenario

7.2. Climate Scenarios for the Ganges, Brahmaputra and Meghna Basins

Due to the importance of the Ganges, Brahmaputra and Meghna (GBM) rivers on the Bangladesh delta not only climate change within the country is important. The Bangladesh Delta Plan should also consider climate change in the upstream areas of the river basins. Total rainfall is expected to increase throughout the GBM basins**(Figure 42)**. The increase is the highest on the southern edges of the Himalaya mountain range while the lowest is in the downstream part of the GBM rivers (also in the upstream parts of the Ganges). These results are consistent with most other studies which show increased total rainfall over the Indian sub-continent.

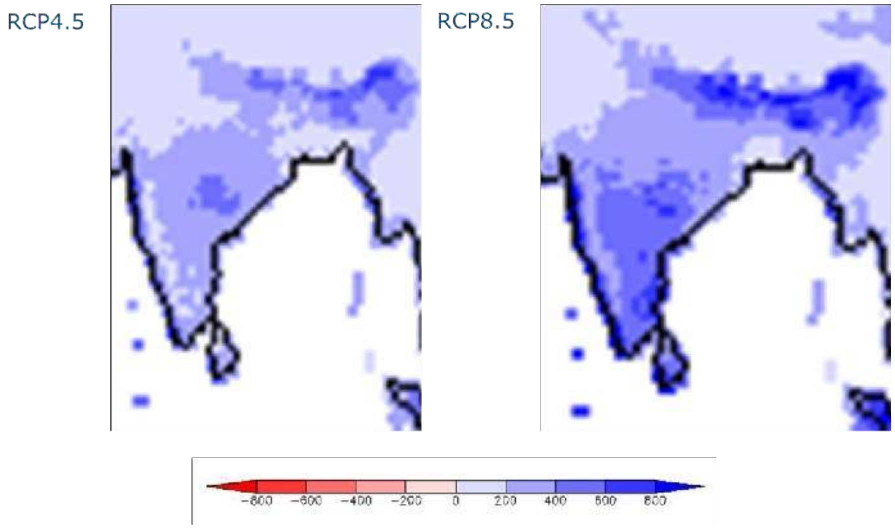


Figure 42: Average change in the rainfall (mm) at the end of the century (2070-2099 compared to 1970-1999) for RCP4.5 and RCP8.5

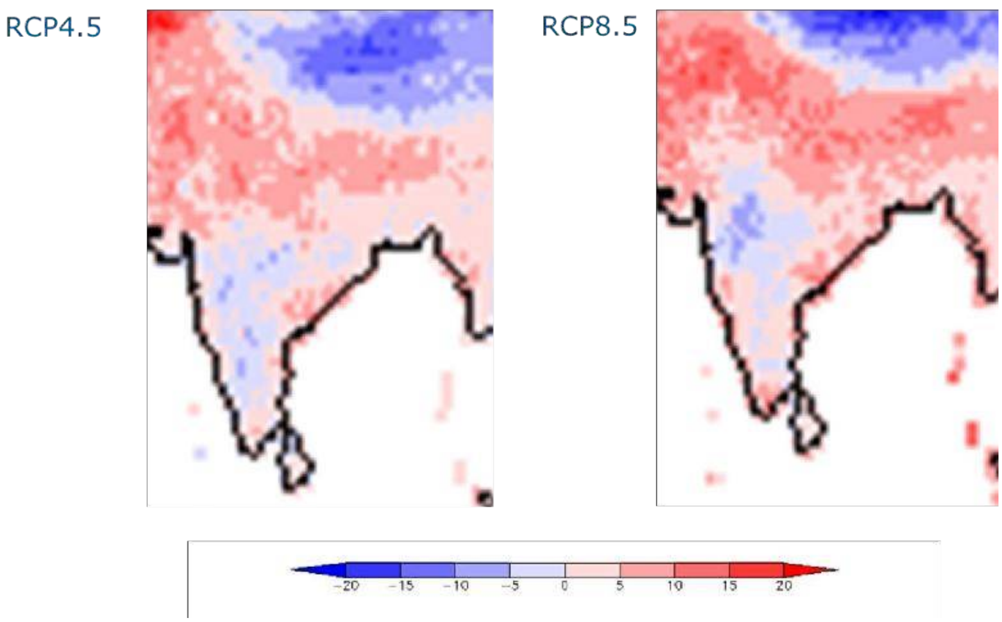


Figure 43: Changes in the average length of the largest period of consecutive dry days at the end of the century (2070-2099 compared to 1970-1999) forRCP45 and RCP85 scenario respectively

Note: A period of consecutive dry days (cdd) is counted when more than 5 consecutive dry days occur

While the average annual total precipitation is increasing, the drought risks are also increasing. This higher future drought risk is shown for example by the increase the average length of the largest period of consecutive dry days **(Figure 43)**. Under both the RCP4.5 and 8.5, this period is increasing. At the same time the rainfall intensity is also increasing **(Figure 44**and **Figure 45)**. First of all the average rainfall intensity is increasing; in the future there will be more rain per event. Also the maximum intensity is increasing. The annual maximum 1-day rainfall event will increase by 20 to 40 mm for the RCP4.5 and even more under high emission scenarios. This indicates an important increase in flood hazard in the future due to climate change.

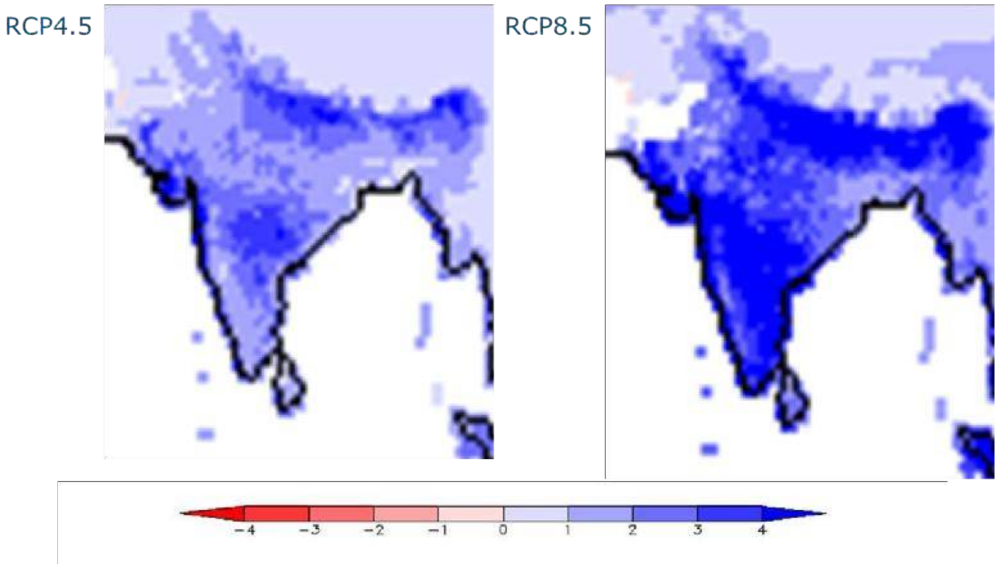


Figure 44: Change in average rain intensity (mm) of daily rainfall events (2070-2099 compared to 1970-1999)

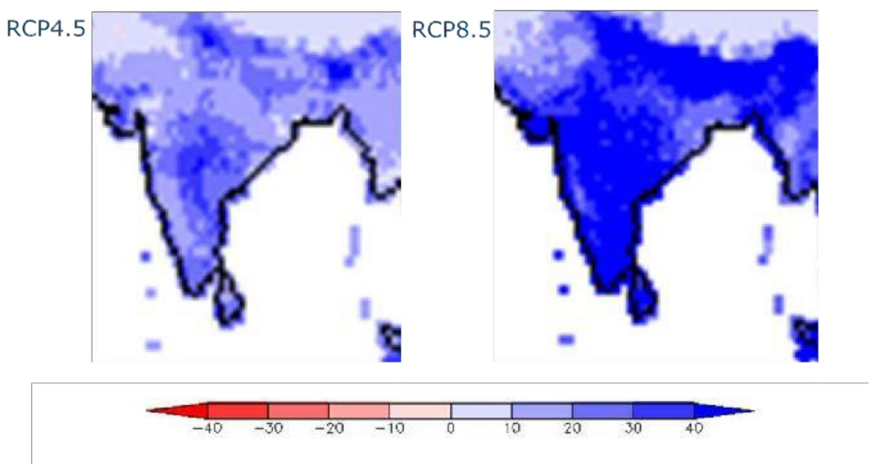


Figure 45: Change in annual maximum 1-day rainfall event (mm) (2070-2099 vs 1970-1999)

Changes in future climate of the GBM basins will have an impact on the future flows of the rivers. The issue is also discussed in other baseline studies and is treated in detail in the scenario development for the BDP2100 project. Most of the available analyses of future climate changes on the Ganges and Brahmaputra basins show that peak discharges and monsoon river flows will increase while the dry season flow will decrease. For example Mirza et al. (2003) showed increases in floods in all three GBM basins especially in the Ganges basin. Also analyses by Van Vliet et al. (2013) and Ludwig et al. (2013) using CMIP3 and CMIP5 model output linked to the hydrological macroscale VIC models show increases in peak run-offs. The impacts of climate change on low and dry season flows are less consistent compared to high flows but overall the majority of models and analyses indicate reduced flows during the dry season (Van Vliet et al. 2013; IPCC 2013). Also analyses at Wageningen University by Ludwig and Van Vliet (in prep.) using CMIP5 models coupled to the VIC model indicate that climate change will increase monsoon flows and peak flows and will reduce low flows and increase drought risks.

8. Relation of Tropical Cyclone Intensity with Climate Change

This chapter discusses future changes in intensity of tropical cyclones in the global basins and specifically in the Bay of Bengal.

8.1. Observations on climate change impacts on tropical cyclones

Emanuel (1987, 2005) has developed a relationship between maximum sustainable wind speed (MSWS) and sea surface temperature (SST) for the Atlantic Ocean, which suggests that a 1^0C rise of temperature will increase the MSWS by 4%, 2^0C by 10% and 4^0C rise by 22%. The wind stress increases at the square of the wind speed. Thus the impact of enhanced SST on wind speed vis-à-vis on storm surge height would be quite large. Considering 2^0C rand 4^0C rise of SST, Ali (1996) developed scenarios of storm surges and found that the storm surge would increase by 21% and 49% with respect to the present. According to recent studies (Emanuel 2011, Mendelsohn et al. 2012, Murnane and Elsner 2012), the increasing frequency of intense Tropical Cyclones (TCs) can account for an upward trend in TC damage under conditions of global warming, regardless of economic growth.

The threat of intense tropical cyclones (TCs) to East Asia has increased in recent decades. Integrated analyses of five available tropical cyclones data sets for the period 1977–2010 revealed that the growing threat of TCs primarily results from the significant shift that the spatial positions of the maximum intensity of TCs moved closer to East Asian coastlines from Vietnam to Japan (Park et al., 2014). This shift incurs a robust increase in landfall intensity over east China, Korea and Japan. In contrast, an increase of TC genesis frequency over the northern part of the South China Sea leads to a reduction in the maximum TC intensity before landfall, because of their short lifetime; thus, there are no clear tendencies in the landfall intensity across Vietnam, south China and Taiwan. All changes are related to the strengthening of the Pacific Walker circulation(see link below) closely linked with the recent manifestation that the warming trend of sea surface temperature in the tropical western Pacific is much higher than that in the central to eastern Pacific.

(https://en.wikipedia.org/wiki/Walker circulation),

Webster et al (2005) examined the number of tropical cyclones and cyclone days as well as tropical cyclone intensity over the past 35 years, in an environment of increasing sea surface temperature. A large increase was observed in the number and proportion of cyclones reaching categories 4 and 5. The largest increase occurred in the North Pacific, Indian, and Southwest Pacific Oceans, and the smallest percentage increase occurred in the North Atlantic Ocean. These increases have taken place while the number of cyclones with lower intensity (category-1, 2 and 3) and respective cyclone days has decreasedduring the past decades in all basins except the North Atlantic.

8.2. Tropical Cyclones and Climate Change using Global Models

Bengtsson et al.(2007) have studied the climate change impacts on tropical cyclone formation using atmosphere-ocean global circulation models, AOGCMs, with T63, T216 and T319 resolutions. For the T63 resolution, three ensemble runs are explored for the period 1860 until 2100 using the IPCC SRES scenario A1B and evaluated for three 30 yr periods at the end of the 19th, 20th and 21st century, respectively. There is no significant change between the 19th and 20th century. However, the results show a considerable reduction in the number of TCsup to 20% in the 21st century, but no change in the number of the more intense storms. Reduction in the number of storms occurs in all regions. A single additional experiment at T213 resolution was run for the two latter 30-yr periods. The T213 experiment has been performed using the transient sea surface temperatures (SST) of the T63 resolution experiment. Also in this case, there is a reduction by ~10% in the number of simulated TC in the 21st century compared to the 20th century but a marked increase in the number of intense storms. It is noted that in this experiment the number of storms with maximum wind speeds greater than 50 m s^{-1} increases by a third. Two additional transient experiments at T319 resolution where run for 20 yr at the end of the 20th and 21st century, respectively, using the same conditions as in the T213 experiments. The results are consistent with the T213 study. The total number of TC were similar to the T213 experiment but were generally more intense. The change from the 20th to the 21st century was also similar with fewer TC in total but with more intense cyclones.

Knutson et al. (2010) have made projections based on theory and high-resolution dynamical models, which consistently indicate that greenhouse warming will cause the globally averaged intensity of tropical cyclones to shift towards stronger storms, with intensity increase of 2–11% by 2100. Existing modelling studies also consistently show a decreasein the globally averaged frequency of tropical cyclones, by 6–34%. Balanced against this, higher resolution modelling studies typically project substantial increases in the frequency of the most intense cyclones, and increases of the order of 20% in the precipitation rate within 100 km of the storm centre. For all cyclone parameters, projected changes for individual basins show large variations between different modelling studies.

8.3. Climatic Impacts on Tropical Cyclones of Bay of Bengal using HadRM2 regional model

Singh (2007) has conducted simulation experimentsusinga high resolution regional climate model (HadRM2) (50kmx50km grids) for the Bay of Bengal, which was run with 1990 GHG level as control (CTL) and the other with an annual increase of 1% in the greenhouse gas concentration for 2041-60 from 1990 onwards. The results show 36% increase of the frequency of tropical cyclones in Pre-monsoon and 48% increase in post-monsoon season(**Table 15**).

Table 15: Simulated frequency of tropical cyclones in the Bay of Bengal for 2041-2060 [reproduced after Singh, 2007]

Experiment	Pre-monsoon (Mar-May)	Post-monsoon (Oct-Nov)
CTL	11	21
GHG	15	31
% increase	36.4	47.6

The results on intensity simulations for May, October and November show that the model has simulated an enhancement in the average maximum wind speed of the storms for enhanced GHG compared to control. In October the average wind speed has increased from 42 knots (1 knots=1.82 km/hour)for the control period (1990) to 48 knots for the run with higher greenhouse gas concentrations representative for 2050.In November the speed increased from 52 knots for control to 60 knots for GHG.Relatively the wind speed increased byabout 14-15% due to climate change by 2050.

8.4. SST variation for Bay of Bengal and its relation with cyclone Intensity

The literature review in 8.1, 8.2 and 8.3 indicates that the increase of SST due to climate change plays important role in formation as well as intensification of tropical cyclones of different tropical basins of world oceans. Thus it is pertinent to investigate the relation of SST variability with the maximum sustainable wind speed of the tropical cyclones of Bay of Bengal, which will allow to develop equation relating these two variables. **Figure46 (a, b, c** and **d)**shows the trends of SST of the Bay of Bengal for peak months (May, October and November) during the period 1948-2007 (60 year). It is seen that in the Bay of Bengal there is an average temperature at a level higher than 27^{0}C during April-December. The standard deviations are high with values 0.41, 0.36 and 0.43 ^{0}C in May, October and November-December. The trends are 0.015 ^{0}C/year for May, October and December and 0.017^{0}C/year and 0.015^{0}C/year for November. During the 60 years observation the temperature has increased by 0.9 to 1.0 ^{0}C.

The relation of tropical cyclone intensity in terms of maximum sustainable wind speed (MSWS) with SST variation has been investigated for the months of May, October, November and December using the available data within the period 1960-2007. The following criteria are followed in selection of the tropical cyclones and SST:

i. The tropical cyclones which moved north of 15^0 N latitude
ii. The tropical cyclones which sustained for 4 days or above after attaining the strength of tropical cyclone

The results of the scatter diagram and regression analysis for tropical cyclone intensity (maximum sustainable wind speed (MSWS)) against the monthly average SST for May, October, November and December have been shown in **Figure 46 (a, b, c** and **d),Figure 47, 48, 49**and**50**. It is relevant to mention that if the tropical cyclone is formed in the first week of the month then the SST of the previous month is used. It is seen that the MSWS of tropical cyclone maintains positive correlation with SST for the months of May, October and November, but the relation is weak for December. The relationship of MSWS with SST is summarized in **Table 16**.

Table 16: The relation of Vmax (km/hour) with SST (0C) for May, October, November and December

Month	MSWS (km/hour)	Number of samples N	R^2
May	MSWS =80.55*SST-2545	23	0.215
October	MSWS =55.58*SST-1434	16	0.075
November	MSWS =80.43*SST-2078	23	0.262
December	MSWS =26.46*SST-620	19	0.149

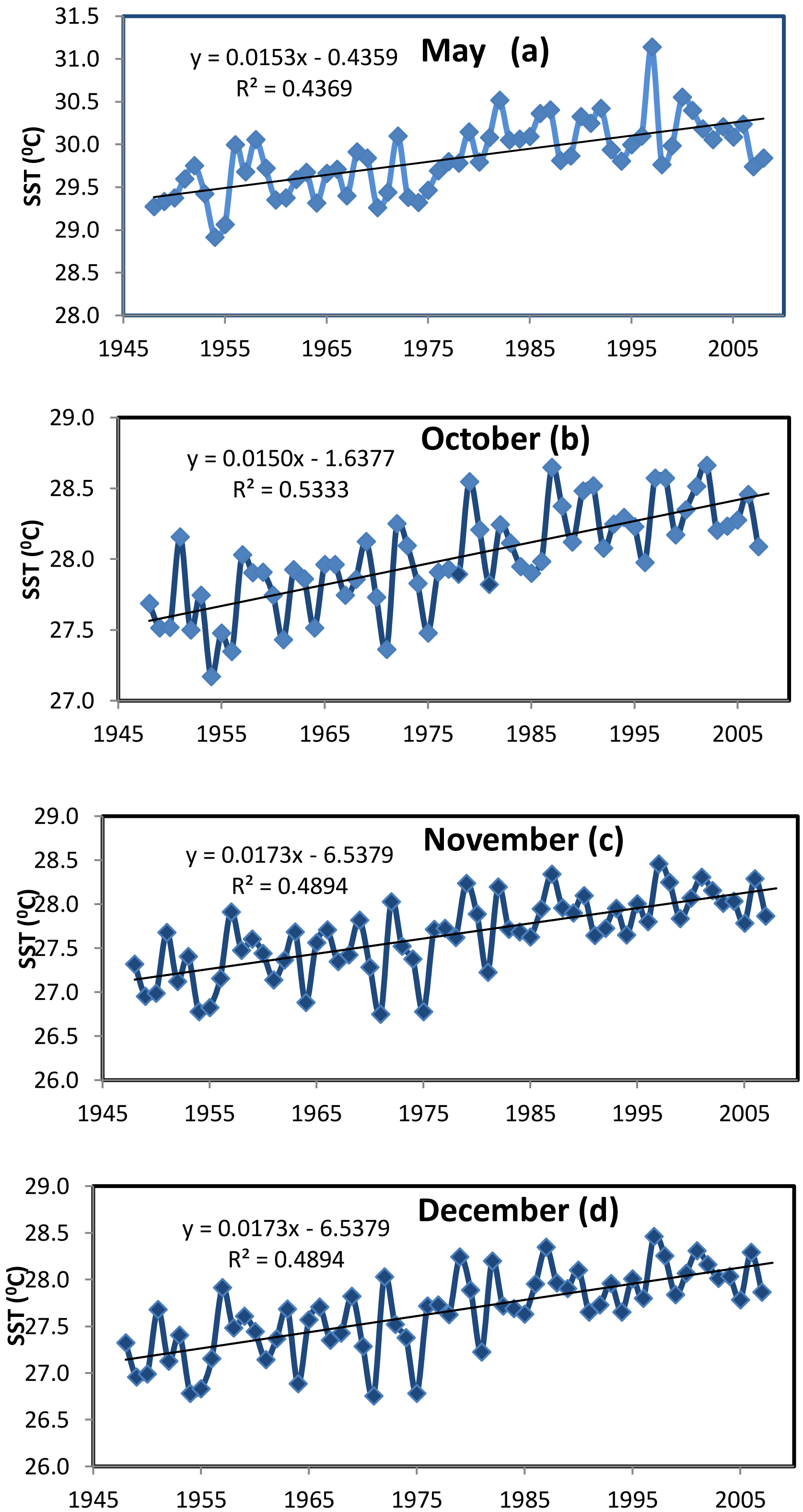


Figure 46: The variation of SST over the Bay of Bengal in top cyclone seasons, (a) May, (b) October, (c) November, and (d) December

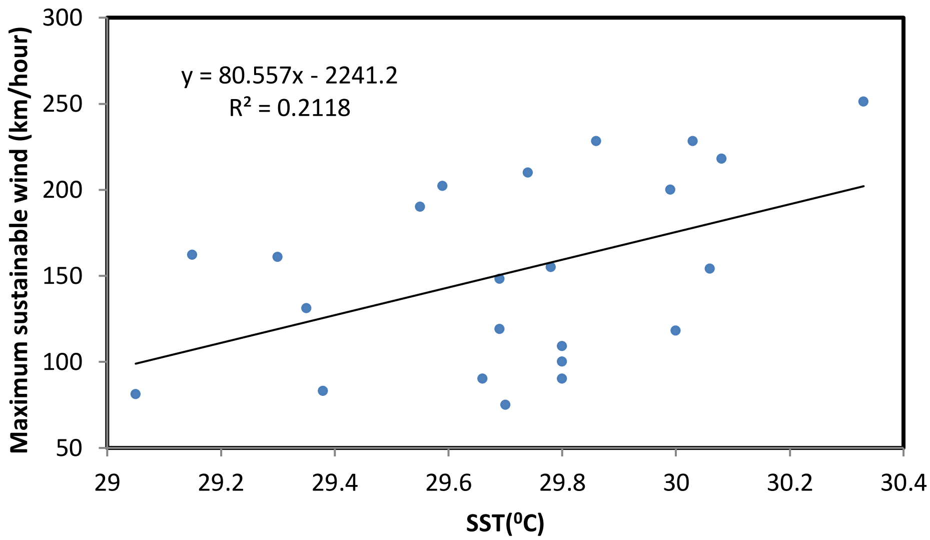


Figure 47: Scatter diagram of SST and maximum sustainable wind (MSWS) of the tropical cyclones of May

Note: The straight line indicates the best-fit regression line relating the SST with MSWS of tropical cyclones

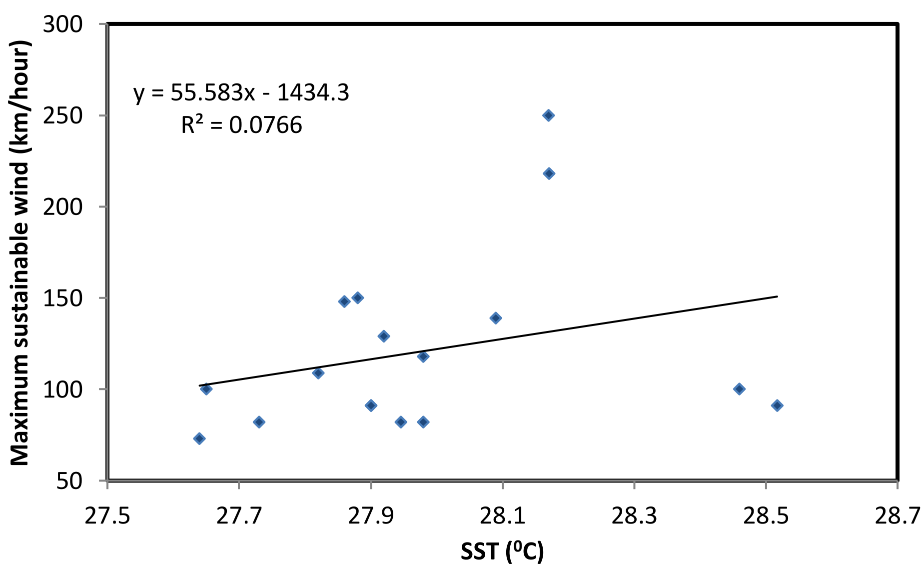


Figure 48: Scatter diagram of SST and maximum sustainable wind speed (MSWS) of the tropical cyclones of October

Note: The straight line indicates the best-fit regression line relating the SST with MSWS of tropical cyclones

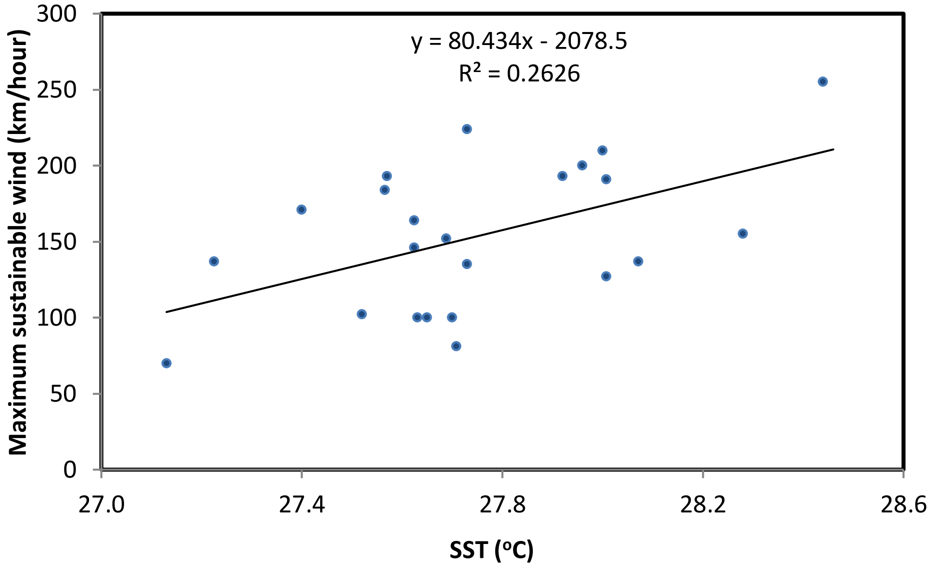


Figure 49: Scatter diagram of SST and maximum sustainable wind speed (MSWS) of the tropical cyclones of November

Note: The straight line indicates the best-fit regression line relating the SST with MSWS of tropical cyclones

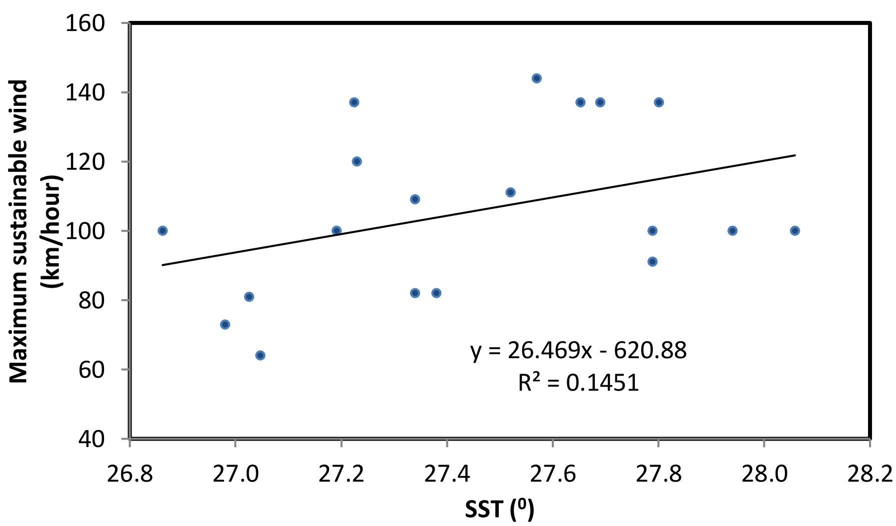


Figure 50: Scatter diagram of maximum sustainable wind speed (MSWS) and the SST of the month of December

Note: The straight line indicates the best-fit regression line relating the SST with MSWS of tropical cyclones

The regression coefficients (slope and intercepts) are not uniform for the regression equations of the different cyclone months relating SST with MSWS of tropical cyclones. The slope is high for May and November (around 80 km/hour for unit change of SST), the slope is 55.6 for October and 26.46 for December (**Figures 47-50** and **Table 16**above). The slope indicates the enhancement of the MSWS of tropical cyclones due to 1°C rise of monthly mean SST. Using these equations the scenarios of maximum sustainable wind are estimated for increase of SST by steps of 0.25^{0}C up to

2.0^{0}C relative to baseline SST of the year 2000 (**Table 17**). According to this analysis, 1.0^{0}C rise of monthly mean temperature would cause the increase of MSWS by around 46% varying from 26-55% for different cyclone months with maximum (55%) in November. It is clearly shown that the intensity of tropical cyclones is highly sensitive to monthly mean SST for the Bay of Bengal. If the SST increases by 1.5 ^{o}C in 2050, then the MSWS will be increased by 69%. It is relevant to mention that there are other atmospheric factors which influence the tropical cyclone formation and intensification. Thus, it is also pertinent to investigate the future scenarios of SST and the probable change of tropical cyclone frequency and intensity using high resolution wind and pressure fields obtainable through downscaling of the GCM results.

According to this assessment, the wind speed of tropical cyclone of the Bay of Bengal will be intensified; the wind speed of a weak cyclone might even be doubled at SST rise of 2^{0}C. But the increase of wind speed may not occur beyond category-5 scale (v_{max}>255 km/hour). The category-5 does not have an upper limit and there is no category-6 as well. It is relevant to mention that the strongest cyclone ever observed in the Bay of Bengal was Sidr, which had maximum wind speed of 255 km/hour (Category-5). According to the existing knowledge of tropical cyclone events in Atlantic and Pacific, the wind speed had rarely reached 300 km/hour but had never exceeded 300 km/hour. The study findings indicate that there will be stronger tropical cyclones in the Bay of Bengal, though the total number is not expected to vary much. The study considered only SST as independent variable, but there are other factors like vertical wind shear and the upper tropospheric temperature. Further studies are required using statistical as well as numerical models to provide further insight.

It is well known that the increased wind speed of tropical cyclone will cause corresponding increase of the storm surges and this will cause a higher vulnerability in the coastal zone, especially in Bangladesh.

Table 17: Increase of MSWS of tropical cyclones due to the increase of monthly mean SST over the Bay of Bengal

Note: The third row indicates the wind speed at mean SST of the respective months

	Enhanced MSWS (km/hour)					Percent increase of MSWS (%)				
Rise of SST (^{0}C)	May	Oct	Nov	Dec	Average	May	Oct	Nov	Dec	Average
0	163	123	146	95	131	0	0	0	0	0
0.25	183	137	166	101	147	12	11	14	6	12
0.5	203	151	186	108	162	25	23	27	14	24
0.75	223	164	206	115	177	37	33	41	21	35
1	243	178	226	121	192	49	45	55	27	47
1.25	Category-5	192	246	128	207	*	56	*	35	58
1.5	Category-5	206	Category-5	134	223	*	67	*	41	70
1.75	Category-5	220	Category-5	141	238	*	79	*	48	82
2	Category-5	230	Category-5	148	253	*	87	*	56	93

Note: * indicates that the percentage of increase of wind speed cannot be calculated because of high uncertainty of the upper limit of category-5 cyclones, especially for the Bay of Bengal where the cyclones rarely attains the Category-5 stage

9. Future Sea Level Rise

One of the most important impacts of climate change for low lying countries such as Bangladesh is sea lever rise. Sea level rise is caused by global warming which affects two main processes. First of all, higher ocean water temperature causes thermal expansion and secondly, atmospheric warming results in the melting of land ice. Between 1901 and

2010 sea level has risen at a rate 1.7 mm/year(Church et al, 2008). Over the last 20 yearsthe rates of sea level rise have increased. From 1993 to 2010, tide gauge measurements indicate a rise of 2.8±0.8mm/year and satellite altimetry data indicate a rise of 3.2±0.4mm/year (Church and White, 2011; Church et al., 2013). In section 3.4 it was also reported from IPCC that from 1980-2000 SLR increased with 2.0 mm/yr and 3.0 mm/yr in the period 1991-2010.

9.1. Thermal expansion as a driver of sea level rise

Thermal expansion of sea water is the change in volume of water in response to a change in temperature. The global average sea level rise between 1870 and 2001 was about 200 mm, with an average rate of 1.7 mm $year^{-1}$ (Church et al, 2008). The contribution of thermal expansion to this rise remains uncertain. From 1955 to 2003, the thermal contribution to sea level rise was estimated to be about 0.3 mm/year(Lombard 2005). In the last IPCC report (2013), thermal contribution was estimated to be between 10 and 18 cm by 2100 for the RCP2.6 scenario (90% confidence interval) and between 20 and 30 cm for the A2 scenario.

9.2. Melting of land ice as a driver of sea level rise

If all global land ice melts, sea levels would rise by more than 64 meters (~7 m, ~55 m and ~0.5 m respectively for Greenland-, Antarctic ice sheet and other glaciers/ice caps) (Allison et al. 2009). This shows the enormous potential for sea level rise as a result of melting land ice. However, not all of this ice will melt at a time in near future, and how much ice will melt is still highly uncertain. During the 1993-2003 period, land ice has contributed about 1.2 ± 0.4 mm yr^{-1} to global SLR (IPCC AR4 2007). Results presented in the last IPCC report estimate the contribution of land ice to global SLR by 2100 to be between0.4 to 35cm. This large range indicates how uncertain this process is. For Greenland it is relatively clear that global warming causes melting of the ice sheet. However for the Antarctic ice sheet this is not clear. The edges of Antarctic ice sheet are shrinking which contributes to global sea level. However, due to increased snowfall the water stored in the central Antarctic could increase which would reduce the sea level.

However in the IPCC report, rapid dynamic changes in ice flow were excluded due to limited reliable model estimates. Therefore sea level projections are probably conservative. Recent new models and research indicate that the contribution of melting land ice to SLR may be substantially more than projected in AR4 of the IPCC **(Figure 51).** Including the dynamic changes Pfeffer et al. (2008) reported that a total sea-level rise of about 2 meters by 2100 could be physically possible however only if all variables contributing to ice melting would quickly accelerate to extremely high limits. More plausibly, they estimated a sea-level rise of about 0.8 meter by 2100.

Hinkel et al. 2014 also developed new sea level rise scenarios taken into account uncertainty in the melt of land ice. For 2100, Hinkel et al. projected total sea level rise to be between 25 and 56 cm for RCP2.6, 37 to 75 cm for RCP4.5, and 55 to 123 cm for RCP8.5. Due to better inclusion in the uncertainty of ice land melt these scenarios are higher than the onespublished in the latest IPCC report (September 213)**(Figure 52)**.

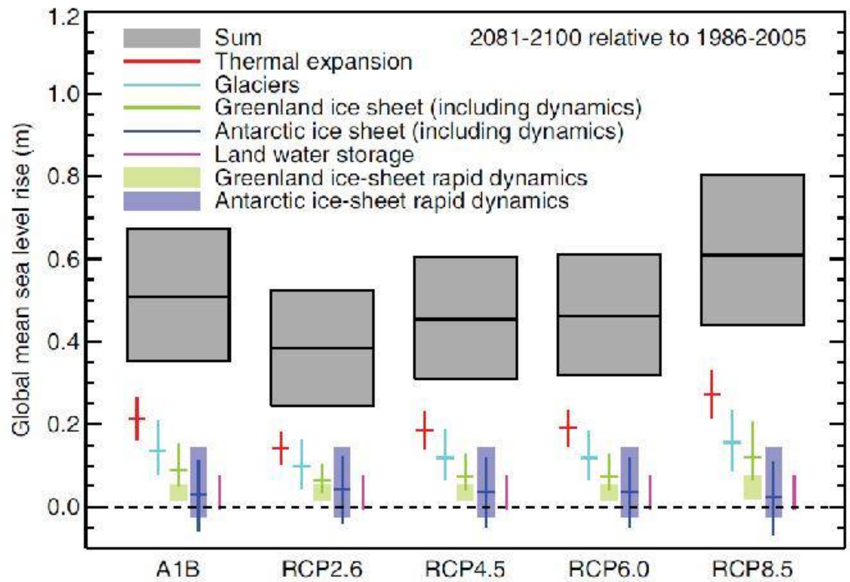


Figure 51: Projections from process-based models with likely ranges and median values for global mean sea level rise and its contributions in 2081-2100 relative to 1986-2005 for the four RCP scenarios and SRES A1B scenario (IPCC, 2013)

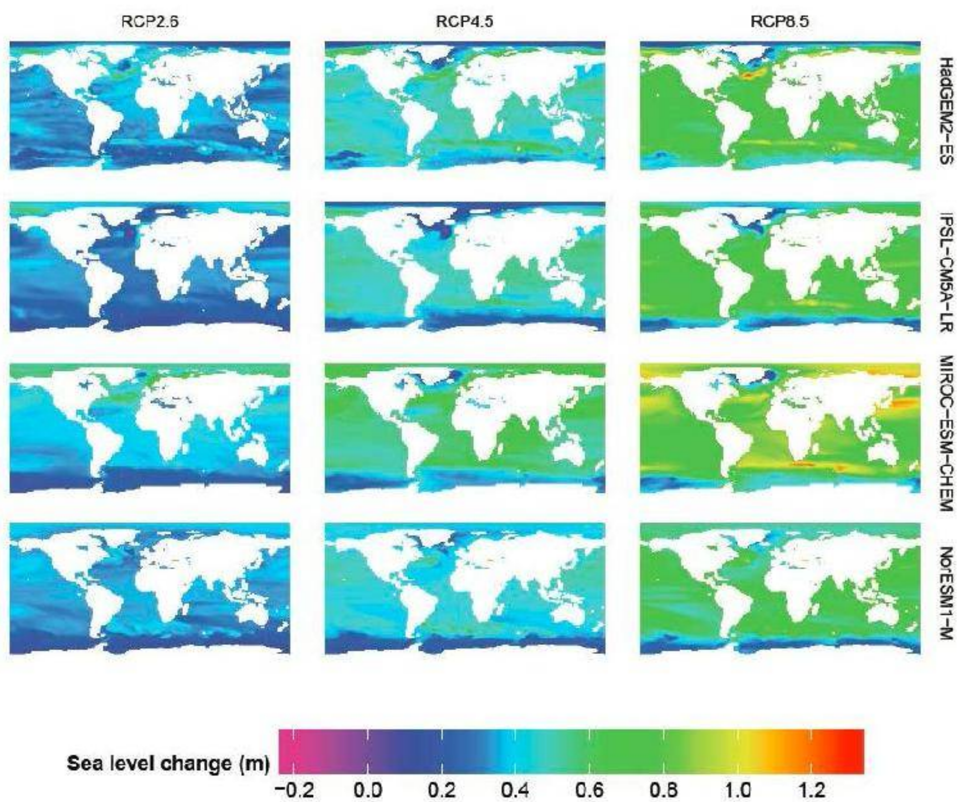


Figure 52: Projected patterns of global sealevel rise for 2100 relative to 1985-2005

Note: Original figure from Brown et al. (2014) using data from Hinkel et al. (2014)

9.3. Regional Sea Level Rise

There are regional differences in sea level rise; some areas could potentiallyexperience more sea level rises than the global average. Regional sea level rise is for example affected by thermosteric and halosteric circulation, i.e. circulation in the ocean due to changing temperature and changing salinity (Pardaens et al. 2011). The last IPCC report concludes that `70% of the global coastlines will probably have a sea level rise within 20% of the global mean sea level change' (Church et al. 2013). For the Bangladesh Delta Plan, it is important to know if the sea levels in the Bay of Bengalwill rise more or less than the global average.

Brown et al. (2014) studied regional future sea level rise for Bangladesh. Regional sea level scenarios for the Bay of Bengal were developed based on the global scenarios by Hinkel et al. 2014. The result showed that sea level rise in Bangladesh is slightly higher than the global average mean. However the differences between the global and regional scenarios are small in most cases; less than 5% with a maximum of 10% higher (Brown et al. 2014). This means that by 2050 sea level rise could be up to 4 cm higher than global mean and up to 10 cm by the end of the century.

9.4. Relative Sea Level Rise

For most of the impacts of sea level rise such as salinity and increased flood risks especially the relative sea level rise is important. The relative sea level rise is also affected by subsidence and sedimentation. It is difficult to develop scenarios for subsidence and sedimentation at delta scale because these processes are highly variable. For more information the readers are referred to the Baseline Study on "Coast and Polder Issues."

10. Use of Climate Change Scenarios in Climate Change Impact Studies

For a consistent climate change impact analyses and the development of scenarios for the Bangladesh Delta Plan it is important that the climate change scenarios will be used for different sectoral impacts. Climate change will especially have an impact on flood risk, water resource management, salt water intrusion, agriculture and aquaculture production. While many impacts remain to be studied, within the consortium it is important that on short notice a decision will be made about which further studies to beundertaken to get insight in crucial issues within the limited time frame of the formulation of the Bangladesh Delta Plan.

A wide variety of information is currently available about climate change impacts but the different results lack consistency. The studies use, for example, different baselines, different climate models, and different downscaling or bias-correction techniques. Also the time period of the studies differ. Some studies focus on mid-century while other studies have done analyses for the end of the century. Also the emission scenarios used differ from study. This makes it difficult to use all these studies for an integrated analysis. Therefore it would be useful to undertake a selected number of studies using a consistent climate change forcing data set. The dataset developed within the baseline study could be used for that. The consistent downscaling and bias correction techniques used in this study ensures that a consistent dataset is available for impact analyses for which, the following variables are available.

The meteorological variables included in the series are:

- Windspeed,
- Maximum temperature
- Minimum temperature
- Mean daily temperature
- Surface Downwelling Shortwave Radiation
- Surface Downwelling Longwave Radiation
- Precipitation
- Snowfall

All data are available at half degree scale not only for Bangladesh but also for the upstream areas, if needed for basin scale analyses. All data are available at a daily time scale from 1971-2100.

Two analyses for two different time scales, as shown below, are suggested to carry out.

1. 2036-2065
2. 2071-2100

These are the common times scales for climate change impact analyses.

It is important that in early 2015 the consortium takes a decision on which additional analysis needs to be done. A plan needs to be developed which analysis can be done within the current funding scheme and time schedule of the Bangladesh Delta Plan formulation project. An additional report will be made available.

It is also recommended to also use the scenario development process to guide developing priorities for the impact assessments.

11. Further Development of Climate Change and Delta Scenarios for the Future

At present the information on future changes in the delta is spread over various other baseline studies. To be able to develop an effective delta plan it is important that these information and reports will have to be compiled under one roof so that it becomes clear what the important drivers and uncertainties are in the future development of the Bangladesh delta.

Scenario analysis will allow the decision makers of BDP 2100 to develop a plan taking these uncertain futures into account. The aim will be to assess the possible impacts of important drivers and to assist the design of important policies needed for sustainable and adaptive delta planning. The scenarios to be developed should be based on the most relevant and plausible changes, which represent critical uncertainties. These are external changes; a context the BDP 2100 project cannot influence directly, like global warming or the regional economy. Within the Scenarios for the Delta Plan in the Netherlands, for instance, the first step was to formulate the focal question(s), such as: which (external) events, circumstances and (autonomous) developments are critical for water management, in particular for flood protection, fresh water supply and water quality? After that, an evaluation was done on the major drivers of change and classified them according to their impact and uncertainty. A similar approach for the Bangladesh Delta Plan may be adopted.

In order to be able to assess the different sectoral trends future scenarios need to be developed for a few selected driving forces. Several steps will be required to arrive at a set of full grown scenarios, as given below. The scenarios will:

1. be a tool for strategy-development;
2. be a simplified analytical description (narrative) of an 'plausible' future;
3. not be forecasts;
4. not be able to be chosen, there will be preferred scenario as 'most feasible' or 'favourite';
5. not include changes in policy;
6. be transparent about assumptions used/chosen.

The recommended approach of scenario-development follows the next 4 steps:

1. Describe Driving Forces (= exogenous forces determining the development of the subject, in this case the Bangladesh-Delta). These driving forces will be derived from PESTEL: Political, Economic, Social/Demographic, Technology, Environment, Legal. Method: desk-research and expert opinion in a workshop;

2. Rank Driving Forces according to tentative impact assessment and (un)certainty about direction of future development. Impact on different levels, viz. in terms of (1) hydrological droughts or flooding, (2) water-related sectors or water use(rs) (e.g. drinking water supply ratio, agricultural crops production, nature values) and (3) social cost-benefit;this will be done by plotting the driving forces in Graph. Method: expert-opinion in a workshop setting, could be the same workshop;
3. Select, based on the previous step, the 2 'main' (meaning: with highest impact and highest uncertainty about the direction of future development on the different impact levels) driving forces, e.g. low and fast climate change combined with low and high socio-economic development (see figure 17). These are the two axes for scenarios, in their extremes. This makes a total of four scenarios. It is important to always use an even number, with an uneven number people often want to 'choose' the middle one, but one cannot choose a scenario.
4. With use of the other driving forces that have been identified, a plausible and consistent narrative for each of the scenarios will be formulated, describing what will happen with Bangladesh in each scenario without changes in policy. Method: make the 'headlines' and 'storyline' in a workshop continue with desk-work and finalize the 'narratives' with stakeholders.

The following picture shows scenarios used in the Dutch delta process, based on the two main drivers and axes: economic growth and climate change **(Figure 53).** If same drivers are used in the BDP, the numerical data for climate change scenarios and socio-economic scenarios (e.g. population growth, agricultural developments) could most likely be collected from other Baseline Studies and supplemented with insights from these studies, or additional modelling exercises, if required.

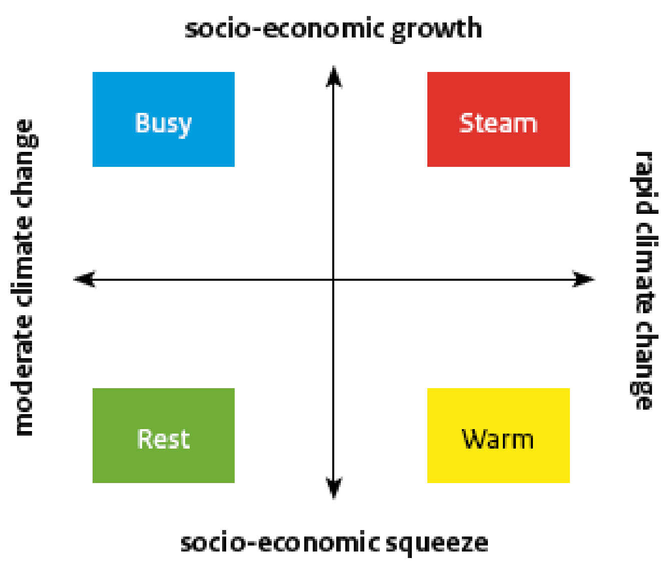


Figure 53: Example of scenarios developed within the Dutch Delta Plan process.

The **socio-economic scenarios** (with high or low climate change), including the narratives and numerical data, can be further developed sector-specific and spatially for the mid and long-term. This will result in a spatial representation of the landuse and related figures. It is described in a narrative storyline for each sector (e.g. agricultural self-sufficiency nationwide), visualized on maps for different moments in time (e.g. agricultural land) and information tables or graphs (e.g. types of agricultural crops and water needs per crop).

The **climate change scenarios** will be based on the analyses presented in the document with a low (RCP4.5) and high emission scenarios (RCP8.5). This will be enriched with climate change impacts assessments of the different sectors/issues with a focus on water safety and fresh water supply.

The scenarios can be used to evaluate the robustness of strategies and will help in analyzing and assessing key water related impacts. Crucial in the process is an understanding that the scenarios represent plausible autonomous outcomes, and the scenarios cannot be chosen or influenced, and are not covered by water management policies.

The following steps are envisioned:

a. The numerical data of the key socio-economic drivers for the narratives (e.g. population growth, economic growth, sectoral growth) will be derived from various baseline studies, past and current (inter)national trends and expert consultations.
b. Further development of the climate change scenarios for critical indicators and development of climate change impact scenarios on key water related sectors.
c. The narratives and key drivers will be formulated translated into plausible, transparent and non-directive spatial land and water use developments for the different high and low growth scenarios (e.g. development of agricultural, industrial sectors, urbanization), bearing in mind high and low climate change scenarios. This will be done for the short, mid and long term (for example 2030, 2050, 2100 but this is yet to be decided). During a consultation with key experts and stakeholders (possibly during a Delta Atelier) a common understanding is sought on where and how urban areas, sectoral activities, infrastructure could develop for each scenario without policy interventions.
d. The sectoral and land-use developments are visualized spatially per scenario on maps and described in accompanying figures. *Either by drawing or possibly by using the 'touch table' or another device.* The land and water use scenarios will be the resulting output of four spatial landuse and climate change scenarios (maps and tables or graphs) for different time periods that are plausible, water policy-neutral and robust.
e. A final step is an assessment of the vulnerabilities and opportunities.The major hazards and risks on water demand, flood risk and water quality (and ecosystems) – are identified and discussed for each land-use/climate scenario. An impact assessment will be developed for each scenario on the level of hydrological, sector/water(use) and social cost-benefits. Where possible and feasible, this should be quantified and modelled.

The spatial scenarios will create a common understanding of the effects and level of robustness of different adaptation strategies, and will help in determining tipping points of existing and new strategies. The transient scenarios are used for the adaptation pathways approach. Within these transient scenarios, some time periods are made spatially explicit (for instance the years 2030, 2050, 2100), which creates awareness on the meaning of robustness, and helps in selecting possible options by identifying the impacts within the different scenarios.

The scenario narratives need to be developed in such a way that they enable a further spatial representation and can be used for the adaptation pathways approach. The actions outlined in **Figure 54**are envisaged, of which the aim is threefold: (1) to develop narratives and spatial visualization of the scenarios, (2) to enable an impact assessment of the scenarios and (3) to contribute to the development of adaptation pathways in the second half of 2015 or early 2016.

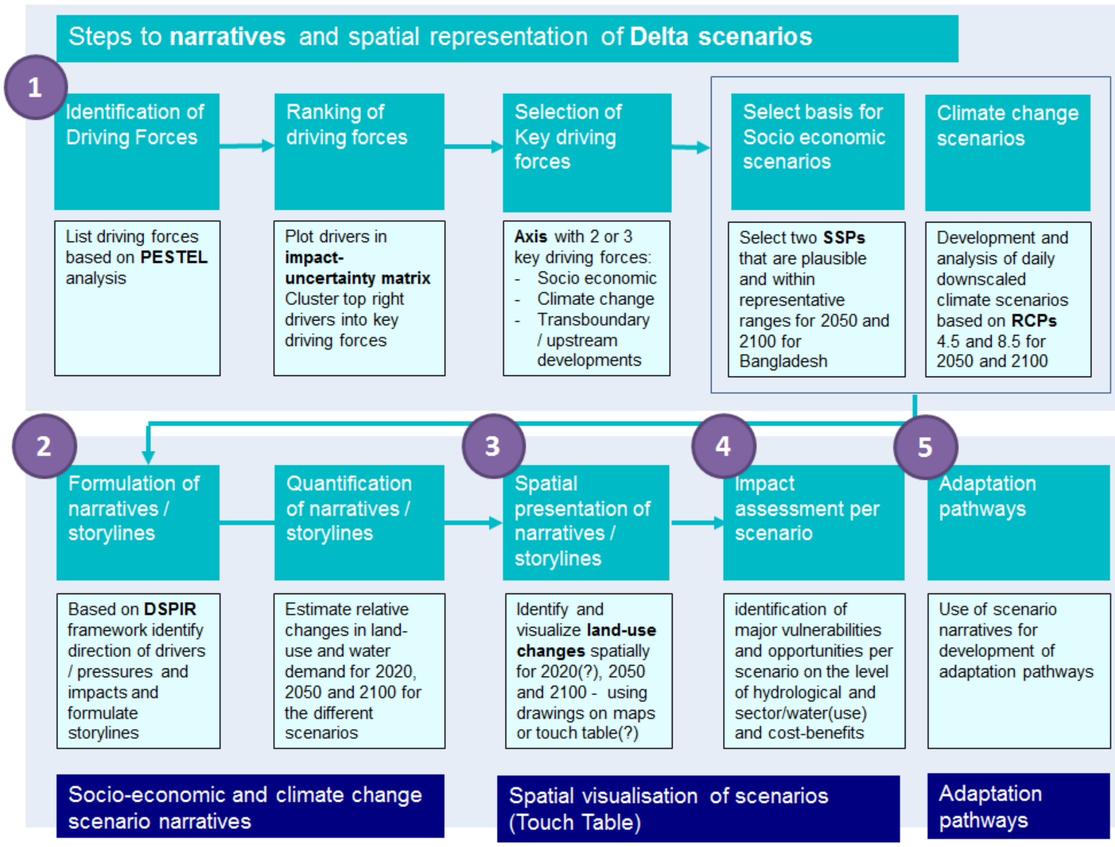


Figure 54: Schematic representation of different steps needed to develop Bangladesh Delta Plan Scenarios.

It is recommended to develop the scenarios in the period the January – March 2015. At that moment, the baseline studies will be available (in draft). A review and summary of the baseline studies relevant for the scenarios development will the starting point for the first consultation workshop on the scenarios. The first consultation is planned at the end of January 2016, with two main objectives:

1. To create a common understanding of scenario development in the BDP - importance and use
2. To jointly develop and formulate the scenario narratives for the Bangladesh Delta plan

The consultation workshop will be succeeded by a Delta Atelier, which is scheduled for February. During the Delta Atelier, the first outcome of the consultation workshop on the narratives will be presented.

After the consultation and Delta Atelier, the narratives will be further developed in a time period of 6 weeks (February- March 2014). The narratives will include major developments of the main drivers per scenario, such as land-use change and water demand, for a time frame of 2050 with outlook towards 2100. The narratives will assess the main impacts on floods, water availability and water quality. This will be done using the input of the consultation workshop, the baseline studies and other input from different experts.

12. Climate Change Aspects in Sixth Five Year Plan of Bangladesh

The overall climate change impacts on different sectors and the problems of the coastal zone have been separately discussed in the Sixth Five Year Plan (SFYP). In the report’s Final Part-1, vulnerabilities are identified and the needs for sustainable adaptations to climate change impacts have been emphasized [see Box-1 (SFYP-1)].

Box1: Paying Special Attention to the Problems of the Coastal Region of Barisal Division

Despite recent progress, the head count poverty is the highest in Barisal, which is predominantly a coastal region. Among other adverse factors, the large incidence of natural disasters is a major detrimental factor to growth and poverty reduction in Barisal. The onslaught of the Sidr and Aila cyclones and associated damages to the Barisal economy in the recent years are striking examples of this vulnerability. Moreover, being a coastal region, Barisal faces a higher risk of the adverse effects of climate change. To address these concerns, in addition to policies and programs to remove the constraints of lagging regions in general, the Sixth Plan will seek to reduce the vulnerabilities of Barisal and other coastal belt regions through focused programs in agriculture, environment, climate change and disaster management. Specifically, the comprehensive program will include: (i) development of infrastructure; (ii) increasing crop and non-crop agriculture production that are best suited to the climate of the coastal belt; (iii) development of small and cottage industries using the energy from the solar system; (iv) provision of agricultural credits and micro-credits (v) improvement of existing waterways; (vi) programs to strengthen human development focused on the poor; vii) ensuring better access to safe drinking water; and (viii) enhanced preparedness for natural disasters.

The Sixth FYP has recognized that the predicted climate change and sea level rise due to global warming is an important issue for the country. Climate change scenarios such as a sea level rise, increased air and sea surface temperatures, enhanced monsoon precipitation and run-off, reduced dry season precipitation, heat waves and increase in the intensity of tropical cyclones and storm surges, floods, and prolonged droughts have all been experienced in the recent past, which have significantly affected the country's development processes. According to Intergovernmental Panel on Climate Change (IPCC), Bangladesh will be among the worst victims due to climate change. Sea level is apprehended to rise on account of escalating atmospheric temperature and the frequency of cyclone-storms will increase. As projected, the impacts of climate change may force millions of people to migrate, squeeze settlements and resource-use patterns, and have serious implications on the physical and natural environment. Food and energy security will be threatened which may lead to a rise in different types of diseases and frequency of natural calamities. The high density of population mayaggravate problems. Over the years, the people in Bangladesh have been known for their capacity to adapt to various circumstances. However, adaptive capacity is linked to aspects of poverty and knowledge, and it is not easy to oversee whether the changes to be expected can be within or outside the boundaries of what people can adjust to. Research is required is this area, to fill the knowledge gaps, but meanwhile action needs to be taken.

The Government of Bangladesh plays a pro-active role and a large number of programs of climate change adaptation and conservation of nature have been included in the Sixth Five Year Plan aiming at sustainable development, improvement of livelihood and alleviation of poverty. These include development of saline tolerant rice, afforestation and development of green belt in the coastal zone, climate resilient infrastructure development and raising the height of the embankments, especially the coastal polders, livelihood development, managing water supply, sanitation and human health, dredging of the rivers, implement clean development technology and enhance the NGO activities towards Climate Change Adaptation (CCA) and Disaster Risk Reduction (DDR).

While perceiving the long-run consequences of environmental degradation to the country's ecosystem and citizen's welfare, the Government has set a number of goals to attain a sustainable environment and to address the fallout of climate change. With a view to attaining these goals, the comprehensive objectives relating to environment and climate change under the SFYP have been outlined.

The plan has emphasised on the shared responsibility for improvement of the environment by all partners in development including various government organizations, local government bodies, NGOs, research and training institutes. Private sector will be increasingly involved in providing support to the environment protecting programs under the Sixth Plan. The SFYP has set a few Climate Change Benchmark and Targets as shown in **Table 18**.

Table 18: Sixth five year plan benchmark and proposed target programs

Theme	Program	Benchmark	Target
Food security, social protection and health	Institutional capacity for research on climate resilient cultivars and dissemination	Capacity exists, certain new varieties released recently	Extension service to be geared up
	Adaptation against drought, salinity resistance and heat	Very limited experience	To be started
	Adaptation in fisheries sector	Very limited experience	Initial studies for ideas on adaptation
	Adaptation in livestock sector	Very limited experience	Initial studies for ideas on adaptation
	Adaptation in health sector	Very limited experience	Initial studies for ideas on adaptation
	Water and sanitation programs for climate vulnerable areas	Limited experience	Immediate actions needed
	Livelihood protection in ecologically fragile areas	Little experience	Initial interventions to be made
	Livelihood protection of vulnerable socio-economic group	Major experience	To be made immediately
Comprehensible disaster management	Improvement of cyclone and storm surge warning	Limited experience	Needs review for improvement
		Some experience	Needs review for improvement
		Limited experience	Needs review and pilot intervention
Infrastructure	Repair and maintenance of existing flood embankments	Limited activity	To be taken up immediately
	Repair and maintenance of existing cyclone shelters	Limited activity	To be taken up immediately
	Repair and maintenance of existing coastal polders	Limited activity	To prioritize and taken up immediately
	Urban drainage needs assessment	Limited activity	To prioritize and taken up immediately
	Adaptation against floods and constructing new embankments	Limited activity	Needs review for improvement and construction
	Adaptation against tropical cyclones and storm surges through landuse planning	Limited activity	To be taken up immediately
	Planning and design of river training and bank erosion migration works	Major experience with limited success	Needs review for significant improvement
	Resuscitation of rivers and khals through dredging	Limited activity	To prioritize and taken up

Theme	Program	Benchmark	Target
			immediately
	Earthquake resilient structures and landslide protected structures have to be constructed and retrofitted	Limited activity	To prioritize and taken up immediately
Research and knowledge management	National centre for research, knowledge management and training on disaster and climate change	Limited experience	Scope to be extended immediately
	Climate change modelling and their impacts	Limited human and institutional capacity	Training to be arranged for imparting skill
	Preparatory studies for adaptation against sea level rise (SLR)	Capacity exists, limited experience of adaptation	To be initiated and continued
	Research on climate change adaptation for knowledge and technology generation	Capacity exists, some technologies are in use	To be expanded the scope and ongoing effort
Low carbon development	Renewable energy development	Limited experience	To be expanded
	Management of urban waste	Limited experience	To be taken up immediately
	Afforestation and reforestation	Some experience	To be taken up immediately
	Rapid expansion of energy saving devices	Some experience	To be introduced in phases
	Improving energy efficiency in transport sector	Limited experience	Immediate need
Capacity building	Revision of sectoral policies for climate resilience	-	Immediate need
	Maintaining CC in national, sectoral and spatial development programs and policies	-	Immediate need; BCCSAP to be part of National Plan
	Strengthening human resource capacity	Limited capacity	To be started
	Gender consideration in CC	-	To be started
	Strengthening institutional capacity	Limited capacity	To be started
	Maintaining CC in media	Limited experience	To be started

12.1.1. Disaster Management Strategy in the 6thFYP

The Sixth FYP will carry forward the implementation of the approved National Disaster Management Plan 2010-2015. It will continue the comprehensive all hazard, all risk and all sector approach and be built on the foundations laid in the last several years and learn from the positive experiences. The Bangladesh Disaster Management Model which made the basis for revising the disaster management policy and planning documents has mainly comprised of two inter-related elements: Disaster Risk Reduction and Emergency Response. The plan will focus more on Disaster Risk Reduction (DRR) in order for reducing the relief and recovery needs and also be prepared to deal with any emergencies.

The part-2 of the 6th FYP has noted the vulnerability of the coastal zone due to climate change impacts, cyclones, storm surges and tidal inundation, salinity intrusion and water logging because of which the agricultural, livestock and aquaculture activities are at serious risk and need additional supports. Considering these challenges, climate change vulnerabilities and unexplored potentials of the region, the Government of Bangladesh has decided to prepare a comprehensive ten year master plan to provide a road map for an integrated development effort in Bangladesh's coastal zone aiming at i) increased agricultural productivity and sustainable food security; ii) poverty reduction and iii) alternate livelihood development for the poor. The Master Plan will focus on emerging new potentials in the delta mainly i) technological breakthrough for increasing productivity- new varieties and breeds, plant and animal health systems and strengthening Farmers Field Schools etc; ii) harnessing seasonal and occasional quality surface water available for irrigation and iii) enhancement of agricultural productivity through increased cropping intensity, reducing post-harvest losses, modelling of climate events and options of crop diversification.

The rural development providing infrastructure, safe drinking water and sanitations planning implemented by LGED and relevant agencies take the climate change resilience in to account. These aspects have been taken care of in the 6th 5 year plan. The climate change and global warming etc. have been the key issues among many others which were addressed during preparation of the 6th 5year plan. This 5 year plan emphasizes on the development of renewable energy and provide education on climate change related subjects, disaster risk reduction and adaptations, develop safety of food and drinking water and conduct research to increase crop production and introduce climate resilient crops.

The Sixth FYP-part-II devoted a chapter on Environment, Climate Change and Disaster Risk Management. With a view to achieving the goal of sustainable development, SFYP focused on integrating poverty, environment and climate change into the process of planning and budgeting. In this context, appropriate policy and institutional capacity building for sustainable land-water management, biodiversity conservation and climate resilient development are crucial. Environment, climate change adaptation and mitigation, and disaster risk reduction must be addressed in a broader development context, recognizing climate change as an added challenge to reducing poverty, hunger, diseases and environmental degradation. Disaster risk reduction and climate change adaptation efforts reduce people's exposure to climate-related disasters and early warning and enhanced coping capacity limit their impact on people's lives. In this context, strengthening institutions for environment, disaster, land and water management is crucial for effective adaptation and such effort should build on the principles of participation of community. The Sixth FYP has undertaken a good number of projects for adaptation of climate change, disaster risk reduction, environmental management and mainstream climate change adaptation to development planning and improve environmental governance and transparency, overcome the challenges of natural resource and environment management.

13. Conclusion

The analyses of climate change show large consistencies between recent changes in the observed climate and the projections of climate change. Observations showed that averaged across the country, minimum temperatures have increased by 0.85 °since 1950. Minimum temperatures have increased most during the winter and the least during the monsoon. Maximum temperatures have increased by 0.5 °C over the last 60 years. Rainfall in Bangladesh is highly variable and changes from year to year. This makes it difficult to detect long term trends. However, over the 60 years of data analysed (1948-2011), there is a clear increase of 10% in total annual rainfall. Most of the increase took place during the first part of the analysed period and after 1985 rainfall has been more or less stable. Rainfall especially increased (20%) during the pre-monsoon period from March till May. Rainfall also increased during the monsoon. During the post monsoon and dry season rainfall has hardly changed. Changes in temperature and rainfall are not only caused by global warming but can also be affected by local land use change.

Both global and regional climate change scenarios indicat0e that the historic trends are likely to continue into the future. Temperatures will continue to rise and total annual rainfall is likely to increase in the future. Distribution is still uncertain. The analyses of future climate change scenarios show that averaged across the five climate models rainfall can increase with up to 800 mm in the Northwest of the country and by 300 mm in South East. While total rainfall increases, the number of rain-days is not changing. This indicates that the increase in total rainfall will be the result of more intense rainfall events and intensity of rainfall events will increase throughout the country. The increase in rainfall is especially projected for the monsoon season. During the dry season the scenarios are highly uncertain. However an increase in consecutive dry days indicates that drought risk might increase in the future.

The analyses of historic changes cyclones show that the number of cyclones is decreasing but the intensity is increasing. For the future, this trend is likely to continue. Cyclone intensity will probably increase. To become of use for the delta plan,the climate scenarios have to be used for an integrated climate change impact assessment. There is a need to analyse changes in water demand, availability, salt-intrusion and flood risks.

To further quantify the possible changes in extreme rainfall events and the better understand future changes in the onset of the monsoon there is a need for further downscaling of the climate change scenarios. In addition there is a need to develop improved scenarios on basin wide changes in rainfall and water resource availability. We also recognize a gap between climate change science, the use of the knowledge and climate scenarios for adaptation efforts. There is need to improve this link to ensure that adaptation plans are developed based on actual knowledge of the climate change at national and local level.

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BASELINE STUDY: 09

Disaster Management

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Executive Summary: Study 09

Bangladesh is a disaster-prone country comprising an area of 147,570 km^2 with a population of about 152 million according to population census in 2012. The country becomes the worst victim of natural calamities causing colossal loss of lives and properties. For sustainable development and improvement of the socio-economic condition of the country, the adverse impacts of all the natural hazards need to be reduced. In the past and in recent times, the Government of Bangladesh has undertaken a lot of plans and programmes for risk reduction through disaster management. Out of the overall disasters like floods, cyclones, draughts, earthquakes, salinity intrusion etc., the frequency of cyclones and floods are more severe and recurrent. Bangladesh is a global hotspot for tropical cyclones. Cyclones hit the country's coastal regions in the early summer (April–May) or late rainy season (October–November). Two very severe cyclones hit the country in recent past: one in November 1970, and the other in April 1991. The 1970 catastrophe took a heavy toll of 0.3 million human lives while the 1991 disaster took away 0.14 million people. Properties lost and damaged amounted to billions of dollars. There were other big cyclones from late 19th century to early 21st century causing lesser but damaging impacts on human life, cattle and property. Similarly, floods have become almost an annual phenomenon that occurs during monsoon (June to September). The floods of 1988, 1998 and 2004 were particularly catastrophic, resulting in large-scale destruction and loss of lives.

The main objectives of the baseline study are to identify the problems associated with major hazards and disasters in Bangladesh, like floods, draughts, cyclones, salinity intrusion and earthquakes, and to find an effective and efficient disaster management system in a holistic way, including disaster preparedness and responses, measures and strategies and also preparation of disaster maps. The existing policies, plans of the Govt and the developments made so far in view of the long term changes will be reviewed based on the present practices of disaster preparedness and strategies. The study will establish a common knowledge base and identify the knowledge gaps for future study and research, and identify exemplary projects for implementation.

In order to operate an effective and efficient disaster management in the country, establishing a regulatory framework is a must. Bangladesh has now established a structured regulatory framework that provides legal, policy and best practice documents in which the necessary initiatives and activities relating to Disaster Risk Reduction (DRR) and Emergency Response Management (ERM) are managed and implemented. The regulatory framework has five aspects – legal, policy, planning, response and activity coordination, and guidance support for best practices.

The draft National Disaster Management Policy (DMB, 2010) has underscored a group of broad-based strategies such as: disaster management should involve the management of both risks and consequences of disasters; involvement of local government institutions and also the local community for preparedness programmes; integration of structural and non-structural mitigation measures to be adopted whenever possible, and involving the local community in non-structural measures should be given a high priority.

The Standing Orders on Disasters (SOD 2010) outline the following: arrangement of disaster management in Bangladesh; detail roles and responsibilities of all Committees, Ministries, Divisions, Departments, and other organizations involved in disaster risk reduction and emergency response management; and necessary actions required in implementing Disaster Management Model of Bangladesh.

The problems related to disaster management are numerous, complicated and challenging. Efforts to effectively resolve the disaster management problems require a clear vision of the future conditions and demand new ways of thinking, developing and implementing disaster management programmes and practices. Long-term challenge is the success of paradigm shift from relief and rehabilitation to disaster risk reduction at every step, which largely depends on plan and action of other development ministries and implementing agencies. The magnitude and potential impacts of hazards are likely to be shaped by various external drivers of change including trans-boundary flow, population growth, landuse change, climate change, socioeconomic development and change in governance and institutions. The interactions of these drivers are likely to be more pronounced in future. Hopefully the dedicate ‘scenario group’ in BDP 2100 is developing a set of scenarios and identifying key drivers of change for use within the BDP, based on which the likely impacts of different hazards will be analysed. The measures identified the scenario group include both development tools and methods, strengthening of monitoring, infrastructure and institutional measures and strategies.

The poor are typically worst affected due to water related disasters as they tend to live in vulnerable areas, have least capacity to deal with loss of income and assets, and have limited access to risk sharing mechanisms. As IPCC 5th Assessment report highlights, with a climate change and variability, the frequency and intensity of natural hazards will only increase in future.

The long term strategy of the project is to develop new knowledge and tools required for Early Warning of Storm Surge Inundation for the Coastal community of Bangladesh and prepare inundation maps for pre, during and post disaster management programme. The key activities of the project are: cyclone formation and tracking forecasting, meteorological observation system, hydrological observation system, updating and upgrading of existing cyclone and storm surge model, cyclone and storm surge inundation forecasting in the flood plain at community level, safety of coastal embankments and communities, warning dissemination, and capacity building and technology transfer.

With a loan from the World Bank, a new project titled Bangladesh Regional Climate Services Project (2015-2019) for disaster risk reduction is scheduled to commence soon. The main objective of the project is to strengthen the capacity of the Govt to mitigate climate-related hazards by improving the accuracy and lead time of weather forecasts and warnings and improving the quality of climate service in priority sectors. The proposed project has three main components: strengthening monitoring and forecasting, and strengthening multi-hazard early warning systems; strengthening of climate service delivery, including strengthening BMD’s capacity development; and institutional capacity building, both at national and divisional levels.

Local Disaster Risk Reduction Fund (LDRRF) is a facility to finance small to medium scale structural and non-structural innovative and/or catalytic pilot interventions at the community level. The aim is to convince the Govt to include such sustainable interventions and development plans into its programs and to replicate it to other locations to benefit the broader vulnerable communities. This project is to provide funding opportunities directly available to the local at-risk communities to commence and scale up effective disaster risk reduction and adaptation practices.

The strengthening of early warning systems in communities is a critical component on the global disaster risk reduction agenda. Currently flood forecasting in Bangladesh is made for the river systems, which does not enable farmer and local community to assess the flood vulnerability for their crops, homesteads, livestock and other properties. A collaborative effort of Bangladesh Water Development Board, Department of Disaster Management and local NGOS should be initiated to generate and disseminate forecasting and warning on daily rainfall, river water level and flood plain inundation to farmers, fishermen and local traders. This will enable local community to reduce the flood disaster risk of their lives, livelihoods and properties. The project can start as a pilot program for flood prone unions involving LGIs.

The flood forecasting technology could only provide forecasts for 48 hours, which should be extended to more lead time (10 days) for taking comprehensive flood preparedness/ response activities. The lead-time of forecasts can be extended using climate forecasts. The Climate Forecast Applications in Bangladesh (CFAB) project has paved the way in this regard and the developments achieved should be carried forward.

In many areas of Bangladesh, like the Haors in the northeast, and Chalan Beel or the depression in south-central region, full flood protection will not be advisable because these kinds of measures are not economically viable and at the same time this might result in destruction of the ecologically sensitive wetland environment. Various flood proofing measures should be adopted for the purpose. One of the options may be to build clustered habitats with all the civic amenities. This may be undertaken on a pilot basis under any *Abashon* Project (Housing scheme) for the poor in Haor areas.

At present there is no programme to assess baseline condition for damage and loss assessment. Currently two types of forms are filled up, SOS form and Form D, in order to make disaster response more effective. Based on this assessment, DDM considers and approves the amount of relief support and the district administration implements it. There is no guideline on how to fill up the Form D that reflects the reality of the disaster occurring or has just occurred, obviously meaning there is no standard in the effort of filling up the forms. Obviously, such assessment results in wastage of resources and improper distribution of relief to the affected people. Therefore, standardization of damage and loss with regard to economic value is needed. It is important to conduct baseline assessment and then damage assessment. The UNFCC guidelines for damage and loss calculation have to be followed. Past experiences of the disaster management officials indicate that some kind of gap always exists between assessing the amount of need and the amount that is revealed after the operation. As a result, some affected people may be left out without relief support. In view of such experience, a work plan should be formulated based on a rapid assessment that can be practically effective in assessing realistic amount of relief materials and its timely distribution. In order to provide food and other relief materials in time to the affected people, there is a need of making stock of food at Upazila and Union levels. It is important to strengthen programmes/services and activities to survive through post disaster situation, such as: food for work, money for work, test relief, Employment Generation Programme for the Poorest (EGPP), and Strengthening MoDMR Programme Administration Project.

A long term vision for the disaster management will be based on the policy, plan, strategy and goal of the Govt. The Draft National Policy on Disaster Management has emphasized a group of broad-based strategies as mentioned earlier (page E-2). As there are inherent uncertainties on projected developments, it is essential to have policies and steering mechanisms in place that can be used when unforeseen disaster events and developments take place, where government can play important role for the safety of people and property. Likely impacts of drivers and scenarios will be assessed and then potential strategies and measures will be identified involving policy makers, planners and other relevant stakeholders.

The Vision for the BDP 2100 needs to provide a clear view on the characteristics of a robust and effective disaster management system to support the national socio-economic and policy priorities. Alternative scenarios and various combination strategies and measures will be analysed. In order to select the best suited measures and prioritization, intensive process of stakeholder interaction will be carried out for a final agreement of the Delta Decisions the Delta Framework. After selection of measures, a matrix will be developed describing what will be done, and by whom and when, and also who will finance.

In order to select strategies and measures for the 7th five year plan a series of interactions with stakeholders were carried out. A number of measures have been outlined as outcome of the interactions with stakeholders. These measures will be analysed further after finalization of the baseline study. Some of the measures are mentioned and elaborated under Chapter 4 (Outlook and Long term Challenges). The measures are: Bangladesh Regional Climate Services Project for disaster risk reduction; public-private partnership project; Local Disaster Risk Reduction Fund (LDRRF); development of modelling systems for the community level; improvement of lead time for flood forecast; loss and damage assessment, institutional strengthening, and Ganges Barrage and Brahmaputra Barrage for salinity control in times of climate change and upstream withdrawal of flow.

Even though disasters like flood and cyclone occurring frequently in the country, there always remains a knowledge gap between the technology applied to mitigate the disasters and the people who are the victims. Sophisticated technology like mathematical modelling for flood forecasting should be interpreted to the level of the local people prone to flood. A similar forecasting and warning systems should also be adopted for storm surge cyclones and monsoon flood inundation during spring tide at local community level. The flood shelter policy should be continuously updated for better management and maintenance of the shelters.

The current practice of forecasting is at 54 points on 29 rivers with lead time up to 5 days. The lead time should be extended to 10 days for better disaster management. This service needs to be expanded for more river points on more rivers; and should be extended to other areas – such as, northwest, north, and southeast, and also for the flash flood regions in the northeast with more lead time. Manpower resources and state-of-the-art technology are not adequate in FFWC for forecasting and warning of flood timely and efficiently; financial support is needed from CDMP and/or other sources. At present forecasting and warning is made at points on rivers; forecasting services need to be expanded to flood plain and community level for the safety of crops, homesteads, livestock and property.

There is a policy for cyclone shelters constructions, maintenance and management (called Cyclone Shelters Construction, Maintenance and Management Policy 2011). There is no such policy for flood shelters, which are not always available at all the high risk flood prone areas. As such, a Flood Shelter Policy should also be formulated.

There is no monitoring mechanism to monitor the coastal embankments and flood embankments along the main rivers to monitor and identify weak points prior to cyclone and severe flood. Embankment breaching at weak points is the main cause of flooding and damage in the embankment, crop lives and livelihood. A minimum budget for emergency repair of the embankments should be made available, when the repair work is small and easy and cost-effective. If any breach on embankment is not done in time, it becomes very difficult, complex and expensive to repair later.

There is a data shortage on (geological) fault segment information at Rangamati. It is necessary to undertake a proper study towards fault mapping with the help of field survey and Landsat images.

A proper Epicentre study is required on the epicentre of Borokol earth quake that occurred in 2003.

1. Introduction

1.1. Background

Bangladesh is a disaster-prone country having an area of about 1, 47,570 km^2 with population nearing 149.77 million according to population census held in 2011. The country becomes the worst victim of natural calamities causing colossal loss of lives and properties. The adverse impacts of all the natural hazards affecting socio-economic condition need to be reduced for sustainable development. On realization of this reality, the Government of Bangladesh has undertaken a lot of plans and programmes for risk reduction through disaster management. Bangladesh is a global hotspot for tropical cyclones. Cyclones hit the country's coastal regions in the early summer (April–May) or late rainy season (October–November) The severe cyclone on 12 November 1970 took a heavy toll of 0.3 million human lives in Bangladesh and put property damages to billions of US dollars. Another worst cyclone which hit Bangladesh coast on 29 April 1991 that killed 0.14 million people and property damages were more than two billion US dollars. The Cyclone SIDR was also severe in nature and took lives of 3,406. The cyclone of 1876, 1919, 1961, 1963, 1965, 1970, 1985, 1988, 1991, 1994, 1995, 1997, 2007 and 2009 were also of severe nature. Floods are annual phenomena occur during monsoon from June to October. The floods of 1988, 1998 and 2004 were particularly catastrophic, resulting in large-scale destruction and loss of lives. Four types of flooding occur in Bangladesh. Rainfall induced general flood caused by overflowing of rivers, flash floods in the hilly areas, tidal flood in coastal region, cyclone induced storm surge.

Climate change and sea level rise add new dimensions to community risk and vulnerability. Although the magnitude of these changes may appear to be small, they could substantially increase the frequency and intensity of existing climatic events (floods, droughts, cyclones etc.). Current indications are that not only will floods and cyclones become more severe; they will also start to occur outside of their "established seasons". Events, such as drought, may not have previously occurred in some areas and may now be experienced.

The country has experienced over 200 natural disasters since 1980, leaving a total death toll of almost 200,000 people, and causing economic damages of approximately USD 17 billion (MoDMR, 2013).

The government acknowledges the need for pre-disaster mitigation and preparedness of the people, as opposed to the earlier concepts of responding after a disaster has taken place, as a necessary as well as a cost-effective approach. The Disaster Management Vision of the Government of Bangladesh is to reduce the risk of people, especially the poor and the disadvantaged, from the effects of natural, environmental and human induced hazards, to a manageable and acceptable humanitarian level, and to have in place an efficient emergency response system capable of handling large scale disasters (DMB, 2010). After the floods of late 1980s and the killer cyclone of 1991, the concept of acting only after the occurrence of disaster has been replaced by the concept of total disaster management involving prevention/mitigation, preparedness, response, recovery, rehabilitation and development.

In order to formulate a holistic nation-scale development plan the Government of Bangladesh undertook the Bangladesh Delta Plan 2100 Formulation Project with assistance from the Government of Netherlands. The time horizon of this planning process is long-termed for 50-100 years. However, short-termed planning activities may be included in the 7th five year plan and subsequent five-year plans of the government. This project will focus on 19 different thematic areas covering 8 working sectors of the government. The project was launched through holding a workshop at Planning Commission on 27 August 2014. The timeframe of the project is 30 months starting from March 2014.

Currently the baseline study phase is going on for all thematic areas of study. As envisaged like other thematic areas, the purpose of the baseline study of disaster management is to explore the current situation of disaster management and relief regarding policy/planning documents, current practices, and find out knowledge and activity gaps, and challenges.

Institute of Water Modelling (IWM) is entrusted with the baseline study on the thematic area disaster management under BDP 2100. The baseline study focused on reviewing of policy, plans and strategy. The evaluations of past studies, identification of knowledge gaps and future potential measures have also been investigated under the baseline.

1.2. Objectives and Deliverables

The objectives of the baseline study are:

- Selection of major hazards and trends
- To review policies, plans, developments in view of the long term changes
- To identify problems, challenges and opportunities
- To assess the present practice of disaster preparedness and responses; measures and strategies
- To prepare/provide disaster maps
- To establish a common knowledge base
- To identify knowledge gaps and need of future study and research
- Lessons learned from past projects and to identify exemplary projects for implementation

Deliverables:

- Fact sheets on projects, programmes, organizations/institutions, materials on policies, planning, orders, frameworks etc. – all related to disaster risk reduction and management activities
- List of major hazards
- Maps and/or figures of flood, drought, cyclone-induced storm surge, earthquake, landslides, erosion hazard GIS layers as input to the Delta Ateliers/Hot Spot analysis
- Model results on hazard assessment, data, input to information portal;
- Draft and Final Baseline Study Reports

1.3. Structure of the Report

This report contains 6 (six) Chapters and 5 (five) Annexes. The first chapter is introductory and also mentions objectives and deliverables. Chapter 2 describes major hazards and related problems. Chapter 3 narrates the past and present plans and projects on disaster management, while chapter 4 gives an outline for the future scenario and long term challenges. Chapter 5 describes the long-term Delta vision and the last, Chapter 6, discusses knowledge gaps and related challenges.

A joint fact finding workshop was held in December 2014 with a view to gathering opinion of people knowledgeable and experience in disaster management in the country. The outcome is provided in Annex A. Annex B presents thematic pillars, programs and actions under Bangladesh Climate Change Strategy and Action Plan (BCCSAP) and also ensure environmental sustainability and disaster management (post-2015 development agenda of Bangladesh proposal to UN). Fact sheets of various projects under relevant agencies and the associated reports are given in Annex C. All the annexes have been put under a separate volume (Volume 2) of this baseline study.

2. Descriptions of Major Hazards and Problems

2.1. Introduction

The Ministry of Disaster Management and Relief (MoDMR) has identified 32 hazards that occur in Bangladesh. Under the present study five (5) hazards have been identified through participatory way involving professionals of planning, implementing, knowledge and academic institutions. The selected hazards are:flood, drought, cyclonic storm surge, salinity intrusion and earthquake.

The descriptions of hazards are presented in the following sections.

2.2. Descriptions of Major Hazards

Flood

Floods are annual phenomena that occur during monsoon from June to October. Bangladesh is under sub-tropical monsoon climate; annualaverage precipitation is 2,300 mm, varying from 1,200 mm in the north-west to over 5,000 mm in the north-east. About 80% rainfall occurs over five months from May to October. The country has 405 rivers including 57 trans-boundary rivers, among them 54 originated from India including three major rivers the Ganges, the Brahmaputra and the Meghna (*Ref. Bangladesher Nod Nodi,BWDB, August 2011*). Three rivers originated from Myanmar. Monsoon flood inundationof about 20% to 25% area of the country is assumed beneficial for crops, ecology and environment, inundation of more than that causing direct and indirect damages and considerable inconveniences to the population (BWDB, 2014). The Ganges-Brahmaputra-Meghnariver systems drain a huge rainfall-runoff generated from 1.72 million sq km basin area, where only 7% area lies within Bangladesh.

The floods of 1954, 1955, 1974, 1988, 1998, 2004 and 2007 were particularly catastrophic, resulting in large-scale destruction and loss of lives. Four types of flooding occur in Bangladesh: Flash floods caused by overflowing of hilly rivers in eastern and northern Bangladesh (in April-May and September-November). Rain floods are caused by drainage congestion and heavy rains. Monsoon floods are caused by major rivers usually in the monsoon (during June-September). Occurrence of coastal floods is due to cyclonic storm surges. The flood of 1988 during August-September inundated 89,000 sq. Km. Areas of 52 districts of the country and caused loss of 1517 human lives. The 1998 flood alone caused 1,100 deaths, rendered 30 million people homeless, damaged 500,000 homes and caused heavy loss to infrastructure (DMB, 2010). Bangladesh has demonstrated effective flood management with the improvement of early warning and its dissemination, establish shelter, institutional development and community participation for flood preparedness and response that reduced the risk and loss from flood tremendously.

Drought

Bangladesh has been experiencing severe drought hazard mainly during dry season and also in the monsoon because of inadequate and uneven rainfall. Drought varies from place to place. Over the years it is seen that north-western region suffers most from the drought. As much as 17% of the Aman crops, the main paddy crops in the wet season, may be lost in a typical year due to drought. Between 1949 and 1991, droughts occurred in Bangladesh 24 times (ADPC, 2014). Very severe droughts hit the country in 1951, 1957, 1958, 1961, 1972, 1975, 1979, 1981, 1982, 1984 and 1989. Past droughts have typically affected about 47% area of the country and 53% of the population (WARPO, 2005).

In 1973 one of the most severe droughts in the present century hit the country which was one of the causes of the 1974 famine in the northern part of the country. The 1975 drought affected 47% of the entire country and caused sufferings to about 53% of the total population (DDM,2014). During 1978-1979, severe drought caused widespread damage to crops, reducing rice production by about 2 million tons and directly affected about 42% of the cultivated land and 44% of the population. It was one of the most severe droughts in recent times.

Drought affects not only seasonal crops, but also fruit-bearing trees, forestry and the environment as a whole. Moreover, the crop environment during the monsoon (Kharif-II) season is not favourable for achieving full potential yields because of uneven distribution of rainfall, flooding etc. To combat the drought, it is essential for Bangladesh to utilize its water resources, both surface and groundwater. However, Bangladesh has increasingly used her groundwater resources to such as extent that the depletion of groundwater resources as well as arsenic contamination is occurring at alarming rate in the groundwater reservoirs due to over and unplanned withdrawal. The scope of increasing the irrigation areas by LLP is limited. In these circumstances, there is no option but to use surface water to meet the water deficit created by droughts in the Kharif-II season and hence, surface water utilization projects such as barrages across the rivers, installation of pumping houses for lifting water from the rivers are essential.

Cyclonic Storm Surge

Tropical cyclones originated from the Bay of Bengal accompanied by storm surges are one of the major disasters in Bangladesh. The country is one of the worst sufferers of all cyclonic casualties in the world.

Bangladesh is a global hotspot for tropical cyclones. Cyclones hit the country's coastal regions in the early summer i.e. during April–May or late rainy season from October–November. Tropical cyclone is a low-pressure system which develops in the tropics and is sufficiently intense to produce sustained gale force winds of at least 63km/h. If the sustained wind reaches hurricane force of at least 118km/h the system is defined as a severe tropical cyclone. Tropical cyclones can cause significant phenomena which can adversely impact on communities and the environment. The most common features are destructive winds, heavy rainfall and cyclone induced storm surge that can lead to flooding. The Bay of Bengal is one of the hotspots for the generation of tropical cyclones. About one-tenth of the global numbers of cyclones that form in different regions of the tropics occur in the Bay of Bengal (Gray, 1968; Ali, 1980). Most of the cyclones hit the coasts of Bangladesh with a north-eastward approaching angle. In recent years cyclones Aila and Sidr hit the south western coastal zone, which implies that the whole coastal area is vulnerable to cyclones and storm surges.

In November 1970, the most severe cyclone of the century, with respect to surge height, inundation and loss of life occurred. The cyclone produced a surge height of up to 10 meters, which hit the coast at high spring tide, causing inundation of nearly every low lying coastal area in Bangladesh. The loss of life was estimated to 300,000-500,000 (SMRC, 1998). In April 1991, a cyclone produced a surge height of more than 6 meters along a coastal stretch of 240 km in Bangladesh, inundating large coastal areas and offshore islands (SMRC, 1998). Especially since the deadly cyclonein 1991 (with nearly 5 million people affected and over 130,000 people dead) a large scale programme of cyclone shelters was launched (Choudhury et al., 1993).

Cyclone Sidr (November 2007) and Cyclone Aila (May 2009) provide recent examples of devastating storm-surge in Bangladesh.In 2007, Cyclone Sidr, a 10-year return period cyclone with an average wind speed of 223 km per hour resulted in 4,234 casualties and 55,282 injuries. Livelihoods of 8.9 million people were affected and damages and losses from Cyclone Sidr total US$1.67 billion (GoB,2008). In 2009, Cyclone Aila, a 1.2 year return period cyclone with an average wind speed of 95 km per hour caused 190 deaths, 7,103 injuries and affected 3.9 million people.The high numbers of casualties is due to the fact that cyclones are always associated with storm surges. Storm surge height in excess of 9m is not uncommon in this region. For example, the 1876 cyclone had a surge height of 13.6 m and in 1970 the height was 9.11 m (WARPO, 2005). A list of devastatingcyclones is given in **Table 1**.

Table 1: List of severe cyclonesthat hit the coastal area

Date		Maximum Wind speed (km/hr)	Storm Surge height (metres)	Death Toll
11 May	1965	161	3.7-7.6	19,279
15 December	1965	217	2.4-3.6	873
01 October	1966	139	6.0-6.7	850
12 November	1970	224	6.0-10.0	300,000
25 May	1985	154	3.0-4.6	11,069
29 April	1991	225	6.0-7.6	138,882
19 May	1997	232	3.1-4.6	155
15 November (SIDR)	2007	223	--	3363
25 May (AILA)	2009	92	--	190

Salinity Intrusion

River water salinity in the coastal area depends on the volume of freshwater discharges from the upstream river systems, salinity of the Bay of Bengal along the coast, the circulation pattern of the coastal waters induced by the ocean currents together with strong tidal currents in the coastal waters. Mixing of the fresh water from the upstream river system and saline water from the Bay of Bengal in the coastal water occurs due to the turbulence generated both by wind and tidal currents. Average salinity concentrations at the coast are higher in the dry season than in the monsoon, due to the lack of freshwater flow from the upstream. The salinity generally increases almost linearly from October (post-monsoon) to late May (pre-monsoon). At the end of May, salinity level sharply drops due to rainfall and upstream flow of freshwater through the river system. The salinity levels are at the minimum in the wet season, usually during September or early-October. The annual minimum flow in the Ganges decreased from 1920m3/s in 1974 to 730m3/s in 2013 (BWDB, 2013). Over the years, the salinity has intruded significantly in the coastal Ganges delta because of the reduced flow in the Ganges, the only freshwater source in the zone. Observed salinity data shows that the salinity was found to be as high as 9.3 ppt in 2013 (IWM, 2013) whereas it was less than 0.5ppt before 1975 (Khulna Newsprint Mill, SWSMP 1993). Reduction in trans-boundary flow reduces the area where river water is suitable for irrigation (0-2ppt salinity) especially in the Ganges dependent area.

The effects of climate change on river salinity in the coastal area of Bangladesh are expected to manifest in several ways. Changes in rainfall, temperature, freshwater flow from rivers in the Himalayas, cyclone-induced surge intensification and sea level rise are likely to be the most significant effects of climate change. In particular, salinity ingress is likely to be more severe in the future for two reasons: (i) the sea level will gradually rise and (ii) upstream withdrawal of freshwater flow.

Earthquake

Bangladesh and the north eastern Indian states have long been one of the seismically active regions of the world, and have experienced numerous large earthquakes during the past 200 years.The Great India earthquake in 1897 with a magnitude of 8.7 caused serious damage to masonry buildings in Sylhet town where the death toll rose to 545. The origin of the earthquake was in the north of Bangladesh inside India and the shaking was felt up to Burma at thousand miles from the origin. The casualties from this earthquake were not much since there was limited number of masonry buildings at that time. On 18 July in 1918 an earthquake hit Srimangal with a magnitude of 7.6 and intense damage occurred in Srimangal. Another earthquake in 1930 with a magnitude of 7.1 with the epicentre at Dhubri, Assam caused major damage in the eastern parts of Rangpur district.

The record of approximately 150 years shows that Bangladesh and the surrounding regions experienced seven major earthquakes (with Mb = 7). In the recent past, a number of tremors of moderate to severe intensity had already taken place in and around Bangladesh. The Sylhet Earthquake (Mb = 5.6) of May 8, 1997, the Bandarban Earthquake (Mb = 6.0) of November 21, 1997, the Maheshkhali Earthquake (Mb = 5.1) of July 22, 1999, and the Barkal (Rangamati) Earthquake (Mb=5.5) of July 27, 2003 may be cited as examples (Choudhury, 2005).

Lots of seismic-tectonic studies have been undertaken on the area comprising the Indo-Burman ranges and their western extension and in the northern India. Major active fault zones of the country have been delineated through geological trenching and dating methods. A list of reference of this is provided in Haque, (1990), using data from various sources. A seismic zoning map of Bangladesh was proposed in 1979 by Geological Survey of Bangladesh (GSB) dividing the country into three seismic zones which was accompanied by outline of a code for earthquake resistant design. Later, a new updated seismic zoning map and detailed seismic design provisions have been incorporated in Bangladesh National Building Code (BNBC, 1993). A seismicity map of Bangladesh and its adjoining areas has also been prepared by BMD and GSB.

Disaster Management System and settings in Bangladesh

The Disaster Management and Relief Division (DM&RD), MoDMR of the Government of Bangladesh has the responsibility for coordinating national disaster management efforts across all agencies. In January 1997 the Ministry issued the Standing Orders on Disaster (SOD) to guide and monitor disaster management activities in Bangladesh. The SOD has been prepared with the avowed objective of making the concerned persons understand their duties and responsibilities regarding disaster management at all levels, and accomplishing them. All Ministries, Divisions/Departments and Agencies shall prepare their own Action Plans in respect of their responsibilities for efficient implementation. A series of inter-related institutions, at both national and sub-national levels have been created to ensure effective planning and coordination of disaster risk reduction and emergency response management. Ministry of Disaster Management and Relief (MoDMR), Ministry of Water Resources (MoWR), Ministry of Environment and Forest (MoEF), Department of Disaster Management (DDM), Bangladesh Water Development Board, Bangladesh Meteorological Department, Local Government Engineering Department, Department of Environment, Climate Change Cell, Local Government Institutions (LGI) and NGOs.

2.3. Existing Institutional Framework

2.3.1. Ministry of Disaster Management and Relief

The Ministry of Disaster Management and Relief (MoDMR) has been given the mandate to drive national risk reduction reform programmes. Its mission relative to this agenda is: "To achieve a paradigm shift in disaster management from conventional response and relief to a more comprehensive risk reduction culture, and to promote food security as an important factor in ensuring the resilience of communities to hazards".

The Ministry is the main governing and supervising authority in any disaster related matters, issues and incidences. Hence, it is the focal point of all activities and initiatives at all stages of disaster risk reduction and emergency response management. It is the apex body to formulate policies, plans etc. and mandated with the responsibility of controlling of all disaster related activities and all subordinate organizations. Its founding and development history is presented in the following:

- 1972: Founding. With a view to providing help and support to disaster victims with relief and rehabilitation after independence, a ministrywas formed named The Ministry of Relief and Rehabilitation.
- 1982: From ministry to division; vested under the Ministry of Food while restructuring the ministry as a division called Relief and Rehabilitation Division
- 1988: From division to ministry. The Relief and Rehabilitation Division turned into ministry again called the Ministry of Relief
- 1994: Renaming. The ministry assumed its new name as the Ministry of Disaster Management and Relief.
- 2004: Merging. The ministry merged with the Ministry of Food and assumed another new name – The Ministry of Food and Disaster Management.
- 2010: Restructuring into two divisions: Disaster Management and Relief Division, and Food Division
- 2012: Finally again two separate ministries; named as the Ministry of Disaster Management and Relief, and Ministry of Food.

The Ministry of Disaster Management and Relief runs 3 (three) categories of projects

- Annual Development Programmes (ADP)
- Climate Change Trust Fund Projects (CCTFP)
- Sponsored Projects

Projects under ADP

- Operation Support to the Employment Generation Programme for the Poorest (EGPP)
- Capacity Building for Disaster Risk Financing
- Construction of Multipurpose Cyclone Shelters in the Coastal Belt of Bangladesh
- Procurement of Saline Water Treatment Plant (2 ton truck mounted)
- Construction of Flood Shelters in the Flood Prone and River Erosion Areas (2nd Phase)

Projects under CCTF

- Construction of Cyclone Resistant Houses at Char Area in Aila Affected Districts of Chittagong Division
- Construction of Cyclone Resistant Houses at Char Area in Aila Affected Districts of Barisal Division
- Construction of Cyclone Resistant Houses at Char Area in Aila Affected Districts of Khulna Division

2.3.2. Department of Disaster Management (DDM)

It was originally established in 1992, with the name Disaster Management Bureau (DMB) reorganized and renamed in 2012, as Department of Disaster Management (DDM) under Disaster Management Act 2012.

The roles of DDM includes that

- It has the mandate to implement the objectives of Disaster Management Act 2012 by reducing overall vulnerability from different impact of disaster by undertaking
- Risk reduction activities
- Conducting humanitarian assistance programmes(i.e., relief operations) to enhance the capacity of poor and the disadvantage
- Strengthening and coordinating programmes undertaken by various government and non-government organizations
- It is responsible to execute directions and recommendations by the government

- It conducts research, organises workshop, training programmes, publishes reports and documents, and provides various policy advisory services to the concerned ministry of GoB.

The projects implemented by DDM are as follows:

- Emergency 2007 Cyclone Recovery and Restoration Project
- Construction of Flood Shelters in the Flood Prone and River Erosion Areas
- Construction of Bridges / Culverts (up to 12 m long) on the rural roads (2nd Phase)

However, the department (DDR) needs to develop stronger linkage with FloodForecasting and Warning Centre (FFWC) and Bangladesh Meteorological Department (BMD), since these twoinstitutions generate disaster forecasting information and maps.

2.3.3. Cyclone Preparedness Programme (CPP)

After the most severe cyclone in 1970, by the request of UN, Cyclone Preparedness Programme was established in 1972 with the help of League of Red Cross. The Government of Bangladesh took the programme in July 1973. It is now a joint programme of Bangladesh Government and Bangladesh Red Crescent Society. It is to be noted that CPP is the sole organization which disseminate warning signals to the communities in the coastal area.

Objectives of CPP

- Build up disaster response capacity
- Minimize the loss of lives and properties
- Build up skilled, smart, dedicated volunteers team
- Build up and strengthen preparedness capacity
- Establish and strengthen weather warning signals

Activities – pre-disaster and during disaster time

- Dissemination of warning signals
- Signal dissemination system
- Evacuation/ cyclone shelter
- Search and rescue
- First aid to injured people

Command Area and Volunteers

- 13 coastal districts
- 37 upazilas
- 322 unions
- 3291 units
- More than 49365 volunteers (including 16455 female volunteers)
- It is important to increase coverage for all the 19 coastal districts

2.3.4. Bangladesh Meteorological Department

Bangladesh Meteorological Department (BMD) is a government organization under the administrative control of the Ministry of Defence. It started its journey in 1867 establishing only one observatory in Satkhira, now a district in southwest region in Bangladesh. After independence of Pakistan in 1947 it was renamed as Pakistan Meteorological Services. After the independence of Bangladesh in 1971, it was again renamed as Bangladesh Meteorological Department. Its objectives is to provide effective meteorological and seismological services for protection of life, property and the environment, increased safety on land, at sea and in the air, enhanced quality of life and sustainable economic growth.

Responsibilities of BMD:

- Monitors and issues forecasts and warnings of all meteorological extreme events like tropical cyclone, severe thunderstorm/tornadoes, heavy rainfall, drought, cold and heat wave along with daily routine forecasts round the clock.
- Issues short, medium and long-range forecasts for agricultural planning and operation of daily farmer's activities.
- Provides Flood Forecasting and Warning Centre with rainfall data, forecasts/warnings, radar and satellite image for the operation of flood forecasting and warning system.
- Provides seismological information in and around the country along with Tsunami Advisories and warnings to the Government and public.
- Supplies and facilitates the application of climate data and information to the Government and private agencies for planning and performance of socio-economic development activities.
- BMD is involved with WMO's science-based monitoring of the change/variability of climate and preparation of 21st century climate scenario development activities.
- Archives all weather and climate data, maintenance of historical records of all meteorological and seismological extreme events in numeric and graphical forms

It is important to forecast the coastal inundation at community level due to cyclonic storm surge as well as spring tides. There is need to strengthening institutional capacity for numerical modelling and climate change modelling. There is need of strong mechanism for establishing linkage with BWDB and DDM for sharing information, experience and skill for better disaster management.

2.3.5. Bangladesh Water Development Board (BWDB)

East Pakistan Water and Power Development Authority (EPWAPDA)was founded in 1959 in order to boost food production by mitigating flood damage, saving land from tidal and storm surge and developing water resources as a whole. After liberation in 1972 the EPWAPDA got restructured and the water wing was separated and assumed new name Bangladesh Water Development Board and started its new journey as an autonomous body in a new, liberatedcountry.

Functions and Activities:

Structural and non-structural activities for water resources and disaster management:

Structural activities by BWDB:

- Controlling and developing of rivers and floodplains

- In order to mitigate/prevent flood, drought, provide drainage facilities, constructing dam, retention pond, barrage, regulator, embankment etc.
- Land reservation, land reclamation, estuary control
- Preventing salinity intrusion

Non-structural activities by BWDB:

- Flood and drought forecasting and warning
- Carrying out hydrological investigations and collecting and storing data, information relating thereof
- Activities relating to environment protection and development

Functionally it has 5 wings:

- Administration wing
- Planning wing
- Finance wing
- Implementation wing
- Operation and Maintenance wing

Office of Director General oversees all wings.

Completed works and projects:

- In total 709 projects were completed for water resources and disaster management
- 139 coastal polder for prevention of tide, salinity and storm surge
- Total embankment 10224 km: coastal 4530 km, other 5694 km
- Number of barrages: 4

2.3.6. Flood Forecasting and Warning Centre and Its Services

Introduction

Flood forecasting and warning services (FFWS) are offered by Flood Forecasting and Warning Centre (FFWC) at Bangladesh Water Development Board (BWDB). As per *BWDB Act 2000*, FFWC has the mandate and responsibility for delivering of such services. Moreover, Standing Orders on Disaster (SOD) has the direction on it to become fully operative during the flood season (April to October). The basic input data are for flood forecasting,rainfall and water level to interpret the present situation and generating flood forecasts. The flood monitoring and forecasting depend on:

- Hydro-meteorological monitoring system of BWDB covering Bangladesh
- Additional rainfall and water level data of upper catchment from India
- Additional meteorological data from Bangladesh Meteorological Department (BMD) and European Centre for Medium-range Weather Forecast (ECMWF)
- Satellite and radar images

Hydro-meteorological data so collected are used as input to the numerical model. The results of the model computations are used in preparing flood warning products, such as warning bulleting and inundation maps. FFWC disseminates these through email, fax, mobile message, own dedicated website (www.ffwc.gov.bd).

Aims and Objectives

The aim of FFWS is to alert and persuade people, community and organizations by disseminating flood hazard information so that they can take flood preparedness in order to save lives and properties, and reduce loss and damage.

Products

- Daily flood bulletin and river situation summary
- Forecast bulletin and hydrograph
- Warning message
- Rainfall distribution map
- River situation map
- Special outlook
- Structure-based flood forecast
- Countrywide coarse flood inundation map
- Dhaka city flood inundation map
- Comparison of hydrographs for various years

Brief Descriptions of Certain Products

Flood Forecasting

Flood forecasting and warning bulleting are prepared having computed the probable condition of water level (increase/decrease/static) within certain coming future days by the help of mathematical model simulation upon considering prevailing conditions of weather, rainfall and water level on rivers. Currently advance flood forecasting are done at 54 points/locations on 29 rivers for up to 1 day, 2 day, 3 day, 4 day and 5 days

Flood Bulletin

In the first part, flood information for up to 5 days is mentioned (as described above). In the last part, magnitudes of observed rainfall for 3 days including the two past days are mentioned.

10 Days Advanced Flood Forecasting

It is a probability based medium term flood forecasting during monsoon in which probable maximum, minimum and average water level are forecasted. Currently it is done at 38 points.It may also be applied to agriculture management.

Structure-based Flood Forecasting

Experiment basis flood forecasting has purposely been introduced to see/monitor flood situation along with infrastructure of certain projects since 2013. Under these efforts, the infrastructure are (a) Dhaka – Maowa Road (b) Brahmaputra Right Embankment (c) Embankment of Pabna Irrigation and Rural Development (d) Embankment of Meghna Dhanagoda Irrigation Project. In these cases 5 days forecast are done.

Flash Flood

Forecasting of flash flood up to 2 days in advance at certain stations in Sylhet and Sunamganj district in north east region has been introduced in 2013 on pilot basis.

Interactive Voice Response

It was started in June 2011 on Teletalk cell phone, then through all other mobile phone operators in 2013. Forecasting can be heard by calling the number 10941 from many parts of Bangladesh.

2.4. Current Policies and Plans

2.4.1. Existing Regulatory Literature

Existing Regulatory Literature

In order to operate an effective and efficient disaster management system in a holistic way throughout the country, establishing a regulatory framework is a must. Bangladesh has now established a structured regulatory framework that provides legal, policy and best practice documents in which the necessary initiatives and activities relating to Disaster Risk Reduction (DRR) and Emergency Response Management (ERM) are managed and implemented. The regulatory framework has five aspects –

- Legal
- Policy
- Planning
- Response and activity coordination
- Guidance support for best practices

2.4.2. Legal Aspect

This act was first introduced in Bangladesh in September 2012. The act creates –

- Institutional framework/ facilities to operate Disaster Risk Management(DRM) activities. For example,
    - National Disaster Management Council
    - Establishing Department of Disaster Management
    - National Disaster Management Research and Training (to be established, being progressed)
    - National Disaster Response Coordination Group
    - Local Level Disaster Management Committees and Groups
    - Authority to formulate National and Local Disaster Management Planning
- Legal framework under which activities and actions on DRR and ERM is managed and implemented
- Mandatory obligations and responsibilities on ministries, national and local level bodies/committees regarding DRM activities

2.4.3. Policy

(a) National Disaster Management Policy (being formulated, not finalized yet)

With a view to fulfilling the objectives of the Disaster Management Act- 2012 (DMA-2012), the government, taking account of geographical region, various communities, hazards and sectors, also keeping in line with the regional and international frameworks of disaster management, shall formulate National Disaster Management Policies (Section 19). Such policies are actively formulated now by the government, and it is expected to be finished soon. The draft National Policy on Disaster Management has underscored a group of broad-based strategies (DMB, 2010):

- Disaster management should involve the management of both risks and consequences of disasters and it should include management measures of prevention/mitigation, emergency response and post-disaster recovery
- For preparedness programmes the major focus should be on community involvement for protecting lives and properties
- Involvement of local government institutions shall be an essential part of the strategy in all phases of disaster management – pre, during and post
- Self-reliance should be the key for preparedness, response and recovery
- Non-structural mitigation measures (such as community disaster training and advocacy, and public awareness) must be given a high priority
- Where necessary integration of structural mitigation measures with non-structural mitigation measures shall be adopted

(b) Cyclone Shelters Construction, Maintenance and Management Policies 2011

One could say without doubt that a single night's cyclone can bring a huge loss and damage to lives and properties of the people in the coastal area of Bangladesh. Therefore, in the efforts of saving lives and properties, building of cyclone shelters is of absolute necessity. The initiative of construction of multi-purpose cyclone shelter started after major cyclone occurred in 1991, particularly school-cum-cyclone shelter. There was a similar policy made in 1996 by the Infrastructure Division of the Planning Commission, but it was not adequate with the need grown over time. For example, no policy regarding how a shelter would be used in normal time, repair and maintenance, budget for repair and maintenance, design categories etc. Hence, a comprehensive policy document was formulated in 2011 containing 12 sections. They are 1) Introduction 2) Cyclone Shelter 3) Construction design of the shelters 4) Ensuring necessary facilities of Shelter 5) Management of Cyclone Shelter 6) Responsibility of Local Disaster Management Committee 7) Preserving List of Shelter Centre 8) Management of Earthen Killas 9) Repair, Maintenance, Left Unused and Sale 10) Use of Shelters at Normal Time 11) Management Committee of the Cyclone Shelters 12) Special Instructions. Also, it contains 3 (three) layout drawings which serve a clear guidance to the planning, design and constructing authority. This is very important because cyclone shelters are being constructed by different organizations (for example, DDM, LGED, some NGOs, some INGOs) by having grant from GoB and international organizations and countries.

The shelters are structured buildings on RCC pillars, where groundfloor remains open which is needed for the surgeto pass. There must be ramp facilities for aged and disabled people to climb up to the upper floors. Relevantauthority will open upon proclamation of definite signals, be closed after upon withdrawal of the signals. One very important point is that, no shelter is built for stand-alone purpose, hence the policy ensures multipurpose use. The policy describes about its spatial frequency that a shelter be within 1.5 km from vulnerable community. In fact this will indicate the necessity of constructing more shelters gradually over time until this specification shall have been met. In selecting a location for a shelter, preference will be given to those open spaces around Schools, colleges, madrasas which are not used as playgrounds, also,the policy says - dilapidated education buildings can be removed and multipurpose shelters be built instead.

Regarding construction-design of the shelters, there are 3 (three) standard designs as follows:

Design 1: College/ Higher Secondary School/ Madrassa cum Multiuse Shelter

Plinth area: 275-300 m2 per floor

Land area: around 12 decimal

Containing capacity: 1000 person on each up floor from 2nd floor

6 rooms, at least 3-storey foundation, ramp facilities, 1 room kept reserved for disables and helpless, the other rooms for people and livestock.

Design 2: Primary cum multiuse shelter

Plinth area: 220-230 m2 per floor

Land area: around 10 decimal

Containing capacity: 800 person on each up floor from 2nd floor

4 rooms, at least 3-storey foundation, ramp facilities, 1 room kept reserved for disables and helpless, the other rooms on 2nd floor be for livestock.

Design 3: Multiuse shelters

Plinth area: around 200 m^2 per floor

Land area: around 10 decimal

Containing capacity: 750 person on each up floor from 2nd floor

4 rooms, at least 3-storey foundation, ramp facilities, 1 room kept reserved for disabled and helpless, the other rooms for livestock.

In determining the floor level of the shelter, the policy states that union-wise risk map made by CDMP shall be followed. Plinth level has to be determined at least 3 feet higher than the maximum surge level. Ground floor can be used as shelter of livestock. Regarding structural design considering wind speed and surge height, the policy says that an wind speed of 260 km/h, and 6-20 feet surge height varying on localities have to be followed. It also states that quality in construction has to be maintained. Special importance has to be given so that construction cost maintains cost effectiveness.Another visionary policy item is: in coastal region all government organizations to be built in future shall keep similar shape to cyclone shelters (Section 3.13 of the policy).

2.4.4. Planning Aspect

National Plan for Disaster Management 2010-2015

The main planning document is the National Plan for Disaster Management (NPDM) 2010-2015. This plan was approved by the government on7th April 2010. It outlines:

- The systematic and institutional mechanisms under which DRR and ERM are under taken
- Disaster management vision, strategic goals and conceptual framework
- Disaster management plans

The objectives of the plan:

- To keep the strategic direction of disaster management programmes align with the national priorities and international commitments
- To articulate the vision and goals for disaster management
- To outline the strategic direction and priorities to guide design and implementation of disaster management policies and programmes
- To create a cohesive and well-coordinated programming framework incorporating government, non-government and private sector
- To ensure that the disaster management approach and efforts should be comprehensive and multi-hazard focus
- To illustrate and enlighten other ministries, NGOs, civil society, private sector on how their work can contribute to the achievements of the strategic goals and government vision on disaster management

Core Principles

Drawing on the PRSP, the following core principles have been adopted:

- Country-driven, promoting national ownership of strategies through broad-based participation of government, NGOs and civil society
- Result oriented planning focused on outcomes that will benefit vulnerable communities, especially women, the poor and socially disadvantaged
- Comprehensive effort in recognizing the multi-dimensional nature of risk reduction
- Partnership oriented effort, involving coordinated participation of development partners (government, domestic stakeholders, and external donors)
- A long-term perspective for risk reduction

Scope of the Plan

- Identification of hazard, and analysing them in terms of magnitude and frequency including climate change, and their threats to people, society, and infrastructure
- Identification of elements at risk and how they are likely to be affected
- Investigation of what measures are possible to prevent, mitigate of disaster events and what preparedness measures can be put in place in anticipation
- Distribution of responsibilities relating to planning and action for prevention, mitigation and preparedness among government, non-government and private sector organisation
- Making provision in the national budget for funding activities of DRM, and contingency fund to face immediate need for relief at all levels of administration
- Ensuring that the cost of disaster relief and recovery are managed in an efficient way by a high level committee so that wasting money or duplication of allocation is checked
- Ensuring an effective system within the government to link and coordinate the processes of planning and management for sustainable development, environmental management and disaster risk reduction.

Bangladesh Climate Change Strategy and Action Plan 2009

Bangladesh Climate Change Strategy and Action Plan (BCCSAP) was first introduced in 2008 and revised in 2009. By way of presentation it consists of two parts. The first part (from Section 1 to 5) presents the context, implications and likely impact of climate change, overview of adaptation strategies and outlines mitigation issues. The second part (Section 6) outlined 10-year programme (from 2009 to 2018) to build the capacity and resilience of the country to meet the challenge of climate change of the next 20-25 years (until 2030-2035). The strategy and action plans in BCCSAP 2009 have been developed on 6 (six) pillars. Theme 1: Food security, social protection and health, Theme 2:

Comprehensive Disaster Management, Theme 3: Infrastructure, Theme 4: Research and knowledge Management, Theme 5: Mitigation of Carbon Dioxide Emissions and Low Carbon Development, and Theme 6: Capacity Building and Institutional Strengthening.

Each thematic pillar has definite programmes, objectives, justification, action-list, time line, and responsible organization. Though there is a dedicated thematic pillar for disaster management with proper name 'Comprehensive Disaster Management', but as a matter of fact almost all programmes under six pillars have implications on disaster management either directly or indirectly, be it more or less. However, among these six, virtually the first three pillars have more direct/indirect implications on disaster management. Considering the significance and relevance to disaster management, these three pillars are tabulated briefly with the programmes and actions under each programme. The fourth column 'Remark' contains some opinions regarding actions (as given under Table B.1 in Annex B).

Sixth Five Year Plan 2011 and Disaster Management

The Sixth Five Year Plan (SFYP) was approved by Executive Committee of National Economic Council (ECNEC) in June 2011 and published in December 2011 to cover the development plan for the duration of FY2011-FY2015. It reviewed relevant regulatory documents/frameworks (National Plan for Disaster Management 2010-2015, Standing Orders on Disasters, etc.), national and international drivers (Millennium Declaration 2000, Hyogo Framework for Action 2005-2015, SAARC Framework for Action 2006-2015, Poverty Reduction Strategy Paper etc.). It then put briefly down the Bangladesh Disaster Management mission, vision, objectives, guiding principles for disaster management, policy, planning and strategic framework, strategic goals taken in NPDM as the basis for action matrix in it, comprehensive programme adopted (CDMP Phase 1 and 2). It then sets the disaster management strategy for the SFYP and the challenges in achieving objectives and priorities.

Keeping the main idea that disaster management is the all-hazards, all-sectors and all agency approach, SFYP set nine guiding principles for disaster management. These are:

1. Disasters can either be natural, human induced or technology induced. The DM policy is to provide guidance,plan and prepare for all types of hazards and disasters.
2. Disaster Management in Bangladesh is guided by a number of national and international Drivers, as mentioned above.
3. Disaster risk reduction should be an integral element of every national and sectoral policy at all levels to achieve the overall goal of economic and social development
4. Since risk is dynamic, therefore both scientific and community-level analysis is essential for defining and redefining risks and assessing for all hazards including existing and in future taken climate change into account
5. Disaster management activities in Bangladesh will be designed around a DM Model having 2 elements – Disaster Risk Reduction and Emergency Response Management
6. Effective response management must be designed utilizing risk information and revised through lessons learnt
7. Mainstreaming risk reduction efforts within government, NGO and private sector isviewed as being the key to achieving sustainable all hazards risk reduction and sustainable development
8. Disaster Management in Bangladesh will be enriched through doing applied research andknowledge management. Hence efforts will be made to strengthen research capability and institutionalize knowledge management across academia
9. Women, children, elderly, the disable and other socially marginalized groups will bethe primary beneficiaries of all disaster management efforts

In achieving the overall objectives, moreover, the SFYP sets a number of policy-actions, givenas follows:

- Integrating disaster risk reduction and climate change adaptation approaches in all ongoingand future development plans, programs and policies
- Enhancing professional skills and knowledge of key personnel on disaster and climate change risk reduction (preparedness, warning and forecasting system), and post-disaster activities (emergency response management)
- Strengthening mechanisms to build disaster and climate change risk reduction capacities for the Community and Institutions at all levels
- Community based programming for disaster risk and climate change risk reduction
- Promoting livelihood strategies and options for the most vulnerable that incorporate disaster and climate change risk reduction practices
- Strengthening capacities for disaster and climate change risk assessment for flood, cyclone, drought, river bank erosion, pest attacks, earthquake, epidemics, etc. to establish and strengthen the systems and procedures for effective response management
- Creating a legal and institutional framework for effective response management
- Strengthening national capacity for response management with emphasis on preparedness and support to disaster management committees at district, upazila and union levels
- Improving the early warning and community alerting system
- Strengthening search and rescue capabilities of relevant agencies
- Introducing an effective response management coordination mechanism including a relief management logistic system to handle different levels of emergency response
- Establishing an electronic based information management system

In very early of this century the government took a paradigm shift in disaster management in that it would focus more on to disaster risk reduction from earlier concept of response-relief focus. Since NPDM was introduced in April 2010 and the SFYP was approved in June 2011, the latter is assigned to carry forward the tasks as planned and in the light of the earlier. Also, as seen, draft national policy on Disaster management underpinned three broad-based strategies (DMB, 2010). These are 1) disaster management would involve both risks and consequences, 2) community involvement would be a major focus for preparedness programmes to protect lives and properties, and 3) non-structural measures, training, advocacy and awareness programmes must be given high priority. Taking all these aspects the SFYP sets a number of priorities in all three elements of DM – DRR, ERM and post-disaster recovery. The priorities, briefly, for DRR as follows:

- Professionalizing the DM systems and institutions
- Strengthening the capacity of Department of Disaster Management (DDM, erstwhile DMB)
- Strengthening institutional capacity of sectoral ministries, departments of GOB and non-GOB
- Empowering communities- at-risk
- Reducing vulnerabilities of at risk communities through social safety nets
- Preparedness for Earthquake and Tsunami risks through vulnerability and risks assessments,land use planning, hazard land zoning, contingency planning, strengthening search and rescue capacity, mass public awareness
- Building Knowledge on DRR and CCA through piloting and adaptation research, establishing an integrated approach to disaster management including CC, developing CC scenarios, updating hazard maps
- Strengthening national capability to reduce the risks of chemical, technological and biological hazards; infrastructure collapse, fire,road accidents, launch capsize and landslide
- Strengthening national capacity for erosion prediction and monitoring
- Developing and establishing policy and planning frameworks to incorporate all hazard (including anticipated risks of climate change) risk reduction perspectives into sectoralpolicies and development plans
- Establishing public - private partnerships for disaster risk reduction.

- Supporting regional and global risk reduction initiatives and ensure representation that is consistent with the government integrated all sector risk reduction approach at all levels

The priorities for the Emergency Response during the SFYP broadly are:

- Strengthening and improving an all Hazard Early Warning Systems through technical,technological, and physical capacity strengthening of Bangladesh MeteorologicalDepartment and Flood Forecasting and Warning Centre.
- Establishing and strengthening regional networks for real time data/information sharing.
- Establishing an effective Community Alerting System through capacity strengthening ofCyclone Preparedness Program and Disaster Management Committees (DMC) at District, Upazila and Union levels.
- Introducing Contingency Planning and Disaster Preparedness across all sectors and at alllevels.
- Establishing and improving Search and Rescue Mechanism
- Strengthening GO-NGO and private sector co-ordinations on relief and emergency management.
- Developing and establishing a well-coordinated multi-sectoral post-disaster recovery andreconstruction mechanism.
- Establishing and operating a National Disaster Management Information Centreconnected with all 64 Districts and high-risk Upazila DMCs
- Ensuring protection and support to the most vulnerable, especially women and children

The Post-Disaster Recovery Priorities during the SFYP will broadly include:

- Incorporating early recovery into the disaster response mechanism
- Developing mechanisms for damage and losses assessment to be the basis for recoveryplanning
- Developing and establishing post disaster recovery and reconstruction mechanisms
- Incorporating disaster and climate change risk reduction measures into post-disasterrecovery and rehabilitation processes and use opportunities during this phase to address the underlying factors of the disaster and climate change risks
- Linking post disaster recovery efforts with the development plans and programs

In all three elements of disaster management, pre-disaster, during disaster and post-disaster strengthening institutional capacities and inter-ministerial coordination as well as coordination with the NGOs is necessary and vital in disaster management effectively.

The Challenges as recognised by the SFYP

1. Lack of policy coherence: The effectiveness and strength of risk governance is a part of overall governance and administration of the country. It was envisaged that weak institutional and local capacity and fragmented policy framework might continue for next few years. It felt the need of a set of policies at higher hierarchy, meaning disaster management act and policy.
2. Trans-boundary nature of hazards and climate change: Occurrence of it and their management involves community of practice front, regional and international diplomacy front, scientific and technology front.
3. Policy – reality gap: A formidable gap is likely between formulated policies and its actual implementation
4. Gap between risk reduction and relief-recovery.
5. Risk accounting and public investment: Quantification of risks in case of disaster management and climate change has not arrived at such practical level that a practical and comprehensive assessment is done. As a result, estimation for investment planning, recovery and redevelopment could not stand on a sound base.
6. Main streaming of disaster risk reduction: Though SOD referred to formulating a range of sectoral guidelines, as envisaged this would take a couple of years and hence mainstreaming would suffer.

A discussion on gaps and challenges referring to SFYP

Referring to Challenge 1: Lack of policy coherence - Expectation for the act and policy has now been met, as the Disaster Management Act 2012 was passed in September 2012, and the final version of Disaster Management Policy is going to be published in near future. Referring to Challenge 6: Mainstreaming disaster risk reduction, guidelines have been drafted and hopefully the final version will come out in near future (see Sec 2.4.7).

Referring to priority on DRR given above and in SFYP (p-485): reducing risk of chemical, technological and biological hazards, infrastructure collapse; fire; road accidents; launch capsize and landslide. In this regard, multi hazard approach of analysis has been initiated by DDM and CDMP. As usual, in the earlier stages the historical major hazards are getting rooms for attention and analysis, for example, flood, cyclone, drought, earthquake, salinity etc. Along with giving attention to the study on major hazards, the future study (for example in the 7th FYP) may include such hazards with more occurrences like chemical, technology-induced, biological hazards, infrastructure collapse, fire, road accidents, launch capsize, water logging, and landslide.

Referring to guiding principle 8 (p-19), and in SFYP (p-481) enriching disaster management through applied research and knowledge management is set as one of the guiding principle. Also, United Nations Framework Convention for Climate Change (UNFCCC) pleadsto improve scientific knowledge about disaster reduction (p-99, NPDM). Though a number of studies have been carried out in the area of disaster management, it is felt that applied research has not received proper attention along with a lack of database. The next plan may give due attention to this deficiency.

Referring to the priority – professionalizing disaster management systems and institutions (SFYP, p-484), lessons incorporated in national curriculum; postgraduate courses are offered in around 20 universities; undergraduate courses have been introduced in few universities. This efforts and initiative should be continued. Also, upazila could be considered as key point in terms of practical field operations of disaster management. Upazila level might be fortified with proper staff educated and trained in disaster management.

2.4.5. Planning Aspects in Broader Development Framework

Poverty Reduction Strategy Paper 2

This paper which describes 'Steps towards Change: National Strategy for Accelerated Poverty Reduction 2', was prepared to cover the period 2009-2011.

PRSP recognizes:

- Regional variations in poverty have been recognised. This variation is influenced by the natural hazards in that, poverty tends to be higher where incidence of occurring natural hazards is more.

Elements of Strategies

The following strategies have been emphasized for disaster risk reduction at present and in future:

- Emphasises the mainstreaming of climate change considerations and strengthening the adaptations across the sectors
- Promotes afforestation, construction of cyclone shelters, construction of embankment, improvement of salinity control measures
- Recognises water resources development
- Promotes a targeted approach, focusing on poor region

Perspective Plan of Bangladesh 2010-2021: Making Vision 2021 a Reality

The plan was issued by the Planning Commission in June 2010.

Elements of the Plan in the Area of Water Resources Management

- Examination of large scale operation and maintenance activities on embankments and polders in order to prevent salinity intrusion. It pointed out that for such activities different options should be identified and compared; and hence the best option to move forward should be determined
- Rehabilitation of coastal embankment should be viewed in the light of impact of climate change.
- Desalination activities
- Land reclamation activities

National Sustainable Development Strategy 2010-21

Key Challenges

National Sustainable Development Strategy (NSDS) recognizes that the challenge Bangladesh now faces that Bangladesh needs increasing investments to create suitable environment for the economic and social development of the country with the adverse effects of climate change.

Strategies set in NSDS to meet the challenges

- Rehabilitation of coastal polders. There are two elements, one is - repair and maintenance of polders those were damaged, washed away by cyclones Sidr and Aila. And the other is rehabilitation work should consider the issue of climate change.
- Increasing resilience of vulnerable population. Increasing resilience of vulnerable population through taking various measures of poverty reduction
- Ecosystem-based detailed area planning. Formulation of ecosystem based detailed area planning for urban areas, land zoning required for urban development and country planning
- Following building codes. It is necessary to follow building codes for maintaining health, urban environment and earthquake risk reduction
- Strengthening institutional capacity. Strengthening institutional capacity in government sectoral ministries, departments and disaster management committees, and other academic and technical sectors.
- Using SAARC forum. Using SAARC forum for exchanging data relating to hazard assessment and climate change
- Integrating DRR and CCA. Integrating disaster risk reduction and climate change adaptation as core component into the sectoral development plan
- More cooperation and coordination required. Creating and sustaining opportunities to integrate policies, mechanisms and resource management in a coordinated and coherent manner for DRR and CCA
- Afforestation programme should be strengthen for its benefit on DRR (particularly in case of cyclone), CCA and maintaining healthy environment across the country
- Vegetation type. Plantation of types of trees which have deep roots (for not easily uprooted), large canopies that act as windbreaker, bushy (resist wind and protect soil), mangroves (to mitigate erosion, protect wave action etc.)
- Climate tolerant crop variety. To continue and enhance carrying out research and development of climate tolerant varieties of crops and carrying out their field tests so that farmers are motivated to cultivate them
- Cyclone and storm surge warning. Current cyclone and storm surge warning systems should be reviewed and improved where necessary. Improvement of cyclone and storm surge dissemination to local communities by awareness systems and radio communication
- Utilization of climate change funds. Proper use of Climate Change Trust Fund and Climate Change Resilience Fund by strengthening project selection, disbursement of funds and monitoring mechanism

Critical review of NSDS

1. NSDS recognizes scaling up of investments for disaster risk reduction as the challenge. In reality another main challenge would be policy formulation and their implementation. Also, how the integration of DRR and CCA into the developmentplan is set and achieved.
2. NSDS suggests that cyclone and storm surge warning systems be improved. However, this should be true for other hazardsalso, for example flood hazard. Not only warning systems, but also hazard assessment needs to be improved
3. NSDS did not mention the need of loss and damage assessment. For the improvement of disaster management systems, approaches, paving research base and in taking decisions in relief and rehabilitation works, research on loss and damage assessment and improvement of current practices are needed to be improved.

Post 2015 Development Agenda: Bangladesh Proposal to UN

Millennium Development Goals (MDG) were set following Millennium Summit held in 2000 following the adoption of United Nations Millennium Declaration in 2000. The summit set 8 goals to be followed by countries across the world, they are

1. To eradicate extreme poverty and hunger
2. To achieve universal primary education
3. To promote gender equality and empower women
4. To reduce child mortality
5. To improve maternal help
6. To combat HIV/AIDS, malaria and other diseases
7. To ensure environmental sustainability
8. To develop a global partnership for development

There is no doubt that all these goals appear to be very important and their achievements are vital for socio-economic progress of any developing country. However, it is noteworthy that no goals as disaster risk reduction and climate change adaptation was set. But DRR and CCA are issues that have influence on many goals. Disasters and climate change are the main setbacks in progressing of a country.

The tenure of the MDG is from 2000 to 2015. MDG have definitely served a global framework for development, particularly in the developing countries. In this duration Bangladesh made a considerable progress in achieving the set goals. As scheduled in every 3 (three) years Bangladesh prepares progress report and monitors on the fulfilment of the goals, and General Economic Division in the Planning Commission is responsible for this. Bangladesh integrated MDG into economic and social targets in the 6th Five Year Plan 2011-15. The last progress report was made in 2012. It reported that Bangladesh met some considerable targets of MDG such as reducing poverty gap ratio (Goal 1), gender equality in attending primary and secondary education (Goal 3), increasing immunization coverage (Goal 6), reduction of child-mortality rate under five (Goal 4), detection and cure of TB under DOTS (Goal 6) etc. (GED, 2013). No doubt Bangladesh is progressing considerably in achieving most of the goals.

However, some significant weaknesses were revealed in the last progress report, which are briefly put in the following (GED, 2013):

1. Top down approach. MDG being a top down process and follow a sectoral approach where matters were treated in a fragmented/separated manner. Thus in some cases MDG could address the symptoms rather than the root causes of the problem.

2. Narrow indicators. Narrow (apparent) indicators were used in estimating progress which overlooked the overall consequences. For example, progress was made in reduction of poverty, but generated more gaps between rich and poor.
3. Lack of attention on human rights and development. Lack of attention on human rights and development weakened the framework, relied on statistical figures rather than human progress.
4. Accountability and responsibility. The issue of mutual accountability and principle of common responsibilities was practically absent from the MDG framework.

Since the tenure of the MDG is ending in 2015, but there are unfinished agenda. Hence there is some consensus and need felt to continue the ongoing work in order to complete. Also, by the time new need emerged and new set of goals need to be formulated. UN will need new Development agenda for post 2015 era. In response to that Bangladesh prepared a proposal to UN of new set of goals wherein Goal 10 (Ensure environmental sustainability and disaster management) involves disaster management. In this proposal Bangladesh sets some targets and indicators in achieving this goal. The Goal 10, with its targets and indicators, is provided in Table B.2 under Annex B.

Hyogo Framework for Action 2005-2015

Hyogo Framework for Action (HFA) is the outcome of the World Conference on Disaster Risk Reduction held at Kobe in Japan during 18-22 January 2005 where 4000 participants from 168 states were present with a core objective that building resilience of nations and communities to substantially reduce lives and properties (with respect to social, economic and environmental assets).

Objectives (DMB, 2010)

The conference (as mentioned in the preceding para) had the following specific objectives:

- To conclude the review of the Yokohama Strategy and Plan of Action with a view to updating the guiding framework on disaster reduction for the 21st century
- To identify specific activities to ensure implementation of relevant provisions of the Johannesburg Plan of Implementation (JPOI) adopted in 2002 at the World Summit on Sustainable Development
- To share best practices and lessons learned to utilize them in disaster reduction within the context of attaining sustainable development, and identifying gaps and challenges
- To increase the awareness of the importance of disaster reduction policies, and to facilitates and promote implementations of those policies
- To increase the reliability and availability of appropriate disaster-related information to the public and disaster management agencies in all regions, as set out in the relevant provisions of JPOI

Commitments (DMB, 2010)

The following 9 (nine) commitments were contained in the HFA:

- To follow an integrated multi-hazard approach to reduce the frequency and severity of disasters to gain sustainable development
- To put disaster risk reduction issue at the centre of political priorities and policies
- To integrate disaster risk reduction into all development work
- To strengthen the capacity of disaster-prone countries to practically address the disaster risk
- To allocate fund substantively in disaster preparedness
- To make effort to reduce relief-development gap and thereby reducing vulnerability
- To enable civil society actors and affected communities to strengthen their resilience to disasters
- To reduce the gap what we know and what we do, with the critical ingredient being political commitment

- To build on the momentum of this World Conference to accelerate implementation of the HFA

Priorities for Action

Reviewing the deliberations at the said Conference, also drawing on the conclusions of the review of the Yokohama Strategy, the HFA adopted the following 5 (five) priorities for action:

1. Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation
2. Identify, assess and monitor disaster risks and enhance early warning
3. Use knowledge, innovation and education to build a culture of safety and resilience at all levels
4. Reduce the underlying risk factors
5. Strengthen disaster preparedness for effective response at all levels

Summary of National Progress Report over the duration 2011-13 on the Implementation of the Hyogo Framework for Action 2005-15

Bangladesh is scheduled to report its progress in every 3 (three) years. The last report was prepared on the progress over the duration 2011-13 (DDM, 2013). Aiming at 3 (three) strategic goals the progress over the said period on the implementation of the HFA were evaluated. These strategic goals are:

Strategic Goal 1: More effective integration of disaster risk considerations into sustainable development policies, planning and programming at all levels, with a special emphasis on disaster prevention, mitigation, preparedness, and vulnerability reduction.

Strategic Goal 2: The development and strengthening of institutions, mechanisms and capacities at all levels, in particular at the community level, that can systematically contribute to building resilience to hazards.

Strategic Goal 3: The systematic incorporation of risk reduction approaches into the design and implementation of emergency preparedness, response and recovery programmes in the reconstruction of affected communities

Progress Evaluation

Progress evaluation was made on all 5 (five) Priorities for Actions which the HFA set in 2005 (DDM, 2013). A short summary of the progress is provided in Table B.3 in Annex B.

SAARC Framework for Action 2006-15

In the 13th SAARC Summit September held at Dhaka in 2005 the Heads of State or Governments called for formulation of a Comprehensive Framework on early warning and Disaster Management. They underscored the urgent need to put in place a regional response mechanism for all phases of disaster management. Following the Dhaka declaration an Expert Group was formed to formulate comprehensive regional framework on disaster management. Bangladesh prepared a draft 'Disaster Management in South Asia: A Comprehensive Regional Framework for Action 2006-2015' and circulated in the meeting held during 7-9 February 2006. Through a process of review, discussions and amendments SFA was finally adopted later.

The SFA set the following specific goals (DMB, 2010)

- Professionalising the disaster management system
- Mainstreaming disaster risk reduction
- Strengthening of community institutional mechanisms
- Empowering community at risk, particularly women, poor, disadvantaged

- Expanding risk reduction programming across a broader range
- Strengthening emergency response systems
- Developing and strengthening networks of relevant national, regional and international organizations

It is to be noted that these 7 (seven) goals have been taken as goals under the National Plan for Disaster Management 2010-15.

Priority areas identified by the SFA

- Develop and implement risk reduction strategies
- Establish national and regional response mechanism
- Establish a regional information sharing mechanism and develop network of institutions and organizations
- Develop and implement disaster management training, education, research and awareness programmes
- Apply ICT for disaster management
- Establish an effective monitoring and evaluation mechanism

Emphases for implementation and follow up (DMB, 2010)

Some emphases:

- Though all member states will make efforts to bring social and economic progress, yet regional enabling environment is vital to stimulate and contribute to make disaster resilient nations and communities in their respective countries
- All member states shall feel encouraged to apply holistic approach in implementing SFA
- Each member country shall develop their own plan of actions in implementing the SFA (Note: National Plan for Disaster Management 2010-15 is an outcome of the SFA)

Sendai Framework for Disaster Risk Reduction 2015-2030 (UNGA, 2015)

Sendai Framework for Disaster Risk Reduction 2015-2030 is one of the outcomes of The Third United Nations World Conference on Disaster Risk Reduction held from 14-18 March 2015 at Sendai city in Japan. Strategically it follows the Hyogo Framework for Action 2005-2015, and hence it builds on the lessons and experiences earned from implementing the HFA. Hence, such framework marks as an incessant advancement in addressing risk reduction effort by the world community concerned with impacts of disaster. In Sendai Declaration in the conference, the participants valued the important role of HFA played during the last 10 years in building resilient nations and communities, and they further expressed their commitments in implementing this new framework as a guide to intensify the efforts for the future. The framework sets aim to achieve the following outcome over the next 15 years: "*The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries*". In order to achieve this outcome, the framework sets the following goal: "*Prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience*".

Assessing the progress in achieving the outcome and goal set out in this framework through implementing policies and actions by committing countries is a very important but formidable task. The following 7 (seven) targets have been set in the framework in this regard.

1) Substantial reduction in global disaster mortality by 2030. The aim is to lower the average per 100,000 mortality during 2020-2030 with respect to 2005-2015.

2) Substantial reduction in affected people globally by 2030. The aim is to lower the average per 100,000 affected during 2020-2030 with respect to 2005-2015.
3) Reduction of direct disaster economic loss with respect to global GDP by 2030
4) Substantial reduction in disaster damage to critical infrastructure and disruption of basic services – health and educational facilities, including through developing their resilience.
5) Substantial increase in the number of participating countries with national and local risk reduction strategies by 2030.
6) Substantial enhancement of international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this framework by 2030
7) Substantial increase the availability and access to multi hazard early warning systems and disaster risk information and assessments to the people by 2030.

Also, in implementing this framework 19 guiding principles have been set.

In achieving outcome, reaching at goals and implementing all policies and actions within and across the sectors of a country at all levels – local, national, regional and global, this framework sets 4 (four) priorities as follows:

1) Understanding disaster risk
2) Strengthening disaster risk governance to manage disaster risk
3) Investing in disaster risk reduction for resilience
4) Enhancing disaster preparedness for effective response; also, setting motto to '*Build Back Better*' in recovery, rehabilitation and reconstruction.

National Social Security Strategy 2015

National Social Security Strategy has been prepared by the General Economic Division of the Planning Commission with the aim of providing social security of the poor segment of the people of the country.Such strategy is the first ever in Bangladesh. It is now known that this strategy got cabinet approval in June 2015 (personal communication). With reference to nutrition standard a person is to be identified as a poor if he cannot intake food providing one at least 2122 kilocalorie per day. According to the present market price, to get such amount of nutrition one has to spend 1600 BDT. The government is planning under this strategy to provide 50% of this cost. The target group is the poor of all ages and both sexes, however, priority is to be given to children, women, elderly people and disabled. Workable person will get employment opportunity instead of monetary social support. The main features of the safety strategy are:

- Children, women, elderly people of the poor section will get BDT 800.00 per month
- Disabled with get BDT 1600.00 per month
- Duration: from FY2015-16 to FY 2021-22
- Nonagenarian (age between 90 and 99 years) will get BDT 3000.00
- Workable person with age group 19-59 years will get either job support or monetary support.
- Some programmes will be taken upfor freedom fighters, ethnic-minority, *Hijra* (trans-sexual), labourer in the tea estate, people suffering from AIDS
- Estimated expenditure for FY2015-16 is Taka 36.5 thousand crores (Tk 365 million)
- This social support will continue through time

To mention, though there are now a number of programmes in operation under Social Safety Net Programme, this strategy will hopefully help enhance life standard of the poor. Though it appears to be a social programme to bring the poor people out of the poverty line to improve the life standard of them, however,it has indirect immense impact on disaster risk reduction. Because it had rightly recognised the bearing of poverty on the disaster (disaster poverty linkage: wherever the disaster occurs, whatever might be its magnitude the worst sufferers are the poor segment in the society). Moreover, the success of the paradigm shift – shifting focus of the government from post-disaster response-relief to pre-disaster risk reduction will not be successful if poverty-stricken section of people is not raised.

2.4.6. Response and Activity Coordination Supports by Standing Orders on Disasters 2010

The SOD outlines

- The disaster management arrangement in Bangladesh
- Detailed roles and responsibilities of all Committees, Ministries, Divisions, Departments, and other organizations involved in disaster risk reduction and emergency response management
- Necessary actions required in implementing Disaster Management Model of Bangladesh

Note: It is now known that regulations are being formulated in the Ministry of Disaster Management and Relief and in the future the regulations will replace the Standing Orders on Disasters. A fact sheet on SOD is provided in the Annex C.

2.4.7. Guidance support for best practices (not fully completed yet)

In order to assist government, non- government organizations, disaster management committees, civil society in taking practical actions and initiatives for disaster risk management the guidelines being developed (some already developed). Guidelines include 16 components to cover related subjects and sectors to disaster management. For example,

- Community Risk Assessment Guideline
- Disaster Impact, Damage, Loss and Need Assessment Guideline
- Local Disaster Risk Reduction and Emergency Fund Management Guideline
- Indigenous Coping Mechanism Guideline

2.5. Support by Various Councils, Committees, Groups etc. at National and Local Level for Policy Guidance and Coordination

2.5.1. National Level Guidance and Coordination

There are 12 national level bodies that act as national mechanism to provide policy guidance and coordination support in overall disaster management. They are

- *National Disaster Management Council*. It is a 33-member apex body, wherein the Prime Minister is the head, to provide policy guidance towards disaster risk reduction and emergency response management in the country. The council will meet at least once in a year.
- Inter-Ministerial Disaster Management Coordination Committee. It is a 33-member committee to facilitate policy making, planning, programming, implementing measures in disaster management. It will meet at least twice a year.
- National Disaster Management Advisory Committee. It is a 47-member committee to advise on technical, socio-economic matters; meet at least twice a year.
- Earthquake Preparedness and Awareness Committee. It is a 34-member committee whose main responsibility is to review national earthquake preparedness and awareness programme and recommend suggestions for concerned organizations.

- National Platform for Disaster Risk Reduction. 34-member committee is to coordinate various stakeholders for interrelated social, economic and environmental risks and vulnerabilities.
- National Disaster Response Coordination Group. A 10-member committee is to assess disaster situations and activate management systems for response to address the event.
- Cyclone Preparedness Programme Policy Committee. A 6-member committee is to provide policy directives and guidelines to the implementation board of CPP
- Cyclone Preparedness Programme Implementation Board. A 14-member body is to determine the content of the programme and supervise their implementation.
- Committee for Speedy Dissemination and Determination of Strategy of Special Weather Bulletin. A 11-member committee is to decide ways, methods and strategy required for publicity for disaster management.
- Committee for Focal Points Operational Coordination Group. A 43-member committee is to coordinate national and field-level practical activities etc. of the disaster management committees.
- Coordination Committee of NGOs relating to Disaster Management. 29-member committee, ensure coordination regarding disaster management and relief work among government and non-government agencies.
- Disaster Management Training and Public Awareness Task Force. 42-member committee is to provide consulting and advisory services in regard to planning matters, and carry out and evaluate training and awareness.

2.5.2. Local Level Guidance and Coordination

Occurrence of disaster affect both natural and built environment in both rural and urban areas and cause loss and damage to life and property. So local level response and action is very essential; especially during and shortly after disaster local level support and coordination is a key factor in disaster management. But it depends on local level organisations and their response and cooperation. Strong institutional capacities at local level can lead to effective and efficient management of disaster at all time of disaster management. Committees have been formed for City Corporation, pourashava, district,upazila, and union level. These are:

- City Corporation Disaster Management Committee. A 35-member committee.
- Pourashava Disaster Management Committee. A 23-member committee.
- District Disaster Management Committee. A 15-member committee.
- Upazila Disaster Management Committee. A 12-member committee.
- Union Disaster Management Committee. A 14-member committee.

All these committees discharge responsibilities and play roles in risk reduction and emergency response and all phases of disasters – pre, during and post disasters.

Local Disaster Response Coordination Group

Though local level committees are there to play respective roles in disaster management, however when a disaster is imminent or has onset for the sake of speed and simplicity in response management, coordination is practically necessary at lowest level of government organization at the same time with minimum reorganization to implement of new procedures for an event. For this need local level disaster response coordination group is created. They sit for meetings before and during disaster.

- City Corporation Disaster Response Coordination Group. 12-member group.
- Pourashava Disaster Response Coordination Group. 10-member group.
- District Disaster Response Coordination Group. 8-member group.
- Upazila Disaster Response Coordination Group. 8-member group.

Local Level Multi-agency Disaster Incident Management System

There is local level Multi-agency Disaster Management System keeping parity with national Level Multi-agency Disaster incident System. For local level a position, Local Disaster Incident Manager, is established. The local level means the location of point where the incident occurs- be it in an urban area or rural. The manager can establish Disaster Incident Management Point to control the situation and carry out management operations.

3. Evaluation of Past, Existing Plan and Projects for Disaster Management

3.1. Flood

Bangladesh is one of the most flood prone countries in the world. Geographically, there is the Himalayan mountain range in the north of the country across India, Nepal, Bhutan and China. There are also some other hills and ranges to the northeast and the east, while the Bay of Bengal lies on the south.Cherapunji, the world's highest rainfall area, is located just north of the country in Assam, India.

Generally four types of flooding occur in Bangladesh. They are: flash flood, rain-fed flood, river flood, and flood due to cyclone-induced storm surges.There are a number of causes of flooding such as huge rainfall in and around Bangladesh, snow-melt in the Himalayan region, deforestation in upstream countries, low land relief (low land slope) in Bangladesh, but the main source of flood water is the precipitation. Around 80% of the total yearly rainfall in Bangladesh occurs in 5 months from June toOctober. Every year Bangladesh experiences some level of flood, but there were some heavy floods occurred in the last century and in the recent past. Two consecutive major floods occurred in 1954 and 1955 drew attention deeply of the government and policy makers and caused to make Krug Mission which ultimately recommended East Pakistan Water and Power Development Authority (EPWAPDA) vesting mandate to flood control, irrigation and drainage. Major floods occurred in the recent past in 1987, 1988, 1998, 2004, and 2007. Around two-thirds of the country was inundated by the 1998 flood. Major historical floods occurred since 1954 and their inundation coverage are shown in Figure 3.1.Some amount of flooding is good to agriculture and natural fisheries point of view, and which is tolerable to people in the concerned area. But, excess flooding in terms of depth of flooding is surely detrimental to life and property of the people. Prolong flooding is also damaging to life, crops and road communication.

Approximately 37%, 43%, 52% and 68% of the country is inundated with floods of return periods of 10, 20, 50 and 100 years respectively (MPO 1987). In the recent study it is seen that percentage of the country inundated due to floods (excluding eastern hilly area, Hatia, Sandwip and estuary areas around them) for return periods of 25, 50, 100 and 150 years is 57.1%, 61.1%, 80.6% and 81.2% respectively (DDM, 2015). This indicates that the area subjected to flooding has increased from 52% to 61.1% for 50 years and 68% to 80.6% for 100 year return period.

Flood forecasting and warning dissemination are weak which incurred loss and damage of crops, homesteads and properties. Forecasting and dissemination of flooding at community and farmer level through inundation map is missing, which is important to establish for disaster reduction at community and farmer level.

3.1.1. A Study on Flood Hazard Assessment under CDMP (2013)

Extensive flood hazard assessments were done by numerical flood models for major historical flood events in the past. These floods occurred in the years 1988, 1998, 2004 and 2007. Flood inundation risk assessment was also carried out in the changing climate for the years2050 and 2080. These flood analysis was made for 40 flood-prone districts. Table 3.1 gives a statistics about a number of maps whichwere prepared under different flood situations (historical events, return period-wise and climate change).

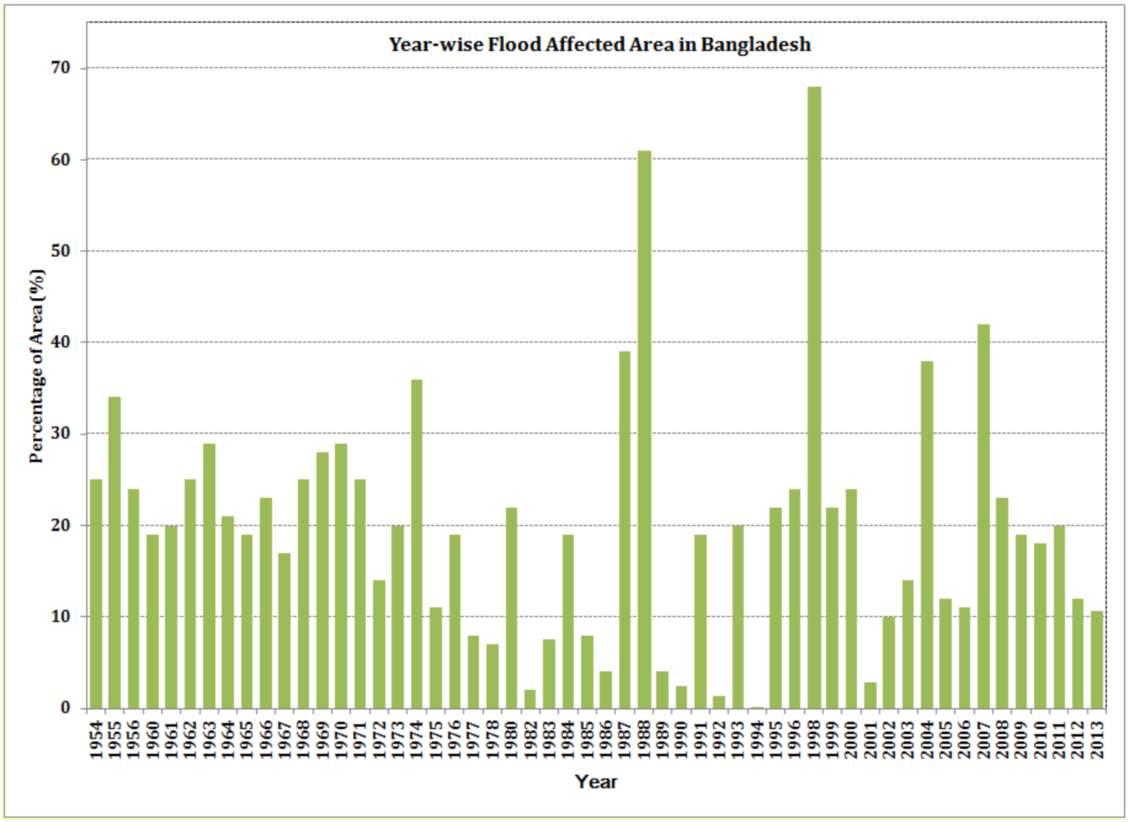

Figure 3.1: Inundation area (in percentage) by major historical floods since 1950s

(Source: FFWC, BWDB)

Table 3.1:An account of flood maps that were made under different flood situations

Flood Event	Historical Event Flood				Return Period Flood		Flood Climate Projected Change		Total
	1988	1998	2004	2007	10	20	2050	2080	
Number of maps	1961	2519	1961	1207	1207	2519	2519	2519	17036

As sample of union flood maps of Barahar union under Ullahpara upazila in Sirajganj district for the historical flood in 1998 and 2004 is shown inFigure3.2

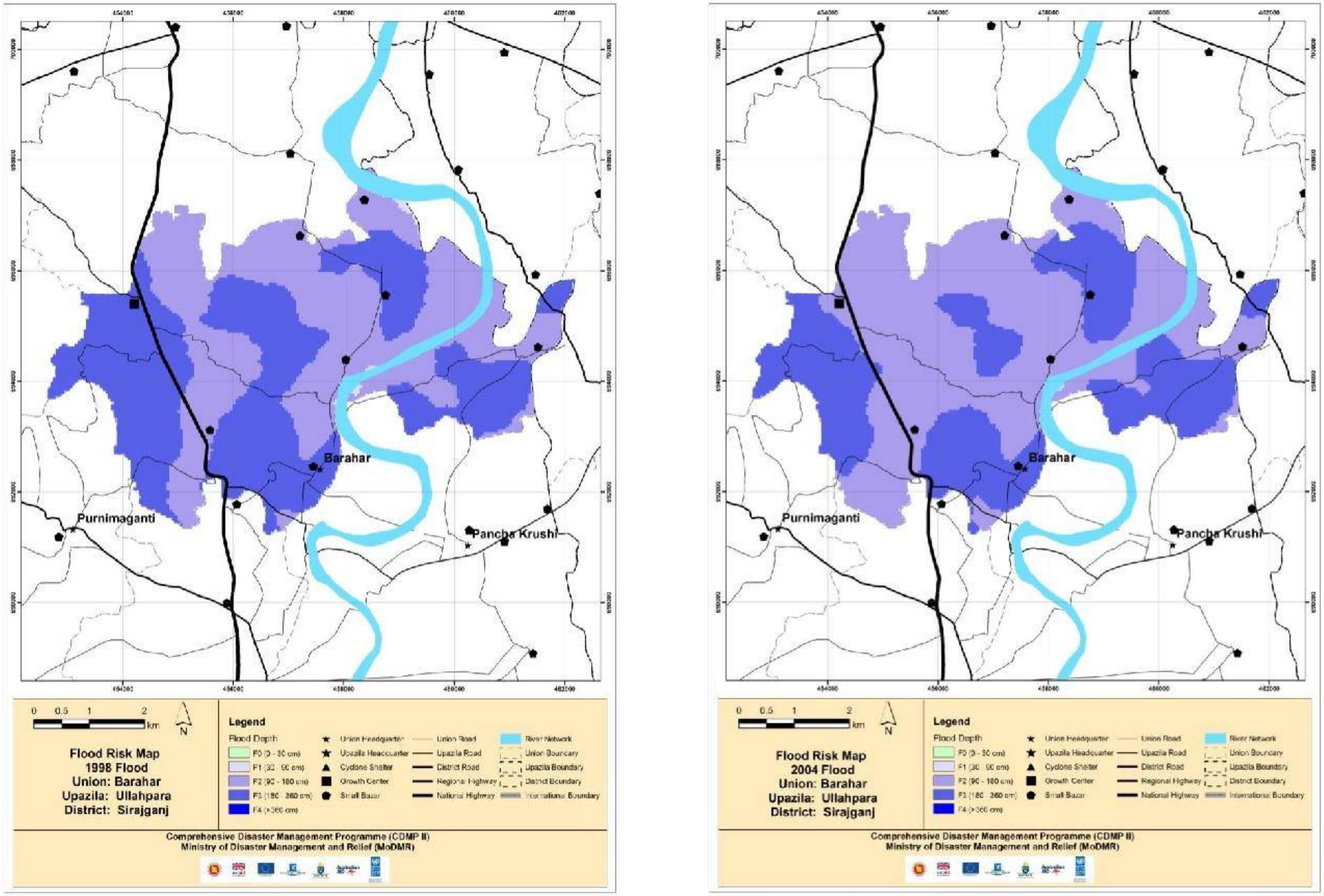

Figure3.2: Flood map of Barahar union under Ullahpara upazila in Sirajganj district for 1998 (left) and 2004 (right) floods

As mentioned earlier, union level flood maps were made in this study. Flood depth category-wise inundated area for Barahhar union under Ullahpara upazila in Sirajganj district were calculated for all historical flood events and under changed climate in the years 2050 and 2080, and is listed in **Table 3.2**below.

Table 3.2: Area under different land type for all the selected events for Barahar union under Ullahpara upazila in Sirajganj district.

Land Type	Class Interval (m)	Area (km^2)					
		1988	1998	2004	2007	1998 flood with Climate Change in 2050	1998 flood with Climate Change in 2080
F0	0-0.3	0.06	0.0175	0	1.53	0.01	0
F1	0.31-0.9	2.14	0.26	0.13	12.7625	0.19	0.095
F2	0.91-1.8	22.76	15.6425	19.1125	16.925	13.29	8.8975
F3	1.81-3.6	7.445	16.485	13.1625	11,875	18.9125	23.4125
F4	>3.6	0	0	0	0	0	0

In overall consideration in this study the percentage of change in flood inundation (depth-category-wise) is provided in **Table 3.3**. It is seen that flooding of F0 and F1 categories does not change much under climate change for the flood event of 1998. However, areas under F2 and F3 are likely to change significantly in times of climate change for flood events of 1998 in 2050 and 2100.

Table 3.3: Percentage change in land type due to climate change

Land Type	% change in 2050	% change in 2080
F0	negligible	negligible
F1	negligible	negligible
F2	-14.8	-43.0
F3	14.5	41.9
F4	0	0

3.1.2. A Recent Study: A Flood Hazard Assessment under DDM (2015)

In addressing assessment of hazards, vulnerability and risk, and to pave a good basis of database generation, disaster risk reduction tools and strategy, Department of Disaster Management is carrying out a study titled 'Multi Hazard Risk Vulnerability Assessment Modelling and Mapping'. The project is nearing completion. Eight main hazards were considered to be studied in this project, which are flood, cyclone-induced surge, drought, earthquake, landslide, Tsunami, health, and technological hazard. Another objective of the project is to arrange training at national and regional level for government officials relating to disaster management and relief, to disseminate the information on how the hazard is assessed along with other outcome of the project. The study was awarded to a consortium of Asian Disaster Preparedness Centre (ADPC), Institute of Water Modelling (IWM), Norwegian Geo-technical Institute (NGI), Asian Institute of Technology (AIT), Faculty of Geo-information Sciences and Earth Observation (ITC) of the University of Twenty. Among these hazards, flood is one of the most prominent one. The objective of the project was to assess all hazards in a probabilistic way, meaning at some return period. Flood hazard was assessed with return periods of 25, 50, 100 and 150 years.

Flood hazard is characterized by excess flood water in an area that brings negative impact to life and property socially and economically. Hence, it involves flood levels (mPWD) and terrain level both with respect to a reference (PWD). MIKE11 numerical modelling system by DHI was used in flood level computation and national digital elevation model was used to provide data for country-wide land level. Since return period-wise assessment needs long data series, country-wide simulated data series (based on all available historical data), 26 years data series from 1986 to 2011 were used. Five regional models were used in flood hazard assessment; northwest, north central, north east, south west, and south east region models. Assessment was done on flood prone areas of Bangladesh. One of the limitations is that the project used the digital elevation model which was built on land level data survey long ago in 1950s and 1960s. Being a densely populated country there have been a huge land use changes by the time. Flood categories as scheduled by MPO (1987) are shown in**Table 3.4**. Maps of 100-year return period of Bangladesh, Sirajganj district and Sirajganj sadar upazila are shown in **Figure 3.3**to **Figure 3.5**.

Table 3.4: Flood categories depending on the depth of flood (MPO, 1987)

Flood Depth (m)	**Flood Categories**
Flood Free	Not Affected
0 – 0.3	Very Shallow
0.3 – 0.9	Shallow
0.9 – 1.8	Medium
1.8 – 3.6	Deep
> 3.6	Very Deep

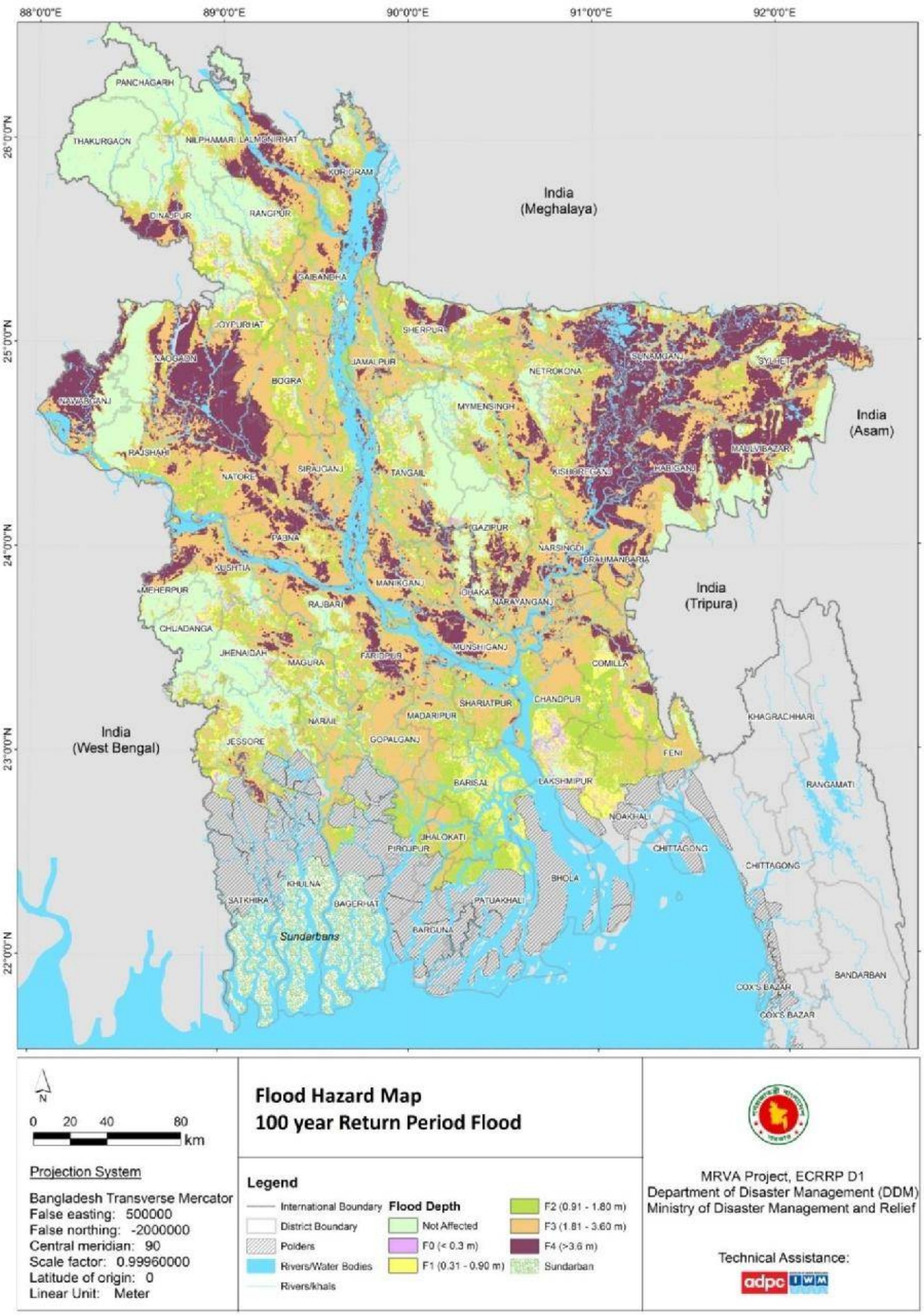

Figure 3.3: Flood depth map for 100-year return period for Bangladesh

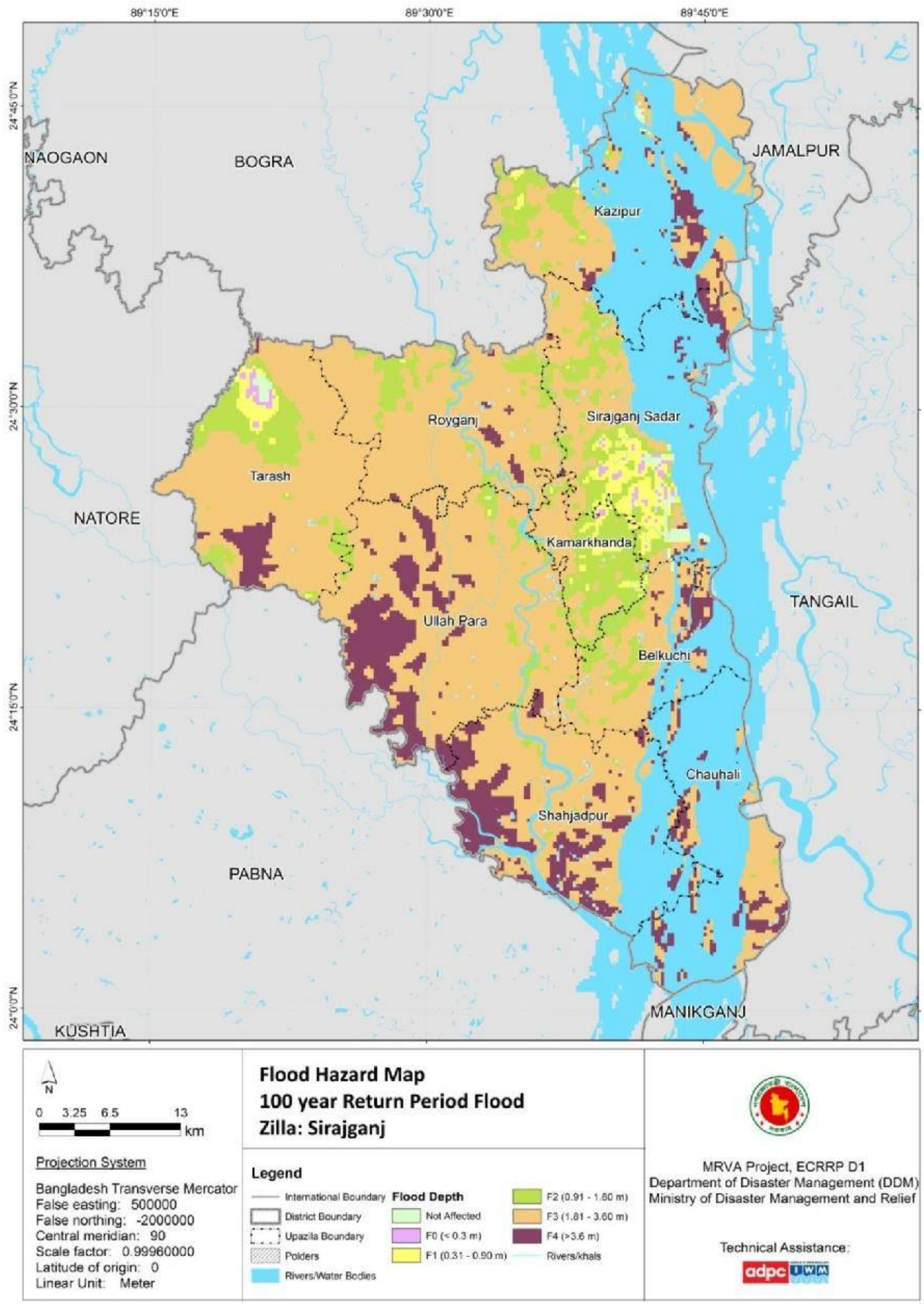

Figure 3.4: Flood hazard (100-year return period) of Sirajganj district

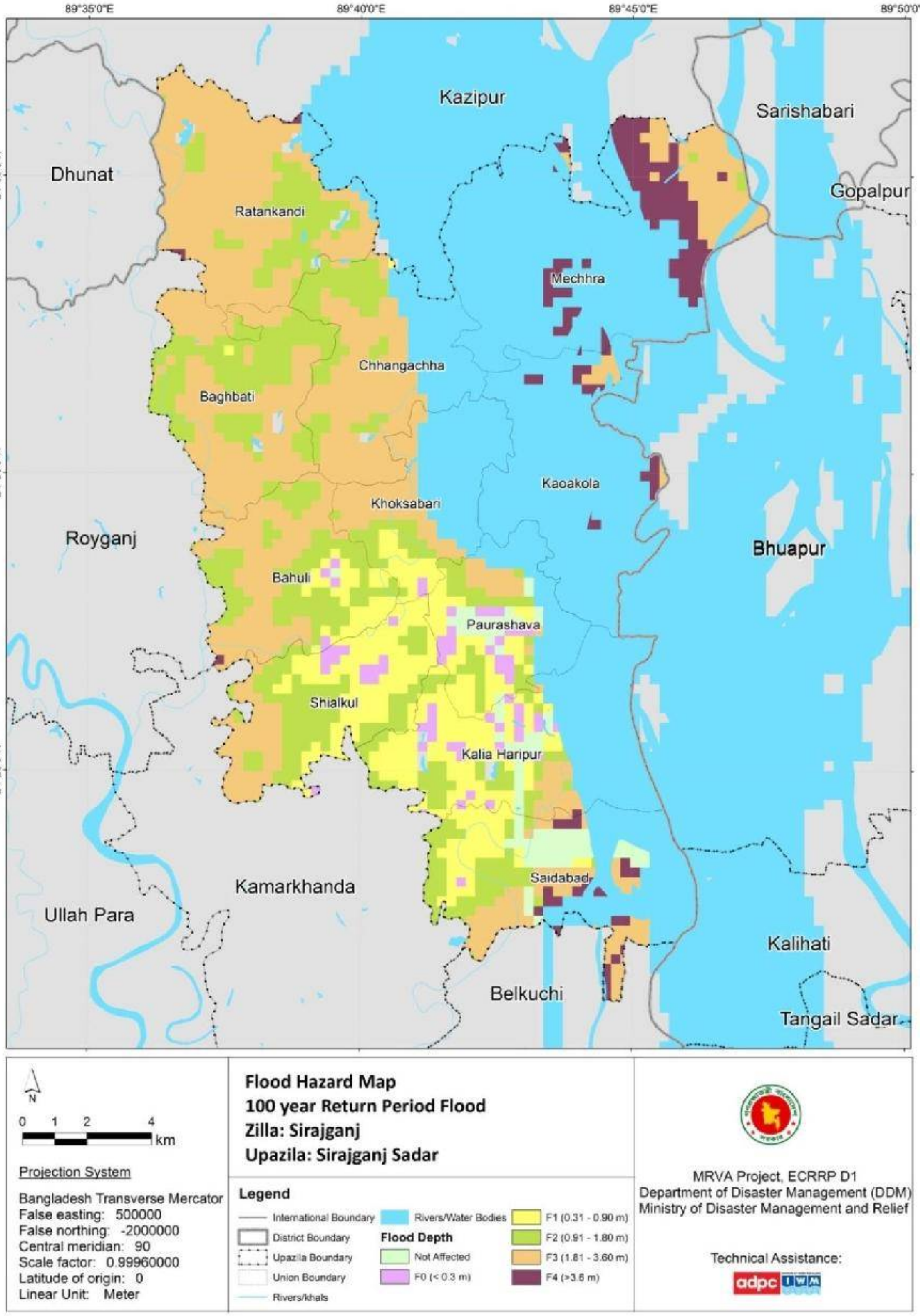

Figure 3.5: Flood hazard map (100 year return period) of Sirajganj sadar upazila in Sirajganj district

Category-wise flood inundation in percentage for all seven divisions in Bangladesh is shown in **Table 3.5**.

Table 3.5: Percentage of inundation area in each depth category in each division

Division / Flood Depth	< 0.3 m	0.3 - 0.9 m	0.9 - 1.8 m	1.8 - 3.6 m	> 3.6 m	Not Affected
Barisal	1.5	7.2	17.8	4.5	0.1	69.0
Chittagong	4.5	3.7	8.2	9.9	1.9	71.7
Dhaka	24.1	7.8	19.2	34.1	10.2	4.5
Khulna	42.9	0.6	2.2	2.2	0.2	51.8
Rajshahi	59.8	3.4	9.0	16.3	2.7	8.9
Rangpur	74.2	2.6	3.5	7.6	4.5	7.5
Sylhet	14.5	1.8	5.4	32.9	41.8	3.6
Total	31.7	3.9	9.3	15.4	8.8	31.0

3.2. Cyclone-induced Surges

The entire southern boundary of Bangladesh is exposed to the Bay of Bengal and eventually to the Indian Ocean. Though as a sea-facing country it has immense economic importance, however, at the same time the economic development is impeded by natural calamities. Nearly every year,low, moderate or devastating cyclones hit Bangladesh coast and cause a heavy toll on lives and properties. Among the hazards that occur in or ht Bangladesh, the cyclone is the deadliest,particularly with respect to loss of lives. Even with the economic importance of the coastal area, heavy growth of population, development pressure, and a large portion of poor people, the country cannot decide whether to live in the coastal area fearing cyclone hazard or migrate to other places. Living with hazard is a compromise and reality, though the rest of theworld is safer in the age of science and technology in 21st century.

It is a proven fact that disaster risk reduction can save lives and properties. The cyclone that hit Bakerganj district in 1876 snatched lives of 200,000, the one in 1970 hit greater Barisal snatched 300,000 lives. But the one with almost the same severity in terms of wind speed hit in 2007 (the Sidr) took lives of only 3406 people (as per government statistics). It has been possible in overall consideration due toincreased education, awareness, facilities and progress of disaster risk management in the country. Around the Andaman and Nicobar Island in the Indian Ocean, the places are the hot spots in developing tropical disturbances that often turn to cyclones of various severities, and hit Bangladesh in April-May and October-November. After identification of any hazard in order to manage its risk, the effective assessmentof the hazard is a must in all stages of disaster management. The effect of cyclone hazard come in two forms, one is the cyclone itself due to severe whirlwind which causes houses, buildings etc. to fall or break down and uproots trees, electric lines etc. This whirlwind in the sea make heavy waves that surge on the coast and enter into estuaries and rivers and then over the land mass to sweep away people and properties. Cyclone is such a hazard that cannot be stopped. But its impact can be lessened by taking risk reduction measures. Therefore, it is necessary and important to assess magnitude of the hazard. Nineteen (19) major cyclones hit Bangladesh coast from 1960 to 2009, the tracks of which are shown in the Figure 3.6.

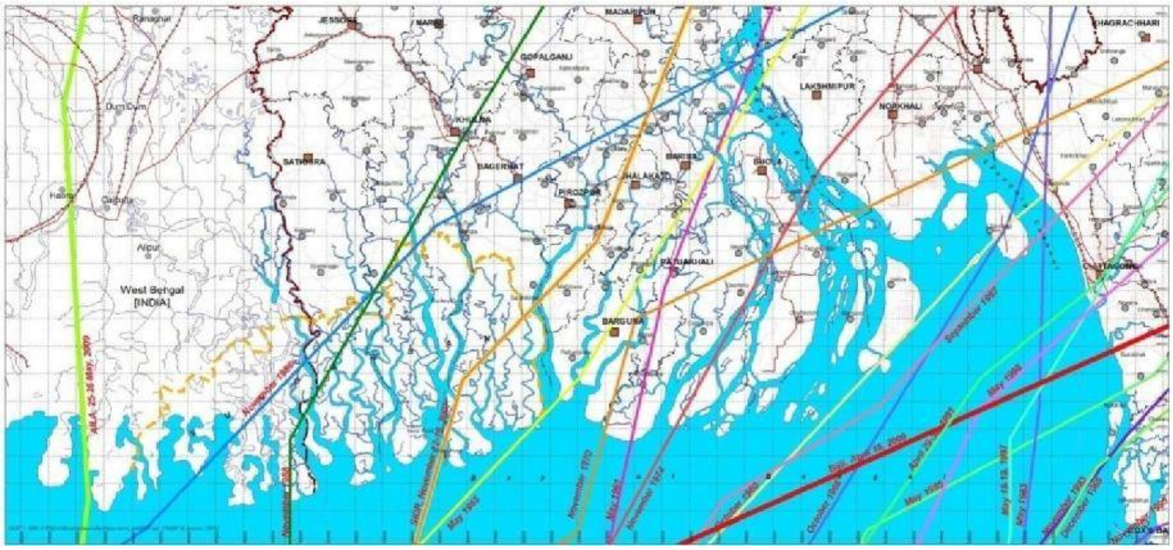

Figure 3.6: Tracks of historical major cyclones hit Bangladesh coast since 1960

Storm surge (the term cyclone-induced surges also used invariably) were assessed in many studies in the past. However, more emphasis was given in the assessments after the devastating cyclone Sidr, after which an extensive project called Comprehensive Disaster Management Programme (CDMP) was introduced to address all disaster-related hazards and to develop ways for disaster management in Bangladesh.

3.2.1. Past Studies

Storm Surge Study under CDMP (2013)

In this study storm surge assessment was done for the entire coastal area considering both base condition and with a potential changing climate in 2050, in which hazard maps were developed for all 19 coastal districts and maps are available down to upazila/union level (Figure 3.7 and Figure 3.8). Historical data of nineteen (19) severe cyclonic storm were used in this study and maps were produced from 44 simulated cyclones (38 simulations at both high and low tide 19*2= 38, and 6 simulations at both tides from 3 synthetic cyclones). Base condition means without changing any historical data. At base condition 101 maps were prepared. Total inundated area is 19146 km^2.

Climate change condition means analysis with a potential changed climate at year 2050 with probable increase of two climate change variables: sea level rise (taking 50 cm) and 10% increase in wind speed of historical cyclone. At climate changed condition 107 maps were made; and total inundated area is 20745 km^2.

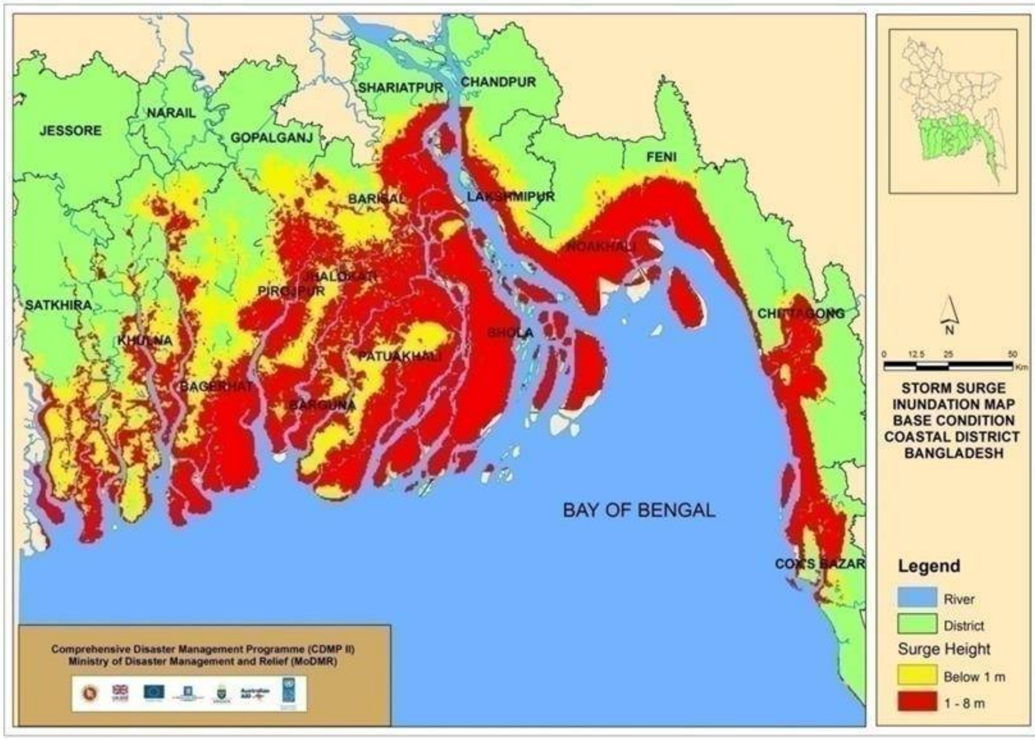

Figure 3.7: Storm surge hazard map showing inundation depth greater than 1m under base condition.

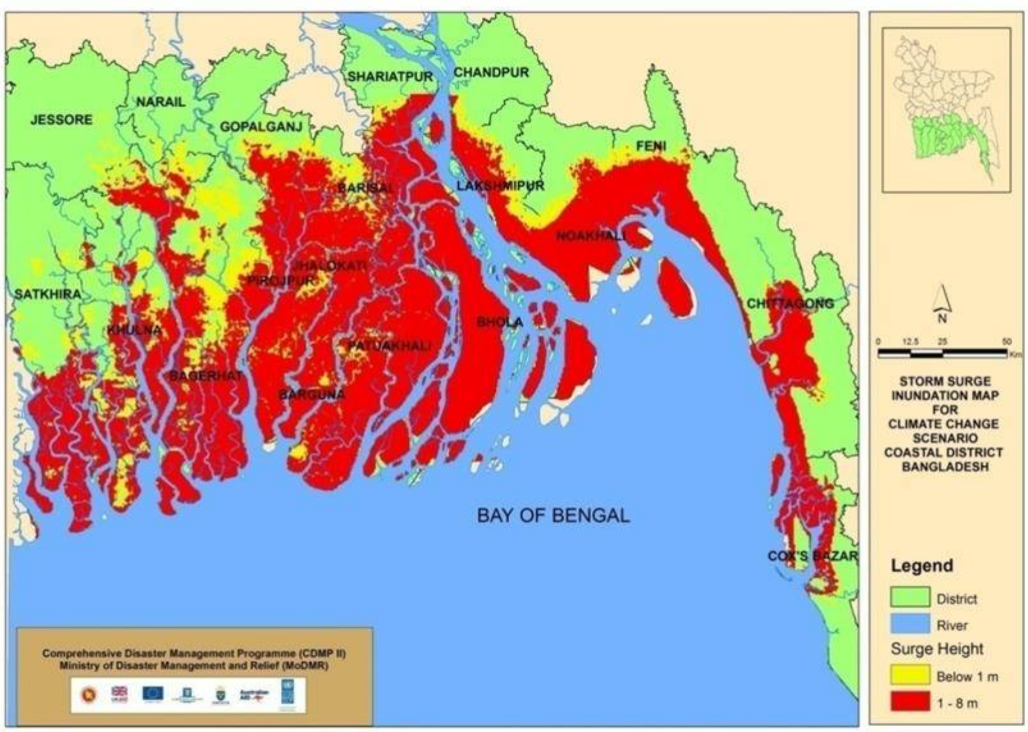

Figure 3.8: Storm surge hazard map showing inundation depth greater than 1m at changed climate in 2050.

Source: Storm Surge Study under MRVA project of DDM (2014)

Under this project storm surge hazard assessment was done for 25, 50 and 100 return periods. In this study the underlying historical data is the same as the study under CDMP (see above). However, five (5) synthetic tracks were considered. As a result a total 48 cyclone simulations were carried out to get a data series for statistical analysis to find return period-wise surge inundation. Maps were prepared for the entire coastal area for all return periods, districts and upazila/union level. No analysis was done at a future point of time considering climate change. Maps for 50 and 100-year return period are given in Figure 3.9and Figure 3.10 respectively. Depth category-wise surge affected areas of the surge affected districts for a 50-year return period cyclone are provided in **Table 3.6**. Division-wise inundation and ranking can be seen in**Figure 3.11**.

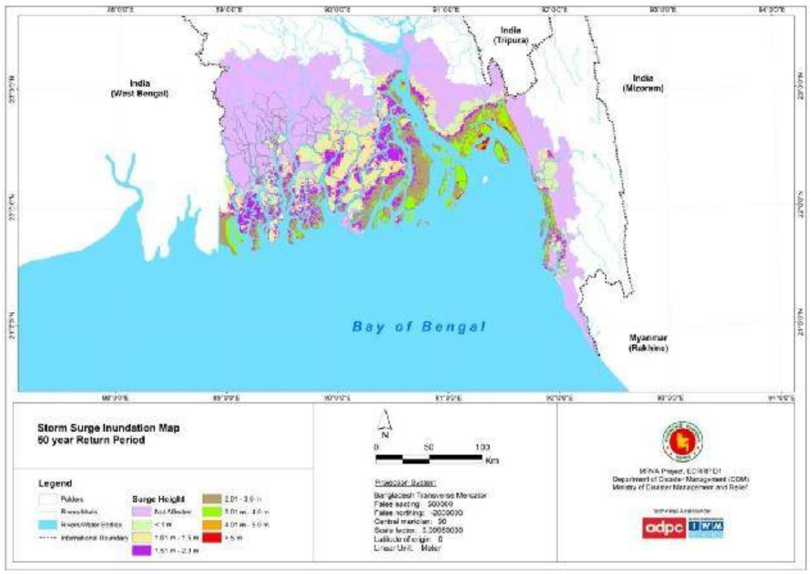

Figure 3.9: Extent and depth-wise category of storm surge inundation at 50-year return period for the coastal area of Bangladesh.

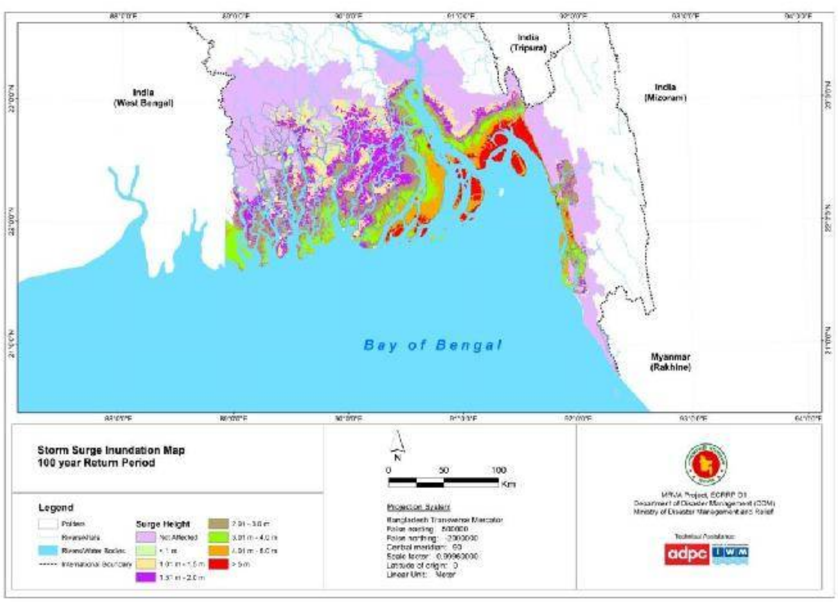

Figure 3.10: Extent and depth-wise category of storm surge inundation for 100-year return period in the coastal areas

Table 3.6: Depth category-wise surge affected areas of the surge affected districts for a 50-year return period cyclone

Divi-sion	District	Dist_area	Area _without _river	Area _not _inundated	% Area _not _inundated	<1m	%	1.01-1.5m	%	1.51-2m	%	2.01-3m	%	3.01-4m	%	4.01-5m	%	>5 m	%	Area _inundated
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Khulna	Bagerhat	4042.73	3496.23	1278.44	36.57	489.87	14.01	511.52	14.63	495.17	14.16	586.88	16.79	118.43	3.39	15.55	0.44	0.39	0.01	2217.79
Khulna	Khulna	4195.72	3354.90	1864.42	55.57	319.61	9.53	415.54	12.39	396.92	11.83	308.57	9.20	44.95	1.34	4.90	0.15	0.00	0.00	1490.48
Khulna	Narail	981.31	981.18	980.54	99.93	0.65	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65
Khulna	Satkhira	3809.12	3249.04	2121.05	65.28	39.07	1.20	177.12	5.45	461.15	14.19	310.58	9.56	131.01	4.03	9.06	0.28	0.00	0.00	1127.99
Barisal	Barguna	1520.71	1213.90	144.45	11.90	256.55	21.13	418.56	34.48	272.36	22.44	112.11	9.24	8.65	0.71	1.17	0.10	0.06	0.00	1069.45
Barisal	Barisal	2546.81	2014.08	571.52	28.38	214.32	10.64	360.83	17.92	436.18	21.66	328.12	16.29	82.64	4.10	19.46	0.97	1.02	0.05	1442.56
Barisal	Bhola	2991.17	1715.84	0.00	0.00	22.70	1.32	51.57	3.01	165.75	9.66	988.31	57.60	372.79	21.73	80.04	4.66	34.70	2.02	1715.84
Barisal	Jhalokati	741.94	655.13	40.16	6.13	151.83	23.17	387.87	59.21	55.52	8.47	18.11	2.76	1.64	0.25	0.00	0.00	0.00	0.00	614.97
Barisal	Patuakhali	3091.08	2199.25	0.00	0.00	117.24	5.33	527.43	23.98	587.89	26.73	678.92	30.87	237.02	10.78	49.74	2.26	1.02	0.05	2199.25
Barisal	Pirojpur	1263.59	1118.10	105.00	9.39	254.64	22.77	488.47	43.69	236.54	21.16	29.07	2.60	4.27	0.38	0.12	0.01	0.00	0.00	1013.11
Dhaka	Gopalganj	1466.21	1459.96	1301.06	89.12	137.93	9.45	19.90	1.36	0.75	0.05	0.33	0.02	0.00	0.00	0.00	0.00	0.00	0.00	158.91
Dhaka	Shariatpur	1242.95	1189.33	943.13	79.30	34.13	2.87	68.76	5.78	68.66	5.77	50.48	4.24	18.84	1.58	4.52	0.38	0.80	0.07	246.20
Chitta-gong	Chandpur	1701.62	1589.69	1470.17	92.48	30.49	1.92	13.74	0.86	12.39	0.78	23.85	1.50	29.96	1.88	8.08	0.51	1.01	0.06	119.51
Chitta-gong	Chitta-gong	4704.07	4347.12	2834.97	65.21	351.58	8.09	179.30	4.12	112.09	2.58	231.88	5.33	447.52	10.29	118.64	2.73	71.15	1.64	1512.15
Chitta-gong	Cox's Bazar	2195.27	2068.87	1374.66	66.44	179.37	8.67	135.10	6.53	148.70	7.19	179.55	8.68	46.71	2.26	4.79	0.23	0.00	0.00	694.22
Chitta-gong	Feni	917.55	898.36	539.02	60.00	103.55	11.53	51.14	5.69	46.62	5.19	53.87	6.00	58.82	6.55	28.80	3.21	16.53	1.84	359.34
Chitta-gong	Lakshmi-pur	1413.25	1199.39	498.21	41.54	210.59	17.56	187.79	15.66	133.19	11.10	98.97	8.25	38.84	3.24	20.06	1.67	11.75	0.98	701.18
Chitta-gong	Noakhali	2944.11	2393.12	846.68	35.38	272.52	11.39	104.04	4.35	108.48	4.53	386.91	16.17	502.94	21.02	97.99	4.09	73.59	3.07	1546.45

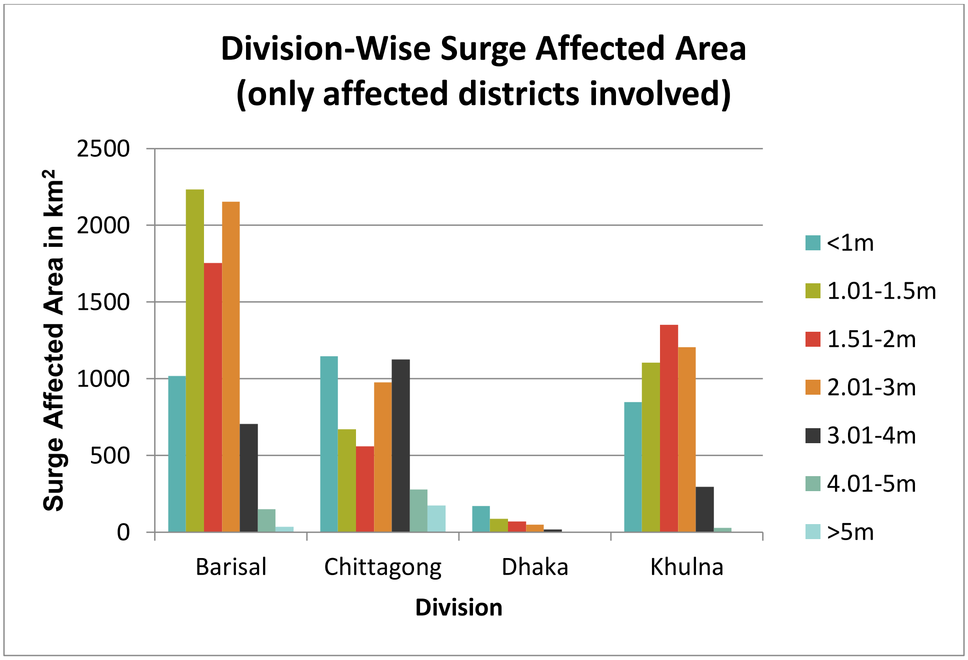

Figure 3.11: Bar-graph of inundation depths for four divisions

3.2.2. Disaster Management: Issues: What Can Be Done

Cyclone Shelters

Number of shelters: In the past by a committee headed by Prof. J. R. Chowdhury a target was set to construct 5000 shelters in the coastal districts. So far around 3739 (in Khulna and Barisal division 1741, in Chittagong 1998) were constructed (source: CDMP, 2013). The current information is that shelters are being constructed phase by phase. However, more number of shelters than this set 5000 can be built in future for coping with the population growth and community need.

Distribution of shelters: Attention should be given to areas with no shelter, or in areas where shelters are sparse. Also, with the population growth there may be more shelters necessary than those targeted.

Shelters with commercial benefit: Multipurpose multi-storied shelters can be built in bazars, hut ie, common place for community. Ground floor can be used for shops. Upper floor(s) should be built open. They can be built on khas land, shops can be leased.

Shelters with mosque: Not everywhere, but in some strategic location in case of foreign aided mosques, multi-storeyed mosque can be built keeping lowest/top floor reserved for mosque, upper one as shelter or vice versa.

Toilet and water supply facilities. Shelters made earlier were without toilet facilities. However, shelters constructed later particularly after Sidr, and after the policy had been made in 2011,were built with toilet facilities. But the number of these facilities may not be adequate.

Security at shelters and killas: The security of the sheltered people needs to be ensured. The fact finding workshop (see Annex A)emphasized the security of the shelters with respect to theft, robbery, or any other event concerning security of people. The workshop suggests that police stations must be vigilant.

Cyclone Resilient Houses

Current status: Fewer than 2 projects (see below) in connection with 3 cyclones (Sidr in 2007, Aila in 2009 and Mahasen in 2013) cyclone resilient houses have been built and shall be built in near future. These houses were constructed for very poor people with plinth area around 150 sft. More such houses should be built.

- *Construction of cyclone resistant houses for AILA affected people in Barisal and Khulna division*. Period: Apr 2010-Mar 2012, and Oct 2012-Dec 2014. Number of houses completed: 4006. Unit cost: BDT 1, 83,540.00 (USD 2295). Plinth area: 150 sft.
- Planned Project: *Construction of Disaster Resilient Shelters for cyclone MAHASEN affected People in BARGUNA District.* Period: Jan 2015-Jun 2016. Number of houses: 570. Estimated unit cost: BDT 4, 35,000.00 (USD 5437.00).

Since worst sufferers are the segments of people who are socially and economically very disadvantaged, such housing projects with proper design and landuse should continue.

Funding: In the past, cost for cyclone resilient houses came from climate change fund. In parallel to this source, government now plans to allocate fund from development budget. It is known that DPP is being formulated.

Design: Design must be hazard specific. For example, flood resilient and cyclone resilient houses should not be the same design. Likewise, in areas under potential threat of earthquake hazard buildings must be earthquake resilient.

Cyclone Preparedness Programme (CPP)

Current situation:CPP has been working for more than 40 years with good stability. After Sidr and Aila, its services got extended to 3 more south west coastal districts – Bagerhat, Khulna and Satkhira. CPP also rendered extensive support to CDMP and its strength in manpower, equipment and services. Now the project actually needs continuous training, regular repair and maintenance of equipment, also permanent fund flow to provide effective services. Detail about this organization has been given in Sec 2.3.3.

Coastal Polders

Currentlythere is more than 5000 km of coastal embankment in 139 polders. Usually they suffer faulty construction and in many cases; height, bed-width, slopes, soil condition are neither adequate nor properly maintained. Moreover, there are holes, undulations, breaks, trenchesetc in addition to illegal occupants. As such they are vulnerable to breaching. In polder areas, crop damage and many casualties occur by breaching the embankments, particularly for estuary and large rivers during cyclones. In view of these, some suggestions are given below:

- **Vegetation strip is a must:** Keeping adequate land-strip on both sides, particularly the outward sea/river side. Dense vegetation layer must be built so that whirlwind is weakened, and the surge is greatly diminished and stopped.
- **Keeping adequate mild slope is a must:** This will provide good stability of embankment and surge protection. Dense vegetation must be grown with local bushy herbs and trees. The outward sea have firm roots. Not planting with trees that uprooted easily.
- **Monitoring weakness of polders :** Must be done
- **Maintenance budget:** Maintenance budget should be provided with accountability to the authority.

A note on vegetation type: Trees and bushes act as a barrier for cyclone wind, coastal surge, and torrent water of flood. But tree must be bushy type and firm-rooted. Vegetation should not be done with trees that spread widely over large areas on roads, embankments and easily uprooted, or branches broken and fallen by winds.

3.3. Drought Hazard

Defining drought in a straight way is somewhat difficult. It depends on the water availability in an area that is required by animals to survive and by plants to grow, live, flourish and give production. Mainly it is looked from the view of agriculture, meaning whether agricultural production suffers. It is usually defined as shortage of water availability for an area caused due to having lower than average amount of rainfall on that area over an extended period of time. When it comes with severe effect on agriculture it comes as a hazard.

There are a variety of drought-hazards, such as:

a) Meteorological drought: It happens when the amount of precipitation is much lowerthan the normal level
b) Agricultural drought: It manifests the deficiency in soil moisture to meet the need for crops in an area, but it depends on the type of crop. If occurs during and just after meteorological drought.
c) Hydrological drought: It manifests the shortage of surface and groundwater supplies. Stream flow and ground water table are the respective measures of this kind of drought. It occurs after a considerable time of meteorological drought.
d) Socioeconomic drought: Shortage of water availability in an area when starts to affect health, well-being and quality of life of people, or when the production is affected.

However, the later three kinds of drought are caused from the meteorological drought.

3.3.1. Past Studies

Drought Hazard Assessment under MRVA Project (DDM, 2015)

This study set a number of objectives: to understand spatial characteristics of drought in different cropping seasons – Pre-kharif, kharif and rabi, to study return periods of droughts of different severity during different cropping pattern, to identify drought prone areas of Bangladesh.

Drought is a very recurrent hazard in Bangladesh, particularly in northwest hydrological region in Bangladesh. From 1960 there were a number of remarkable droughts that occurred in the years 1960, 1966, 1968, 1973, 1977, 1979, 1982, 1989, 1992, 1994-95, 1999, and 2006. The famine stricken year 1974 was partly caused by the drought in 1973.

From climatic point of view there are 4 seasons in Bangladesh (Rashid, 1991). (i) pre-monsoon season from March to May (ii) monsoon (rainy) from June to early October (iii) Post monsoon from mid-October to November (iv) winter season (dry months) from December to February. The main cause of monsoon rainfall is the formation of tropical depression in the Bay of Bengal and their movement towards north,further which, it is obstructedby the hills and ranges in the north beyond Bangladesh. Spatial distribution of rainfall from data period from 1958-2009 across the country is seen in**Figure 3.12**. Around 80% rainfall occurs in the monsoon season. Monthly distribution of rainfall is shown in**Figure 3.13**.

The mean temperature in winter lies between 17 and 20°C, extreme low temperature falls as low as 7°C in winter and rises from 26.9 to 31.1°C in summer; the extreme temperature even goes up to 45°C. It is to be noted that both extremes – low and high – occur in the northwest region of Bangladesh. The highest humidity occurs in the month of September, lowest in March, when the mean values ranges from 70.5 to 78.1%. Dryness study as carried out using methods of Martonne Aridity Index and Thornthwaite Precipitation Effective Index taking 20 years data from 1980-1999 on 50 meteorological stations in and around the country (Shahid et al, 2005). Both indexes indicate that northwest region falls in the category of sub-humid and the central part as humid.

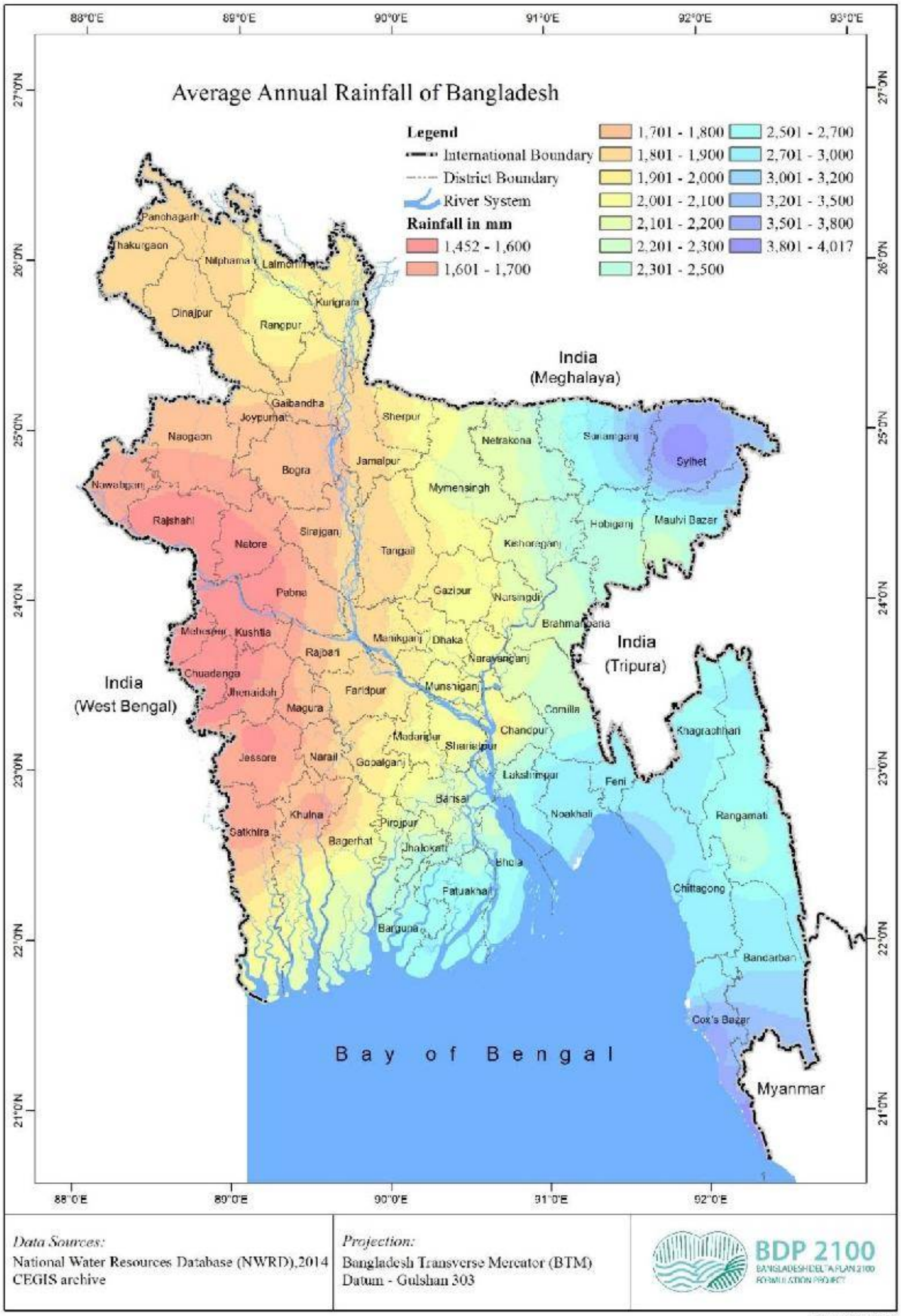

Figure 3.12: Spatial distribution of rainfall analysed from data across the country 1958-2009

Source: DDM

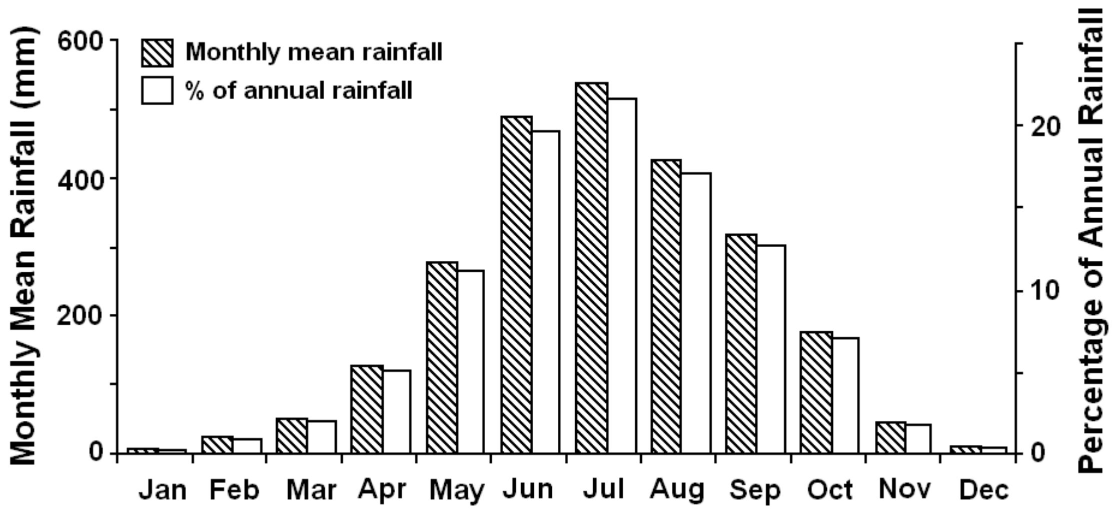

Figure 3.13: Monthly mean rainfall and percentage of annual rainfall

Cropping season: There are two main seasons with respect to crop production – kharif and rabi. However, there is a transitory period when some varieties of crops grow; this season is called pre-kharif. Kharif crops grow in moist soil or soil with wet/inundated with water. As a result it starts from the beginning of the rainfall and its duration is from October toNovember. The main crops grow in the kharif season are Aus, transplanted Aman, broadcast Aman, jute, different types of summer vegetables. The duration of rabi season starts from October/November (much less rainfall ie, nearly end of humid period) and lasts to starting of pre-kharif season. A normal crop calendar for Bangladesh is shown in**Figure 3.14.**

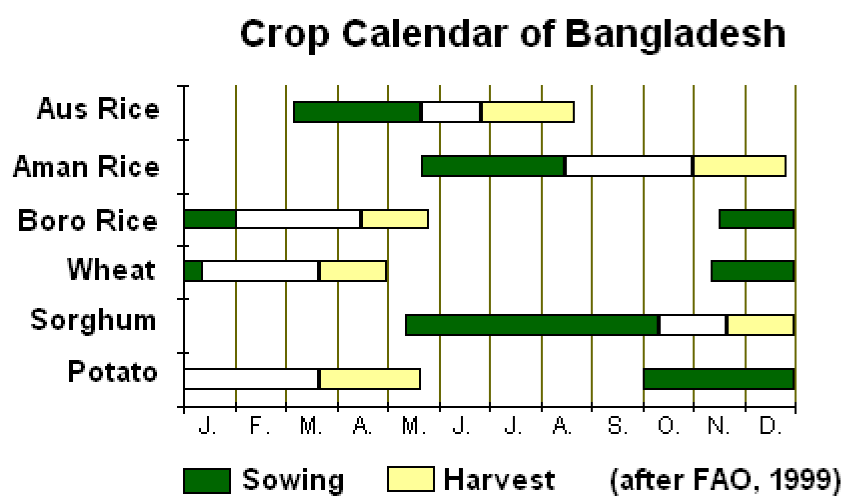

Figure 3.14: Crop calendar of Bangladesh (DDM, 2014)

As drought cannot be forecasted directly, an indirect way characterization of drought is expressed by various drought indices. For meteorological drought, as is the case of DDM study (2015), common indicators of drought include meteorological variables (precipitation, evaporation), hydrological variables (stream flow, ground water levels, reservoir and lake levels, snow pack, soil moisture etc.). There are a number of indices to characterise droughts. For example, percentage of normal method, precipitation- decile method, Bhalme-Mooley drought index method,standardized precipitation index (SPI)method. SPI is better able to show how drought in one region compares to drought in another region. So this study used SPI to find temporal and spatial characteristics of meteorological drought inBangladesh. (SPI is widely used and based on probability of precipitation of multiple time scales, for example one-month, three-month, six-month, nine-month, twelve-month etc,**Table 3.7** (Mckee et al, 1993).

Table 3.7: Drought categories as defined for SPI values (Mckeet et al, 1993)

Sl. No.	SPI Value	Drought Category
1	0 to 0.99	Near normal or mild
2	-1.00 to -1.49	Moderate
3	-1.50 to -1.99	Severe
4	-2.00 and less	Extreme

In the DDM study (2015), SPI has beencategorized into ten subclasses, given in **Table 3.8**.

Table 3.8: Drought categories as defined for SPI values (DDM, 2015)

Sl. No.	SPI Value	Drought Category
1	0.0 to 0.49	Normal condition
2	-0.5 to -0.99	Near normal
3	-1.00 to -1.24	Low moderate
4	-1.25 to -1.49	High moderate
5	-1.50 to -1.74	Low severe
6	-1.75 to -1.99	High severe
7	-2.00 to -2.24	Low extreme
8	-2.25 to -2.49	High extreme
9	-2.5 to -2.74	Low-extraordinary
10	-2.75 or less	High extraordinary

In this project drought events (hazard assessment) was done for time steps of 3, 4, and 6 months. SPI values were computed accordingly at the end of different climatic and cropping seasons to understand the frequency of occurrence in each season. Drought for a particular season in a year is a single event and is independent of other years. For different rainfall stations SPI time series curves are given for 6-month time steps in **Figure 3.15**.

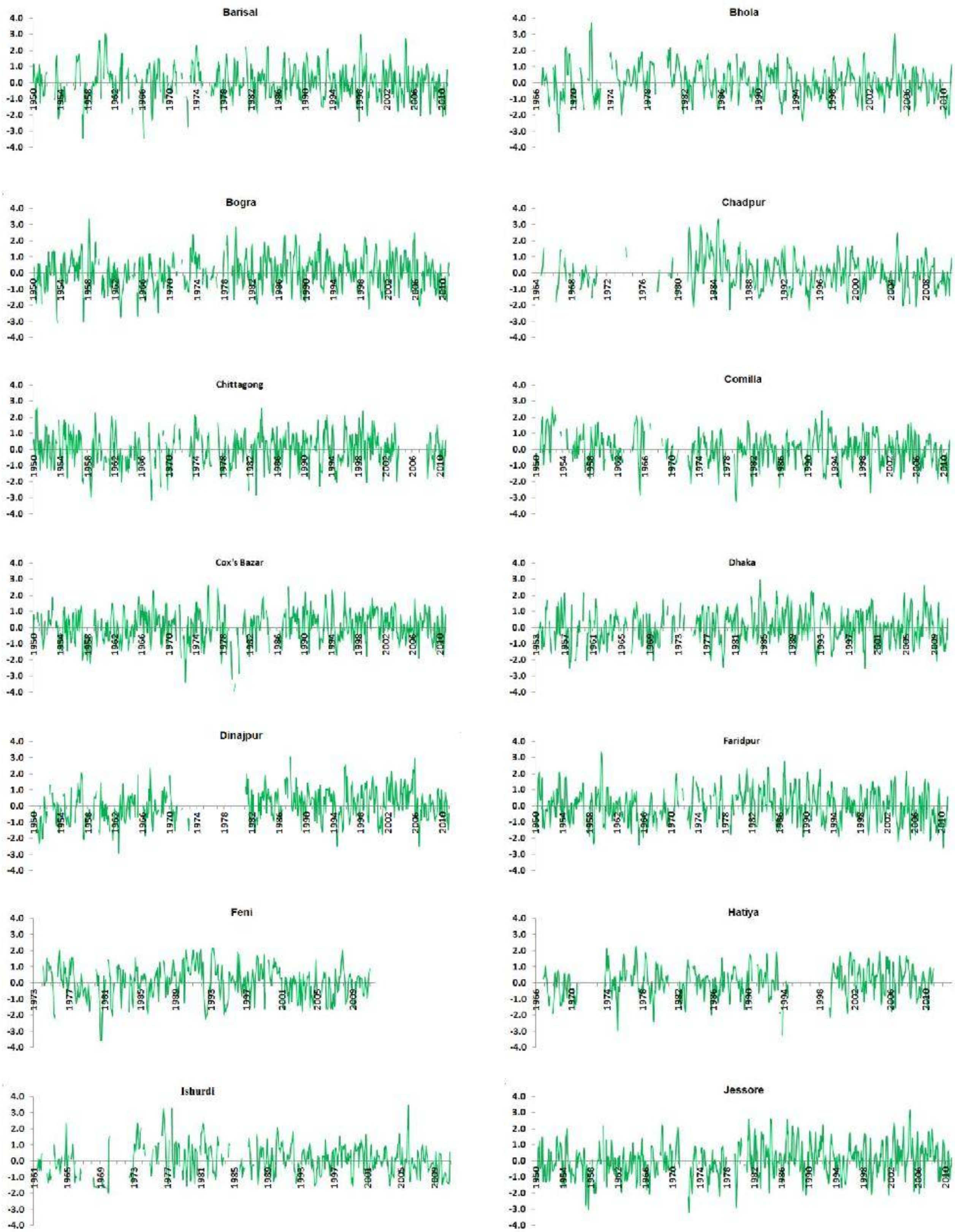

Figure 3.15: SPI time series for 6-month period at different rain gauge locations

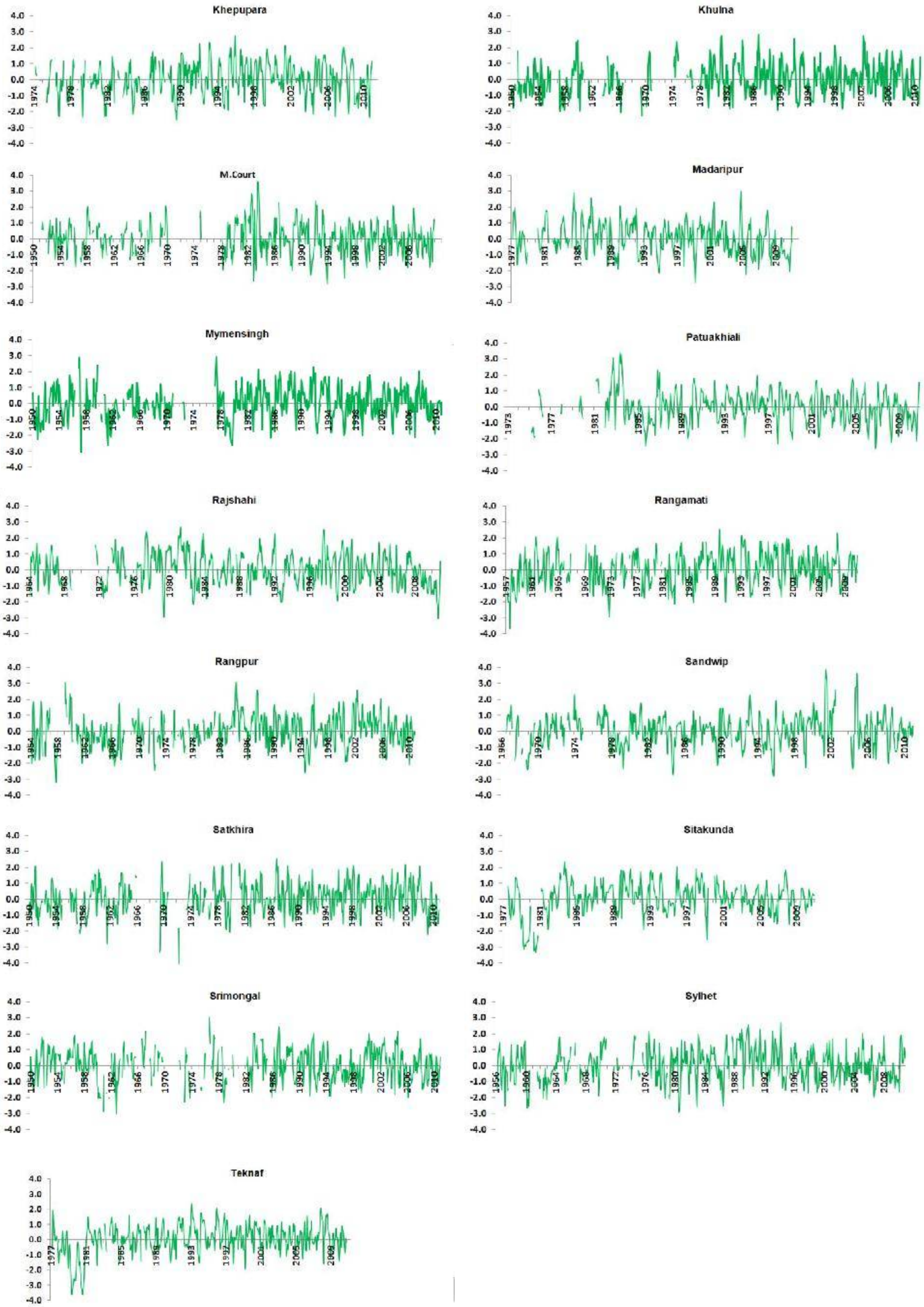

Figure 3.15 (cont'd): SPI time series for 6-month period at different raingauge locations

Figure 3.15 above shows historical occurrences of drought events in different years at different raingauge locations in Bangladesh. It is seen that drought at local scale is common. Across Bangladesh major drought events happened, for example, after liberation of the country; in 1973, 1977, 1977, 1982, 1989, 1992, 1994, 1999, 2006.

Drought hazards have been investigated basing on the frequency of events for each drought types for various cropping seasons. SPI values were computed on the last month of each cropping season meaning that rainfall deficit was over for the whole season. For example, 6-month SPI was computed at the month of October for understanding of drought characteristics for Kharif. Cropping seasons, duration and month of SPI calculation are given in**Table 3.9**.

Table 3.9: Cropping seasons, duration, month of SPI calculation etc.

Cropping seasons	Duration	Duration of SPI comp.	SPI for Month
Kharif	May-October	6-month SPI	October
Pre-kharif/pre-monsoon	March-May	3-month SPI	May
Monsoon	June - September	4-month SPI	September
Winter	December – February	3-month SPI	February
Robi	November – April	6-month SPI	April

In the MRVA study drought hazard was assessed return period-wise for 10, 50, and 100-year for all cropping seasons using corresponding SPI values. As can be seen in Table 3.8the severity of drought can be identified from SPI values. A detail table containing SPI values for29 locations (stations) for all cropping seasons is given in Table B.4 in AnnexB for all return periods.

Drought Maps

GIS was used in spatial modelling of drought hazard assessment. The study made drought maps for all return periods and for all cropping seasons. Meteorological droughts for pre-monsoon (March – May) is given in Figure 3.16 below. Drought maps for other cropping seasons are given in FiguresB.1 and B.2 in Annex B.

Pre-monsoon drought It is seen from Table 3.9of pre-monsoon drought that 10-year return period drought with lowmoderate intensity prevails in northwest region, from 50-year map low extraordinary drought may occur in the same region; the rest of the country drought situation may be of some types ranges from high severe to high extreme. But for 100-year case, extraordinary situation may prevail in large part of the country. Obviously, coastal areas are less prone to 100 year drought. In overall consideration, for pre-monsoon drought is more intense in northwest region than any other parts of the country.

Monsoon drought: Similar drought maps have been prepared for monsoon and dry seasons and given in Annex B (Figures B-1 and B-2). From Figure B-1 for a 10-year return period, high moderate monsoon drought prevails in the northwest region, while it is low moderate for the rest of the country. Likewise, for 50 and 100-year return period the severity pattern is similar in that the more the south and southeast the less is the severity. However, in case of 100-year, most part of the country may undergo a drought of extra-ordinary intensity. Since the major portion of the yearly rainfall occurs in monsoon,the deficit of rainfall shall affect the economy of the country from agricultural production. It has implication particularly in northwest region.

Winter drought: (Figure B.2 in Annex B) For a 10-year return period, low moderate in the northwest, but either normal or near normal drought condition for the rest of the country. But in case of 50-year return period, moderate to severe drought happen for the most parts of the country. For 100-year,extremes and severe condition prevail in the north eastern parts, and generally speaking, starting from northeast, the severity of drought increases more towards the southwest.

Figure 3.16 a: Meteorological droughts for pre-monsoon for 10-yr return period (March–May)

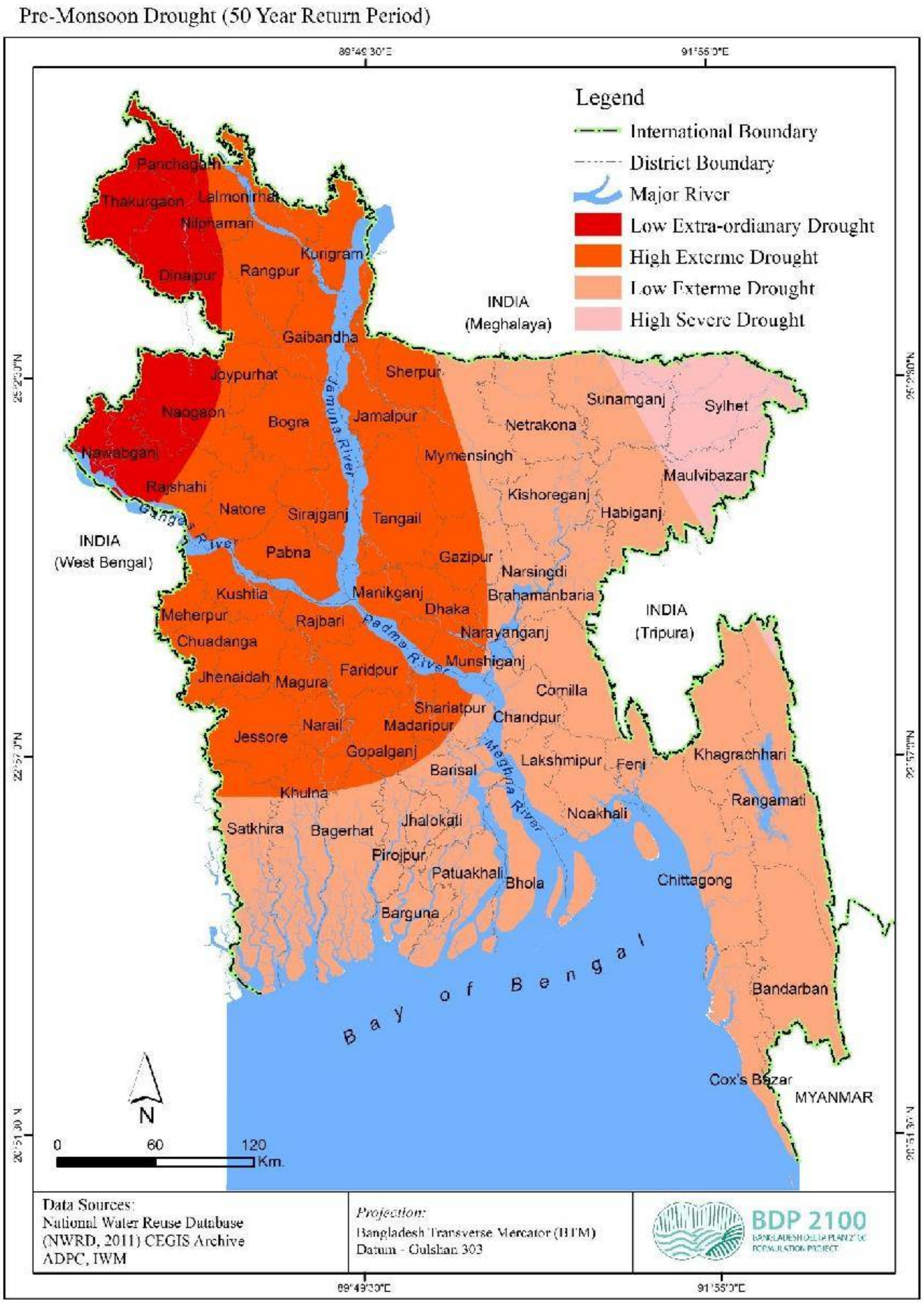

Figure 3.17 b: Meteorological droughts for pre-monsoon for 50-yr return period (March–May)

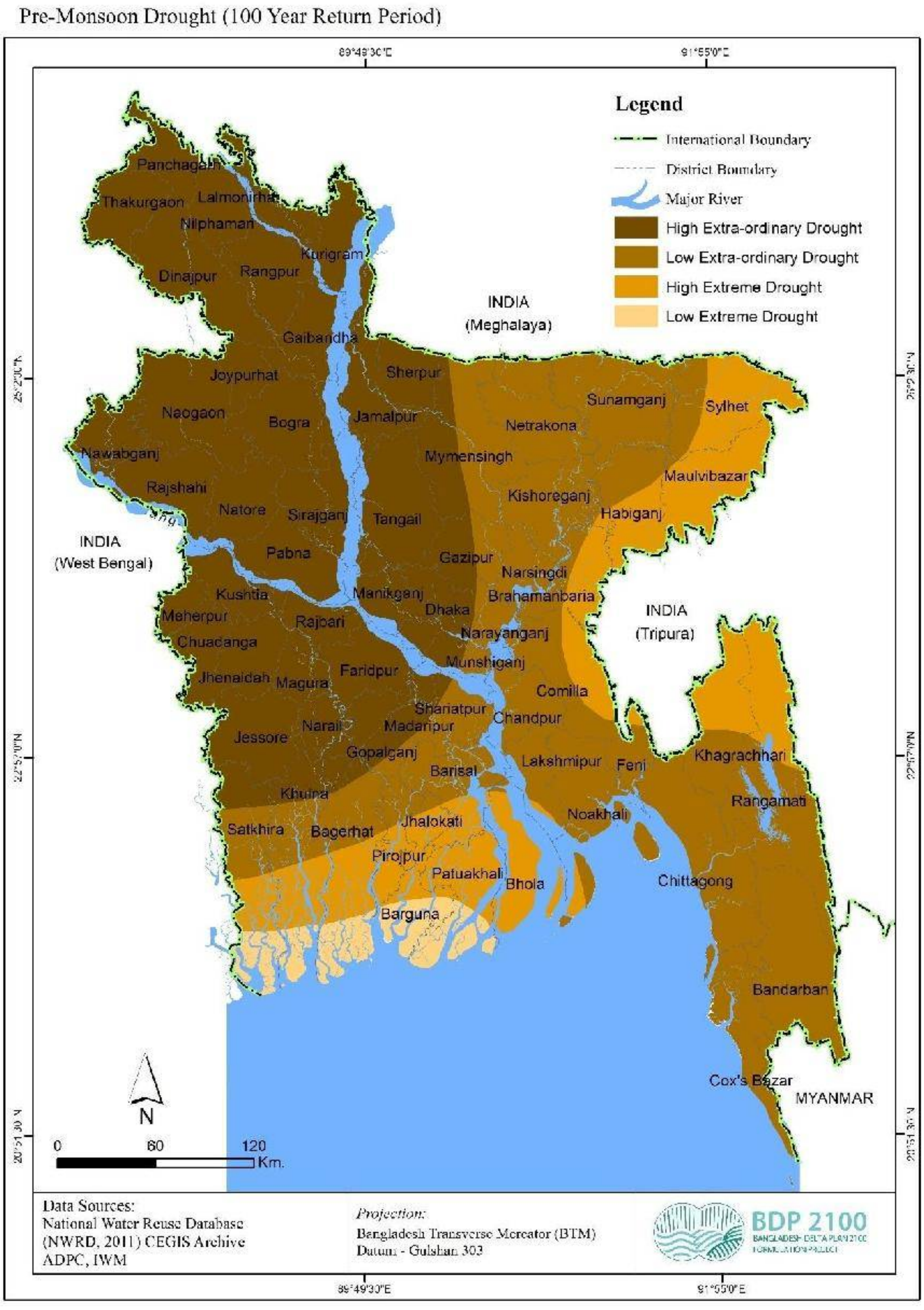

Figure 3.18 c: Meteorological droughts for pre-monsoon for 100-yr return period (March–May)

Drought during pre-Kharif: Pre-kharif season coincides with pre-monsoon; hence it may be referred to the description given in pre-monsoon drought.

Drought during Rabi: 10-year drought with low moderate and near normal for almost allover the country, while 50-year drought as low extraordinary in the northwest. In case of 100-year drought is wide-spread across the country, high extraordinary drought may occur north, northwest and central parts in the country.

Characterising drought by comparing rainfall map, drought map from SPI values and NDVI during kharif season

During kharif season from May to October analysis of rainfall data for the years 2005 (not drought year), 2006 (drought year, as SPI indicated), and 2007 (not drought year) rainfall maps were prepared. SPI were computed for these years. Time series of NDVI (normalized difference vegetation index – a remote sensing based index) for the said period were prepared. Also NDVI deviation maps were prepared by taking difference between NDVI for a particular month and mean-monthly NDVI (data from 2001 to 2012). NDVI deviation maps did not show any much abnormal drought condition. It appears that NDVI may not be a good indicator for showing drought. It is known that NDVI has a lagged response to drought. Also, there is a huge irrigation practices in 11 districts in northwest and south west region.

A brief summary on drought from this study

- depending on climatic and cropping seasons drought have their own characteristics
- during monsoon spatial distribution of droughts varies widely with severity
- droughts in kharif and rabi season are more intense and frequent in northwest region
- during winter drought is more intense in northeast region
- In general and in overall consideration, northwest region experiences more severe drought, hence more vulnerable areas to drought hazard

Past Study on Vulnerability to Climate Induced Drought: Scenario and Impacts by CDMP II, 2014

Climate Change in Bangladesh

(Detail on climate change is given under the Baseline Report on Climate Change)

Temperature: The analysis on the data of BMD over 32-year period from 1977 to 2008 showed a rise of temperature by 0.016 °C/year, 0.02 °C/year and 0.012 °C/year for mean annual temperature, mean maximum temperature and mean minimum temperature respectively.

For mean annual temperature, statistically rising trend was found in 19 stations out of 31 stations. For minimum and maximum temperature, rising trend was found for 17 stations out of 31 stations.

Projection on temperature and rainfall: Two future projections (taking emission Scenarios A2 and B1) in 2030 and 2050 were developed for these two climate parameters. Results are given in Table.3.10

(Note: A2 and B1 are two of the parameters under climate change 'gas emission scenarios', as dealt in the IPCC Third Assessment Report 2001 (TAR), have been superseded by a new set of parameters – 'gas concentration trajectories' – better known as Representative Concentration Pathways (RCPs); detail may be referred to the Baseline Report on Climate Change).

Table 3.10: Emission based future projections on change of temperature and precipitation at national scale (CDMP II, 2014)

Emission Scenario	Temperature change by °C		Precipitation change by %	
	2030	2050	2030	2050
A2	0.73	1.32	4.9	8.1
B1	0.78	1.62	6.3	8.4

Drought vulnerable hot spot: Seasonal drought-prone areas were identified and ranked upazila-wise based on drought map by BARC (2000). Ten most drought affected upazila are listed in the following in Table 3.11.

Table 3.11: Top ten drought affected upazilas

District	Upazila	Vulnerability ranking			Combined rank	Severity ranking
		Rabi	Kharif 1	Kharif 2		
Naogaon	Niamatpur	7	5	3	15	1
Rajshahi	Tanore	6	2	11	19	2
Chapai Nawabgang	Nachole	9	7	4	20	3
Naogaon	Porsha	4	3	16	23	4
Naogaon	Sapahar	5	4	17	26	5
Thakurgaon	Baliadangi			30	30	6
Dinajpur	Hakimpur	18		12	30	7
Naogaon	Patnitala	12	18	1	31	8
Chapai Nawabgang	Shibganj	11	8	14	33	9
Joypurhat	Panchbibi	36		2	38	10

Drought severity analysis through reduction of crop yield: In this study drought severity was classified following crop yield reduction for some crops. Simulations of crop yield were done for some selected crops – BR 11 (Transplanted Aman), BR14 (Boro Rice), and BRRI Dhan 29 (Boro rice) considering two emission scenarios – A2 and B1 in years 2030 and 2050. Drought severity map for BR11 is seen in Figure 3.17. The study took the base year as average condition over the duration 1979-2008. As found in the study there was an overall decrease in production ranging from less than 10% to greater than 40% with respect to base year for BR11 and BR14. But this reduction is in the range from less than 10% to 30-40% for BR29. The drought severity was classified as in Table 3.12. Scenario-wise yield reduction at projected year 2030 and 2050 for different places in Bangladesh is given in Table B.7under AnnexB.

Table 3.12: Drought classification following reduction in crop yield from simulation of crop system model (CDMP II, 2014)

Crop Yield Reduction (%)	Drought Classes
<10	Very slight
10-20	Slight
20-30	Moderate
30-40	Severe
>40	Very severe

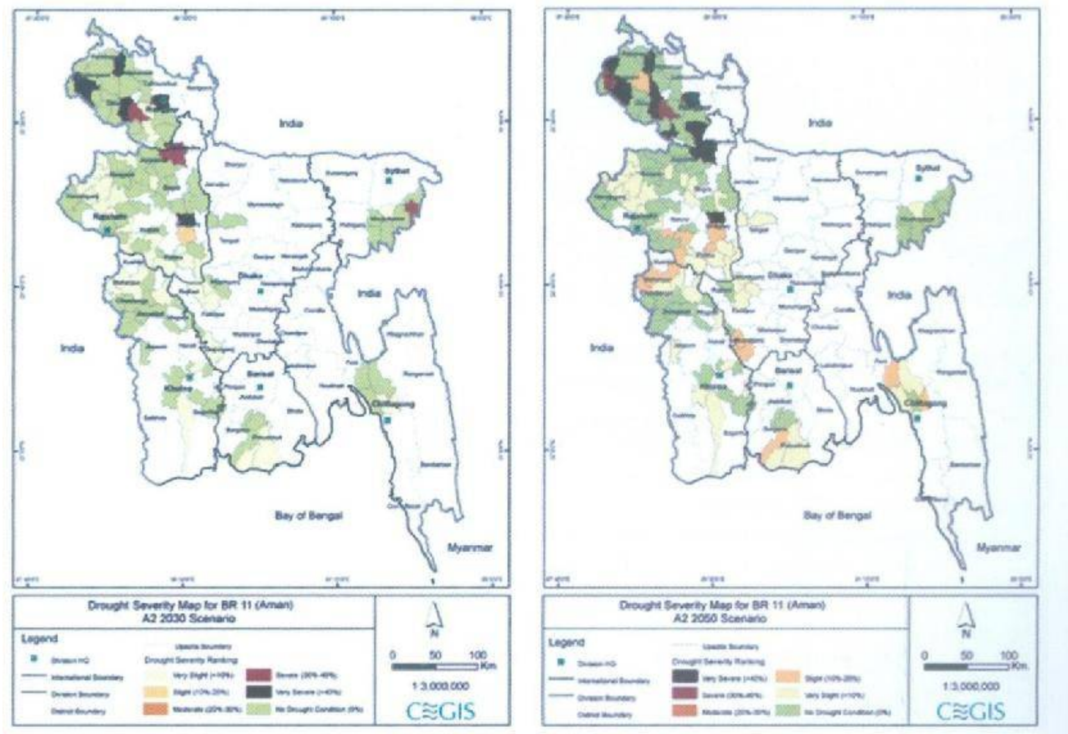

Figure 3.19: Drought severity map for the crop BR11 (Transplanted Aman) under scenario A2 with projection in 2030 and 2050 (CDMP II, 2014)

Adaptation Options to Drought Hazard

The study (CDMP II, 2014) proposed an adaptation option framework which consists of five components. They are:

1. Selecting options based on local knowledge and existing studies
2. Going for location-specific potentially suitable options
3. Prioritization and validation of adaptation options by ground-truthing
4. Review and feedback from relevant organization and government bodies
5. Sharing of knowledge and information in order to develop a National Drought Information System

Adaptation Levels (Stages) and Measures for Drought Hazard

Adaptation measures have been categorized into 3 levels in this study –

1. Farm level adaption measures
2. System level adaptation measures
3. Planning level adaptation measures

Salient features of farm level adaptation measures:

- Adoption of heat, shock and drought resistant varieties of crops
- Probable change from Boro rice to wheat/maize or other less water-demanding crop
- Mulching
- Topsoil tillage
- Modification of crop calendars, that means timing and location of cropping activities following water stress (keeping attention to livelihood option)

Salient features of system level adaptation measures:

- Modification of irrigation technique – timing, amount and technology (shifting to drip irrigation)
- Optimum use of surface, rain and ground water
- Adopting techniques for holding soil moisture (for example, crop residue retention)
- Optimum use of rain, surface and groundwater
- Surface water retention by digging pond
- Application of local organic matter
- Water retention in crop field

Salient features of planning level adaptation measures:

- Government support to farmers if any major crop failure happens, for example price subsidies, food for work programme, credit etc. at least to next crop harvest
- Government may support in exceptional drought years, that means, for example, 5, 10 or more year return period
- Land type selection and crop zoning
- Organised seed production and supply system
- Empowering local government or any local body to allocate water in zones of scarcity

Monitoring Protocol in Drought Management

The study proposed a national drought information system that conceptually has following components

- Data dissemination in community level
- Drought monitoring network
- Central drought information database
- Technology and data transfer network

3.4. Earthquake

3.4.1. Past Studies

Risk Assessment of Dhaka, Chittagong and Sylhet City Corporation Areas (under CDMP I)

Seismic risk assessment of the buildings, essential facilities and lifelines were presented in this study. The study based on GIS database that were developed from existing secondary data and field survey data at Dhaka, Chittagong and Sylhet. The study forecast on potential damage, human and economic impact. HAZUS software package were used as model simulation of earthquake. The assessment methodology used interdependent modules in the package that are (1) potential earth science hazard assessment (2) inventory of buildings, essential facilities and lifelines (3) direct physical damage calculation (4) induced physical damage calculation, and (5) direct economic and social loss. Some information regarding buildings, population are given in**Table 3.13**.

Table 3.13: Salient features of the cities used in the HAZUS model

Items/Features	Dhaka	Chittagong	Sylhet
Ward	91	41	27
Cluster (smaller units in a ward)	552	285	82
Buildings estimated	326000	182000	52000
Replacement value of buildings	16759	3400	940
Population (million)	7.2	2.3	0.4

Five earthquake scenarios were investigated. Three scenarios were from seismic hazard deterministic analysis (2from 5 fault model, 1 resulted from TAG recommendation,that with earthquake moment magnitude 6.0, there is potentialfor earthquake to happen beneath each city). Twoanalysed scenarios (4 and 5) with Seismic Hazard Probabilistic Analysis were carried out, where scenario 4 and 5 were applied for Sylhet, and scenario 4 for Dhaka and Chittagong. From the overall analysis for Dhaka city the worst case scenario was scenario 4; for Chittagong and Sylhet it wasscenario 1 and 5. Loss and damage statistics for the worst case scenario are given in the following **Table 3.14**.

Table 3.14: Loss and damage statistics for the worst case scenarios for Dhaka, Chittagong and Sylhet City Corporation(tabulated from Ansari, 2014)

Items/Features	Dhaka	Chittagong	Sylhet
Buildings (at least moderately damaged)	270604 (83%)	168150 (92%)	51858 (99.5)
Buildings (damaged beyond repair)	238164	142855	50879
Lifeline systems (major highway bridges)	10	4	2
Potable water facilities (at least moderately damaged)	748	72	18
Gas compressor stations (at least moderately damaged)	7	22	1
Electrical power facilities (at least moderately damaged)	54815	28407	9057
Leak and break for water pipeline	1016	727	122
Leak and break for gas pipeline	684	229	97
Debris (million tons)	72	17	5
Triggered ignitions	107	36	13
Hospital bed (before earthquake)	59849	21664	8722
Hospital bed (after one day of earthquake) available for patients already in hospital and for earthquake injured	7441 (12%)	923 (4%)	17 (0.2%)
Fatalities (if occurs at 2.00 am)	260788	95183	20708
Fatalities (if occurs at 2.00 pm)	183450	73213	14276
Estimated economic loss in million dollars (wrt building)	15603	3112	1105
Estimated economic loss in million dollars (wrt lifeline)	364	244	117

Post ground acceleration (PGA) at ground surface for all five scenarios of earthquake for Dhaka, Chittagong and Sylhet is shown in **Figure 3.20.**

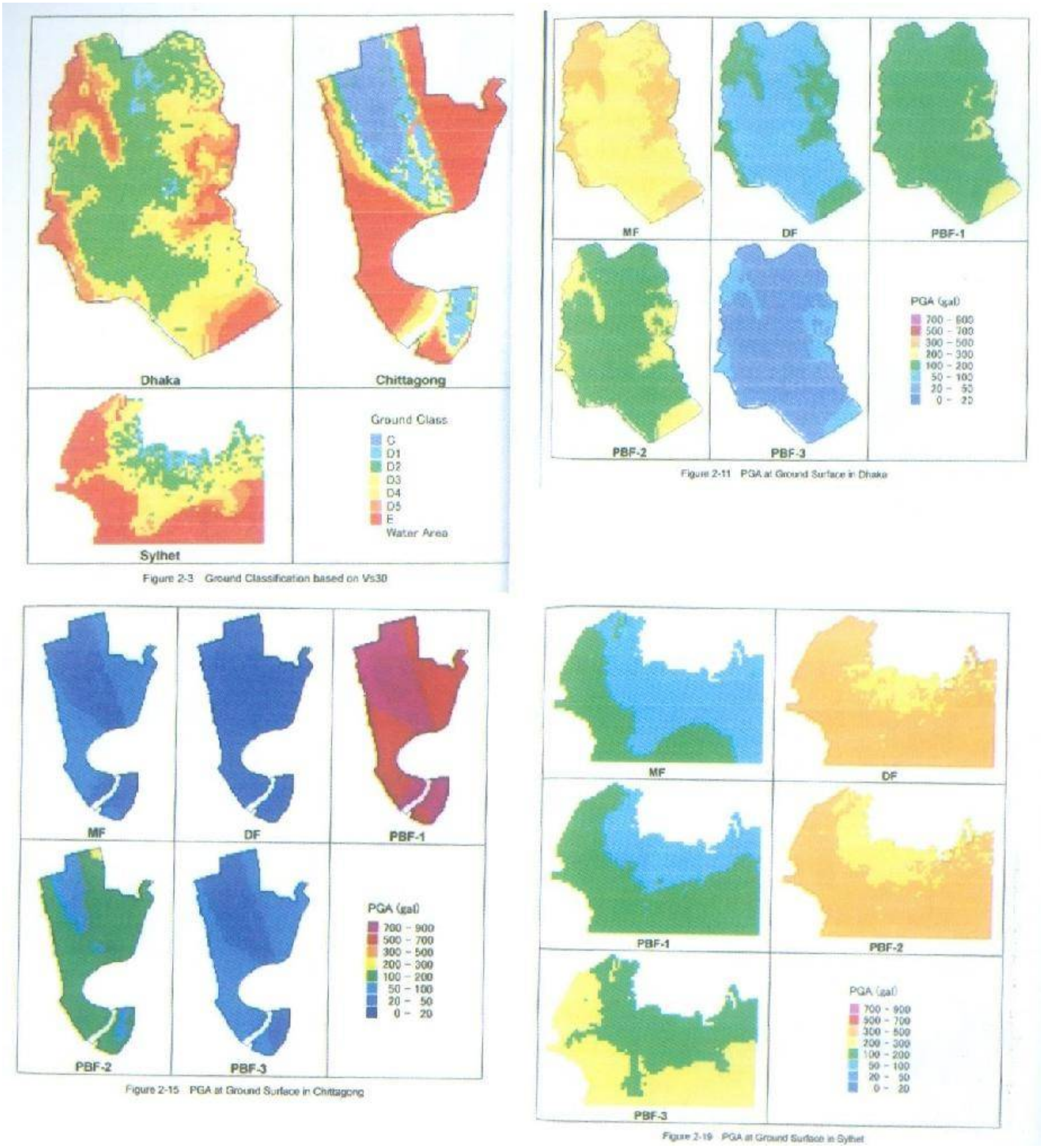

Figure 3.20: Post ground acceleration (PGA) at ground surface for all five scenarios of earthquake for Dhaka, Chittagong and Sylhet

Past Study: Seismic Hazard and Vulnerability Mapping for Rangamati, Bandarban and Khagrachari municipality

This study was done under 'The Earthquake Risk Reduction and Recovery Preparedness Programme' (ERRRP) with the financial assistance from the government of Japan through UNDP/BCPR in 2007-09. The objectives of the study were as follows:

- to prepare regional and local fault maps
- to prepare seismic hazard maps for the three municipal areas
- to prepare seismic vulnerability and risk maps for critical infrastructure for three municipal areas

- to prepare engineering geological maps for the three municipal areas

Hazard and vulnerability maps of Rangamati in this study are shown in**Figure 3.21**.

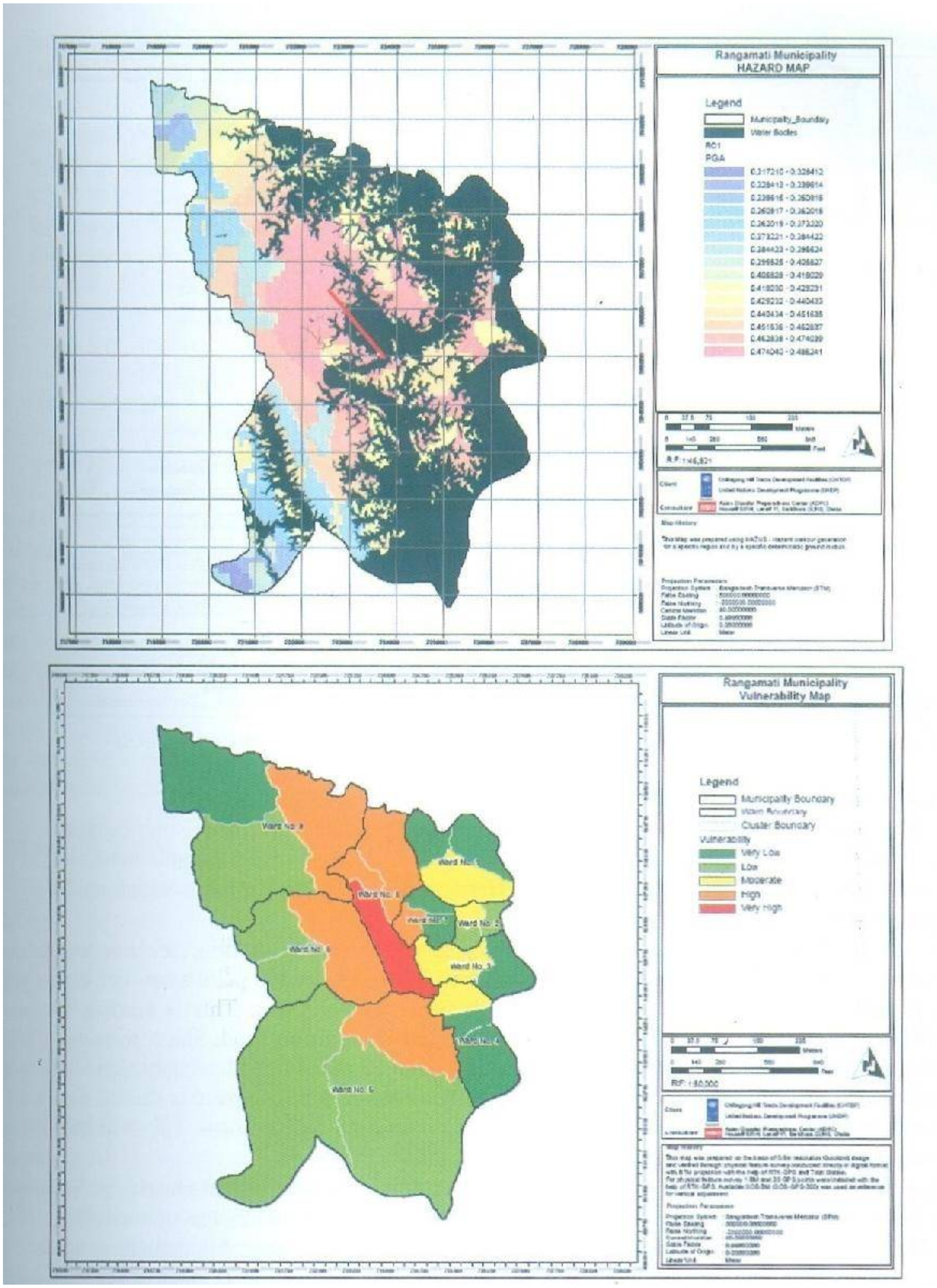

Figure 3.21: Hazard and vulnerability maps of Rangamati in the ERRRP Study

This study found anomalies and indiscipline in regard to landuse, construction of buildings etc. and hence found gaps in the systems and put forward some recommendationsas follows:

Development control and monitoring

Development monitoring process in the three municipalities is not well structured. Municipalities provide permission of building construction but landuse is not checked, which result in haphazard development within the municipal area. Also all hill towns are in shortage of usable land for development activities. Therefore, they require to formulate proper landuse plan for sustainable development control. Also, monitoring arrangement is needed.

Keeping open space

Open Space, Play Field and Natural Water Body Conservation Act 2000 has provisions in keeping these features within the municipal area. But the reality is that the Act is not followed. Therefore, the respective municipalities can take steps to follow the provisions properly.

Drainage problems

There are problems in the already developed area like water logging, shortage of water, vulnerability to landslide. Measures can be taken to mitigate these problems. Present drainage systems can be improved by widening and deepening of drains, drains can be covered by putting slabs on top so that solid waste are not dumped. Regular cleaning of drains shall be done particularly before starting of rainy season.

Landuse monitoring and building height

There should be strict monitoring that no building should be evicted without proper permission. Building heights need to be monitored following Building Construction Rules 1996.

Following building code

The three hill districts have good development pace following the peace treaty, and trend of building construction is increasing day by day. Therefore, for safe and sustainable development respective municipality should follow the Bangladesh National Building Code 1996, to design and build earthquake-resistant buildings.

Fault identification

There is a data shortage on fault segment information at Rangamati. It is necessary to undertake a proper study towards fault mapping with the help of field survey and Landsat images.

Epicentre study

A proper study is required on the epicentre of Borokol earthquake occurred in 2003.

Note: In overall consideration, for the lack of development control and monitoring due to weak institutional settings and management, faulty legislation etc. lead to illegal and improper development which ultimately make environmental problems and renderlives and property vulnerable to hazards like landslide, water logging, earthquake etc.

Past Studies under CDMP Phase II (2010-2014)

The phase II of the programme built on the achievements of Phase I (2004-2009) by ensuring that institutionalization of risk reduction and climate change adaptation occurred across all level of government. The donors committed USD 70 million to Phase II. The duration of the project on seismic components was from February 2012 to June 2014, and included the following tasks:

Task I: Seismic risk and damage assessments and subsequent development of scenarios based oncontingency planning for Rangpur, Dinajpur, Mymensing, Tangail, Bogra and Rajshahi city corporations/municipalities

Task II: Development of detailed building and infrastructure database of Dhaka and Chittagong city corporation areas

Task III: Development of ward level spatial contingency plans for Dhaka, Chittagong and Sylhet city corporation areas

Past Studies (not finalised) under Project: Multi-hazard Risk and Vulnerability Assessment (MRVA) Modelling and Mapping under Department of Disaster Management (DDM, 2015)

In this study a probabilistic seismic hazard assessment was carried out with return periods 100, 200 and 1000 years. The chief objectives were to find earthquake ground motion parameters: Peak Ground Acceleration (PGA) and Spectral Acceleration (SA). The study used the same methods as for developing latest United States National Seismic Hazard Maps (Peterson et al, 2008). The first step of the methodology was to model the earthquake sources in the study region by a combination of smooth gridded seismicity and crustal fault subduction source model. The second step was the identification of suitable model that could reasonably represent attenuation characteristics of ground motion in the study region. The third step was the assessment of hazard at the site (see DDM report 2015 for detail).

Regional tectonic settings: In respect of tectonic settings Bangladesh lies in the north eastern Indian plate and near the edge of Indian ocean. Also, it is located at the junction of three plates: Indian plate, Eurasian plate and Burmese plate. It is known that the Indian plate moves towards north-east at a rate of 6 mmy^{-1} where as it is sub-ducting under Eurasian plate at a rate of 45 mmy^{-1}, the Burmese plate moves at a rate of 35 mmy^{-1} (Sella et al, 2002; Bilham, 2004; Akhter, 2010)). Another major active belt is in the eastern side of Bangladesh, the Arakan-subduction-collision system, which involves oblique convergence of the Indian and Burmese plates.

Modelling of earthquake: In order to describe sources of earthquake that is very complex in nature, sources are modelled as a combination of background seismicity, subduction area sources, and crustal faults. In case of hazard calculation the earthquake which had magnitude of less than 6.0 were considered as point source at the centre of each grid cell. However, those with magnitude greater than 6.0 were considered as dipping faults centred on the source grid cell. The whole study area was divided into 3 source zones, 6 subduction zone areas. Features of subduction zone model and recurrence interval used in this study are given in Table B.6 in Annex B.

Seismic Hazard Maps: Probabilistic seismic hazard maps of PGA were prepared for 5 levels of return periods: 50, 100, 200, 500 and 1000 years. All maps were prepared on the seismic analysis results at the bedrock site condition. For the two return periods i.e., 50 and 100 years, the observed seismicity in and around Bangladesh controls the hazard of structural periods. But for the longer periods: 200, 500 and 1000 years, hazards are controlled by significant tectonic structures. As seen in this study the recurrence interval found from crustal fault model for Dauki fault is 250 years which is close to 200 years of this study. So,more studiesmay be undertaken on tectonic structures in Bangladesh. Maps of PGA corresponding to 50 and 500 year return period are shown in **Figure 3.22** and **Figure 3.23.**

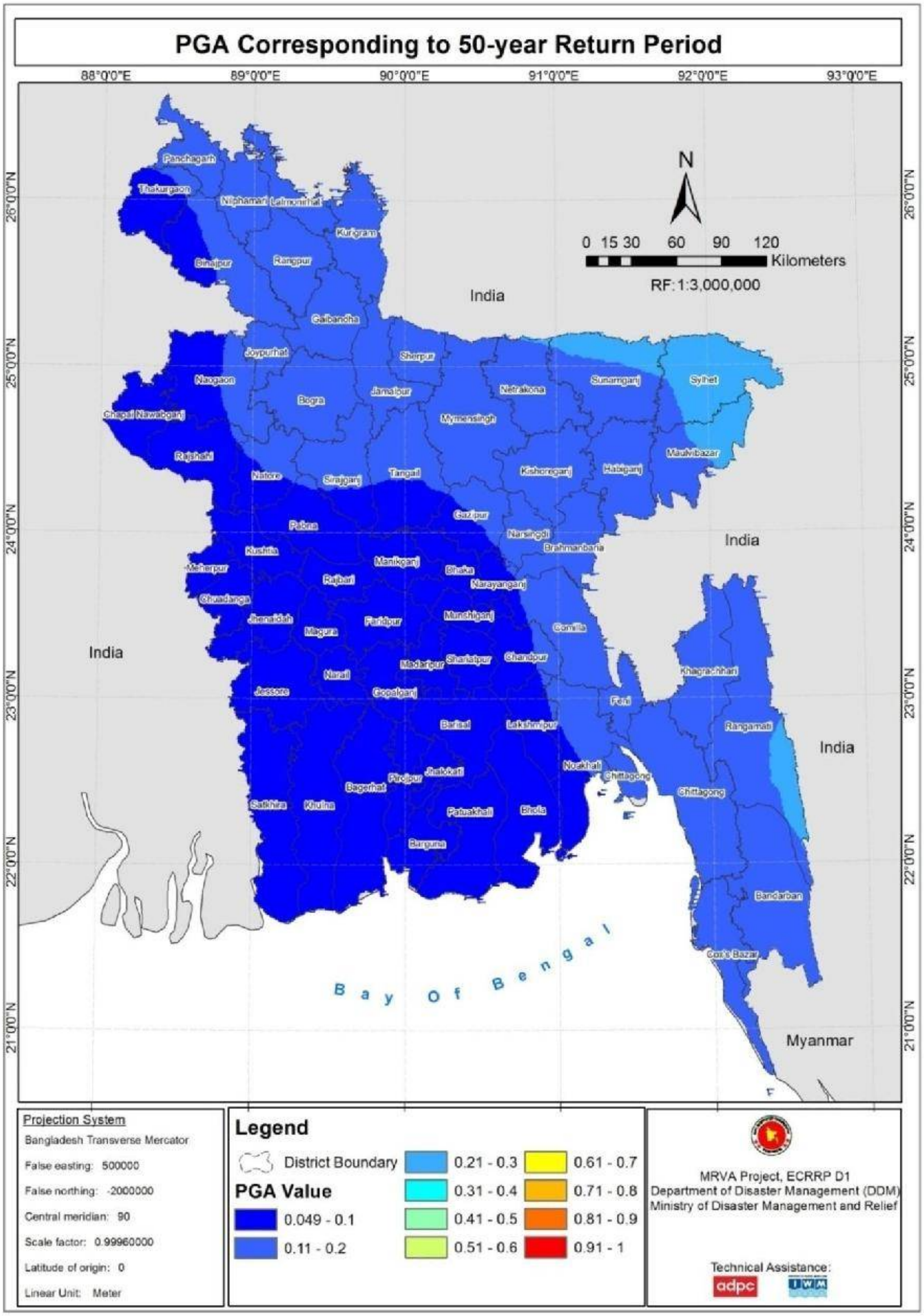

Figure 3.22: Seismic hazard map of PGA for 50-year return period for Bangladesh

PGA Corresponding to 500 Year Return Period

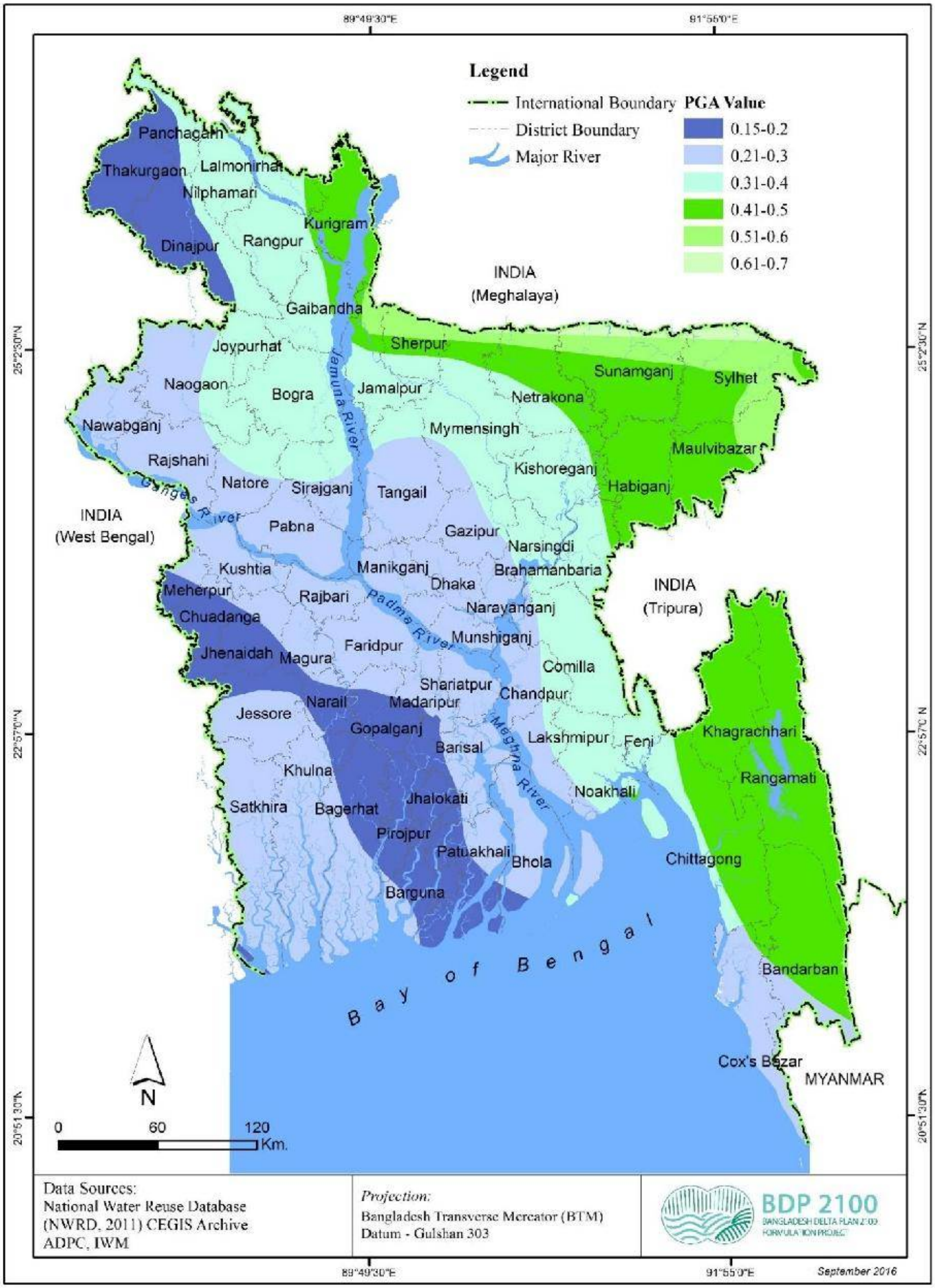

Figure 3.23: Seismic hazard map of PGA for 500-year return period for Bangladesh

3.5. Salinity Intrusion

In order to assess the vulnerability of coastal area of Bangladesh to salinity intrusion, IWM worked for World Bankalong with Lead environmental economist of WB (2012-2014). The study focused on the southwest coastal region where 2.5 million poor (including 1.4 million ultra-poor) are already suffering from shortage of drinking water, scarcity of water for irrigation for dry-season agriculture, and significant changes occurred in the coastal aquatic ecosystems. The study investigated the salt water intrusion of river water to landward due to climate change and sea level rise by 2050 for alternative scenarios of climate change and projections of subsidence of the Gangetic delta (Zahir et al, 2015). The study results indicate that a changed climate will significantly increase river salinity during the dry season (October to May) by 2050. Even in the best future case, the study shows the livelihoods of 2.9 million poor and 1.7 million ultra-poor would be adversely affected. In the worst future case for salinity incursion considered, adverse impacts on 5.2 million poor and 3.2 million ultra-poor would result. **Figure 3.24** shows salinity and poverty situation case scenarios: current, best, worst cases.

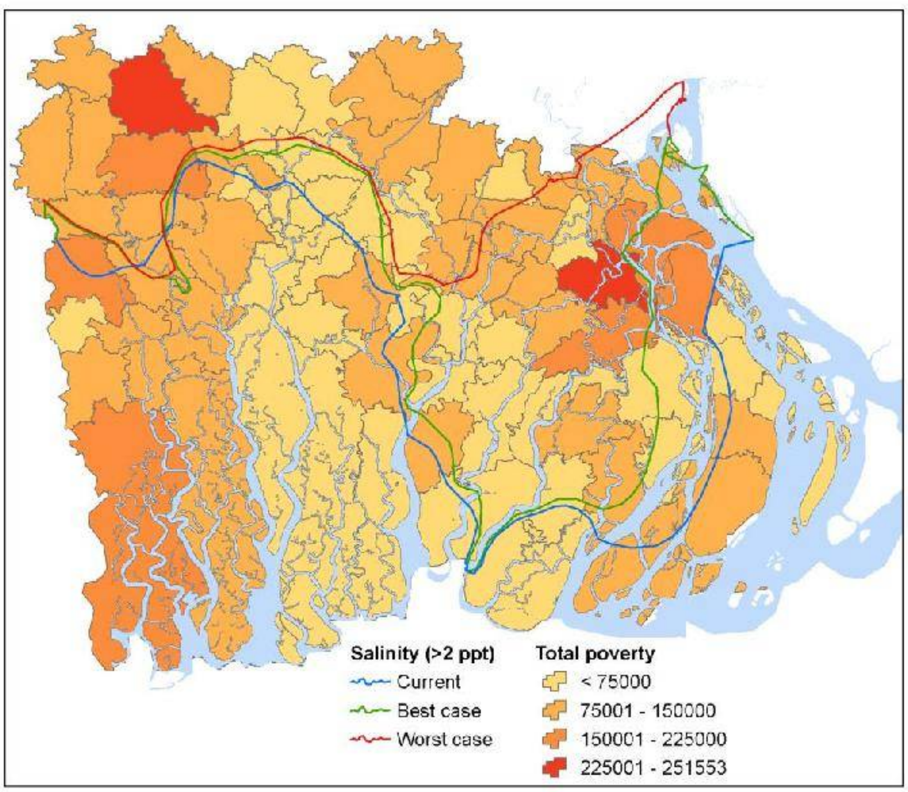

Figure 3.24: Poverty situation and salinity case scenarios – current, best and worst in the south-west region in Bangladesh

[Source: http://blogs.worldbank.org/developmenttalk/left-unattended-53-million-bangladesh-s-poor-will-be-vulnerable-effects-climate-change-2050]

In order to identify the external drivers and their combined effect on salt water intrusion in the Ganges costal area of Bangladesh,Zahir et al(2015) analysed landward movement of salt water into the river system for different scenarios. The study shows that about 19.3% area would be exposed to more saline water (greater 1ppt), which implies decrease of freshwater availability for drinking water supply in the river system is significant in future due to climate change and effect of other drivers. It is also seen that about 13.5% area is likely to be affected for shortage of irrigation water due to increase of river salinity more than 2ppt. **Table 3.15**showseffect of climate change (including precipitation, temperature change and sea level rise) and trans-boundary flow on freshwater availability in the south-west region of Bangladesh during April.

Table 3.15: Effect of climate change (and trans-boundary flow, TBF)on freshwater availability (flow, m3/s) in southwest region during April

Note: Climate Change parameters include precipitation, temperature change and sea level rise

Salinity level (ppt)	Base Condi-tion (2012)	Scenario, 2030					
		Scenario-I: MinTBF+CC+population+landuse change		Scenario-II: Average TBF + CC+population+landuse change		Scenario-III:MaxTBF + CC+population+ landuse change	
		Area (sq. km)	Change of Area over base condition	Area (sq. km)	Change of Area over reference condition	Area (sq. km)	Change of Area over reference condition
0-1 (Potable water)	19,575	15,792	-19.3%	16,738	-14.4%	17,255	-12%
0-2 (Suitable for irrigation)	21,261	18,377	-13.5%	18,909	-11%	19,387	-9%
0-5 (suitable for specific fish species)	26,066	23,517	-9.7%	23,892	-8%	24,722	-5%
>5 (Suitable for shrimp)	12,919	15,403	+19%	15,029	+16%	14,199	+10%

Note: -ve sign refers decrease in area and +ve sign refers increase in area over the 2012 baseline condition

This study shows implementation of the Ganges barrage to divert flow through the GoraiRiver and other distributaries of Ganges River, is predicted to result insubstantial movement of the dry season salinity fronts seaward. This would result in an additional 2660 km^2 of land exposed to less than 2 ppt river water salinity in comparison with the base case, i.e. a larger area would have access to irrigation compared to the present condition, especially in the Khulna division. However, with sea level rise of 22 cm, this additional area would decrease to 886 km^2. Thus, the Ganges barrage would bring considerable benefits, even with a 22 cm sea level rise in the Ganges dependent area.

Currently, there is abundant fresh water for irrigation in much of Barisal Division throughout the dry season. However, this region is likely to become more saline (2-4ppt) with 52cm sea level rise in 2050, damaging fish habitat and sources of irrigation water as seen in this study.

3.6. Additional information on disaster risk reduction and climate change adaptations

3.6.1. Climate Change Adaptation: A Trainer's Handbook, October 2014

Among other objectives and activities of Comprehensive Disaster Management Programme II (CDMPII), one is to provide training to the academic, research and relevant organizations, and non-government organizations with a view to building capacities to design and implement activities concerning disaster risk reduction and climate change adaptation. This training manual is the first of its kind in Bangladesh and has been prepared aiming at training organizations (relevant government and non-government) and also to trainers to design training events (to plan and conduct) in order to provide need-based training for the targeted participants. The handbook contains basic knowledge on principal themes and topics that have been chosen in line with emerging needs and challenges encountered in development aspirations. The ultimate aim of such training is to build capacity, apply lessons thus obtained practically and a reflection of change in behaviour in adaptation purposes and activities.

This trainer's guide consists of three parts: Part One- Training Process, Part Two: Trainer's Guide, and Part Three: The Learning Module. The part one has three phases – pre-training phase that overview the training needs, design of instructions of training, and guides to implementing of training activities. Post-training would go beyond conducting tasks of training discusses optimizing impacts etc.

The part two has three main features – a module dealing with setting parameters for the training, laying foundation dealing the practical applications of modules; and action plan dealing with a module applying climate change adaptations.

The part three contains 12 (twelve) learning modules such as introduction to the course, climate change – the scientific basis, impacts of climate change, vulnerability to climate change, response to climate change, policies and institutions for climate change, adaptation to climate change, mainstreaming adaptation to climate change, climate change and gender, climate smart development, marketing plans and projects climate resilient.

Each module is supplemented with some additional stuff that facilitates trainers during planning and conducting training. Also each module contains a session guide that provides an overview of module and trainer's notes as reference materials and discussion points. Action planning module contains an action planning exercise so that the participants can develop an action plan in a way that their respective organization may become climate smart.

3.6.2. Disaster and Climate Change Risk Maps and Planning Guide, October 2014

CDMP published Upazila atlas called *Disaster and Climate Change Risk Maps and Planning Guide* in October 2014. It was mainly developed on the previous works done by CDMPII on disaster and climate change – their affects, consequences, present and future scenarios etc. The aim of this atlas is to facilitate the local field level concerned authorities (local government, public representatives, planners, non-government individual and organisations) with easy access to information and reference for local level disaster risk reduction and climate change adaptation. In preparing it, two major steps were followed – identification of natural hazards in Bangladesh, and risk and vulnerability analysis. In estimating risk profile the risk was considered as the product of three elements – hazard, exposure and vulnerability. It used previously obtained hazard analysis results by modelling, for example flood, storm surge, salinity etc. In considering base-data, such as physiographic, temperature, rainfall, humidity, sunshine-hour, wind speed, evapo-transpiration etc. was used. As socio-economic factors, population, housing, household size, electricity coverage, land cover, economic activity, unemployment, water supply and sanitation were considered. In exposure analysis, the consideration was given to location of settlements to hazard (for example, settlements and different flood depths), crop cultivation area (for example, Aman), and communication network (say, road). In vulnerability analysis physical vulnerability (population density, types of houses etc.), social vulnerability (household size, dependent population – age less than 9 and more than 65 years), economic vulnerability (agricultural land, livelihood pattern, etc.) were considered. Hence, the atlas provides reference to analyse risk profile of selected upazilas in the form of hazard status (depth and extent of flood, storm surge, level of salinity concentration, drought profile and extent) and well as vulnerability. The year 2007 was considered as base year, and climate change scenario (where applicable) in 2050.

3.6.3. Toolkits prepared for Climate Adaptations and Disaster Risk Reduction

CDMP II published 3 (three) toolkits on Climate Change Adaptation and Disaster Risk Reduction for

- Flood prone and Flash Flood Prone Areas
- Areas Prone to Cyclone, Storm-surge and Salinity, October 2014
- Drought-prone Areas

CDMP II prepared the toolkits for the field level extension officers – both government and non-government and stakeholders to use in their respective areas of work. The aim of this toolkit is to enhance capacity of vulnerable community in the use of sustainable strategy and technology in case of climate change adaptation and disaster risk reduction in areas of respective hazards.

Toolkit on Climate Change Adaptation and Disaster Risk Reduction for Flood prone and Flash Flood Prone Areas, October 2014

It is one of 3 toolkits that CDMP II prepared as mentioned above. The specific objectives are to enhance such capacity in sectoral areas of agriculture, water and sanitation, livestock, fisheries, health, education, and society-based flood forecasting and warning systems. So are 7 chapters contained in this toolkit. Chapter 1 instructs and specifies cultivation of BRRI 51, 52, 28, 29, 45; describes a tool named 'grami' that helps collect crop that went under water for many days; use of cow dung in protecting dry paddy; cultivation methods of BARI wheat 26; cultivation of vegetables by peat technology, floating technology; community seed ground, method of cultivation of variety of yarns, method of cultivation of vegetables year-round in homestead; cultivation of apple kul, and roof-gourd and sweet gourd.

Chapter 2 specifies and shows the means of management of sources of safe water in flood season, making of flash latrines directly on pit (hillock), raised pit latrines, plastic latrines, cluster toilet, floating toilet where scarcity of dry land. Chapter 3 specifies preventive actions on the diseases - cholera, diarrhoea, scabies, influenza, malaria, kalajor, dengue, and swaine flu. Chapter 4 on livestock describes/specifies on a number of diseases and their symptoms of khura disease, torka, badla, throat swelling, titanus, bird flu, ranikhet etc.; also describes cultivation of variety of grass – napier, indigenous baksa grass, para grass, epil-epil, lota grass, making of urea molasses straw; also specifies husbandry of duck. Chapter 5 specifies pisci-culture of mono-sex tilapia, variety of carps, catfish, koi, Thai pangas, Thai sharputi; also describes fish cultivation by way of fencing, in a cage, in trap-pond, also in large pond by society-based initiatives. Chapter 6 specifies/describes adaptation and risk reduction strategies, strategies when flood is ongoing, and steps should be taken in post-flood situation. The last chapter, Chapter 7, specifies methods and procedures in developing society-based flood forecasting and warning systems. This entails involving Union and Upazila Disaster Management Committees with state publicity systems, reconstruction/transformation of those bulletin into local understanding, transformation of measurement taken in cm into easily understandable local measure, estimating and interpreting danger level locally and setting local flood gauge, forming of volunteer group and publicity group, setting local media of such bulletin, using flags (in yellow and red colour) in transmitting early warning bulletin, developing skills of DMC and volunteer group, implementing drills relating to flood warning etc.

Toolkit on Climate Change Adaptation and Disaster Risk Reduction for Areas Prone to Cyclone, Storm-surge and Salinity, October 2014

The specific objectives are to enhance such capacity in sectoral areas of agriculture, water and sanitation, livestock, fisheries, health, education, and society-based flood forecasting and warning systems. So are 7 chapters contained in this toolkit. Chapter 1 dealing with agriculture sector instructs and specifies cultivation of BRRI 47, 41, 23, 27; cultivation methods of BARI wheat 26; cultivation of vegetables sajina, method of cultivation of variety of yarns, cultivation of apple kul, cultivation of sunflower, water melon; cultivation of vegetables by sarjon method, year-round cultivation of vegetables around gher (water body in which fish is cultivated).

Chapter 2 dealing with water and sanitation specifies the means of rainwater harvesting system, making of pond sand filter and its uses (surface water treatment taking water from a pond useful in areas where deep tubewell are not effective due to the presence of iron, arsenic, salinity in water etc.), ringwell/dugwell, management of sources of safe water in cyclone and storm-surge occurring season, making of eco-san (ecological sanitation) toilet, community/cluster toilet. Chapter 3 specifies preventive actions on the diseases - cholera, diarrhoea, heatstroke, scabies, influenza, malaria, kalajor, dengue, and swaine flu. Chapter 4 on livestock describes/specifies on a number of diseases and their symptoms of khura disease, torka, badla, throat swelling, titanus, bird flu, ranikhet etc.; programme/schedule of immunization; also describes cultivation of variety of grass – napier, para grass, cowpy grass, German grass, jumbo grass; also specifies husbandry of duck with different methods. Chapter 5 involving fishery sector describes risk, vulnerability and possible actions; also specifies pisciculture of shrimp (galda in Bangla), prawn (bagda) – both in along with paddy and after paddy, pangas, gift or mono-sex tilapia, Bhetki fish, and culture of crab. Chapter 6 involving education sector specifies/describes adaptation and risk reduction strategies in pre-disaster, during disaster and postdisaster situation. The last chapter, Chapter 7 involving cyclone signals, describes categorically cyclone signals in-use and necessary actions to follow in response to both warning and danger signals.

Toolkit on Climate Change Adaptation and Disaster Risk Reduction for Drought-prone Areas October 2014

The specific objectives are to enhance such capacity in sectoral areas of agriculture, water and sanitation, health, livestock, fisheries, education, and society-based drought warning systems. So are 7 chapters contained in this toolkit. Chapter 1 dealing with agriculture sector instructs and specifies cultivation of BRRI 56, 57; cultivation methods of BARI wheat 26; preparation of community seed ground, cultivating rice using direct sowing method by the help of drum seeder; establishing kul garden, cultivating sajina, method of cultivation of variety of yams; method of preserving rain water in small pond for irrigation purpose; year-round cultivation of vegetables in homestead, method of cultivation of maize.

Chapter 2 dealing with water and sanitation specifies the means of setting up of deep tubewell, rain water harvesting system, making of pond sand filter and its uses (surface water treatment taking water from a pond useful in areas where deep tubewell are not effective due to the presence of iron, arsenic, salinity in water etc.), ringwell/dugwell, community/cluster toilet. Chapter 3 specifies preventive actions on the diseases - cholera, diarrhoea, heatstroke, scabies, influenza, malaria, kalajor, dengue, and swine flu. Chapter 4 on livestock describes/specifies on a number of diseases and their symptoms of poisoning of nitrate and nitrite, torka, khura, nematodiasis, PPR, ranikhet, gumbaro; programme/schedule of immunization; also describes diet management of livestock – straw of maize, epil-epil, lota grass, urea molasses straw. Chapter 5 involving fishery sector describes risk, vulnerability and possible actions; also specifies pisciculture of mono-sex tilapia, seedling of large carp fish, catfish, kai, Thai pangas; methods of culture of fish in seasonal pond; also describes food production and management for fish; some disease of fish and their preventive/curative measures. Chapter 6 involving education sector specifies/describes adaptation and risk reduction strategies in pre-disaster and during disaster situation for drought hazard. The last chapter, Chapter 7 involving society-based drought warning system, describes responsibility of disaster management committee in establishing drought warning system at local level, application of climate forecasting in agriculture in drought-prone areas.

4. Outlook and long-term challenges

4.1. Drivers of change and scenario

The problems related to disaster management are numerous, complicated and challenging. Efforts to effectively resolve the disaster management problems require a clear vision of the future conditions and demand new ways of thinking, developing and implementing disaster management program and practices.Long-term challenge is the success of paradigm shift from relief and rehabilitation to disaster risk reduction at every step, which largely depends on plan and action of other development ministries and implementing agencies. The magnitude and potential impacts of hazards are likely to be shaped by various external drivers of change including trans-boundary flow, population growth, land-use change, climate change, socio-economic development and change in governance and institutions. The interactions of these drivers are likely to be more pronounced in future.

The prediction of sea level rise resulting from global warming has been widely recognized as a major threat to low lying coastal zone of Bangladesh. Bangladesh, located on the Ganges-Brahmaputra delta, stands out as being among the most vulnerable to the threat of inundation due to sea level rise, monsoon flooding and cyclonic storm surge. Sea level rise, extreme weather events and climate change are part of the priority development challenges. Sea level is already increasing at the rate of more than 2mm/y, and could increase further. The intensity of the storm surges will also potentially increase.

A scenario can be formulated combining drivers of change. The definition of a driver is any natural or human-induced factor that directly or indirectly causes a change in an ecosystem. Scenarios and their likely effects enable in identifying which decision, investment and intervention should be made in the short term and which options for long-term. In Bangladesh Delta Plan formulation project, a dedicated 'scenario group' is developing a set of scenarios and identifying key drivers of change for use within the BDP, based on which the likely impacts of different hazards would be assessed. Scenarios are needed to evaluate the robustness and effectiveness of potential measures and strategies.

4.2. Future Development and Potential Strategies

A preliminary assessment is provided of potential intervention/measures and strategies for furtherdevelopment under the BDP 2100 with specific reference to disaster. The measures include both development of tools and methods, strengthening of monitoring, infrastructure and institutional measures and strategies.

4.2.1. Development of modelling systems for Coastal Inundation forecasting and warning at Community Level

The strengthening of early warning systems in communities is a critical component on the global disaster risk reduction agenda.Bangladesh is highly prone to hydro-meteorological and climate related hazards that systematically result in loss of life, livelihoods and property. These include phenomenon such as tropical cyclones and associated storm surges, drought, monsoon floods and coastal inundation andlow pressure in the Bay. The poor are typically worst affected due to these water-related disasters as they tend to live in vulnerable areas, have least capacity to deal with the loss of income and assets, and have limited access to risk sharing mechanisms such as insurance. Key socio-economic sectors of Bangladesh such as water resource management and agriculture are highly depended on weather and climate. As IPCC 5th Assessment report highlights, with a climate change and variability, the frequency and intensity of natural hazards are expected to increase. The Bangladesh Meteorological Department (BMD) is the main government agency with the mandate to issue weather forecasts and also plays a crucial role in science based monitoring on climate change/ vulnerability, development of long term climate scenarios, and delivery of climate services. It monitors and issues forecasts and warnings of all meteorological extreme events like tropical cyclones, severe thunderstorms/ tornados, heavy rainfall, draught, cold and heat wave along with daily routine forecasts round the clock. It is mandated to provide short, medium and seasonalweather forecast for agricultural planning and also provide input in terms of rainfall data, forecasts/ warnings, radar and satellite images for the operation of flood forecasting and warning system of Bangladesh Water Development Board.

Lack of knowledge for assessing the flood vulnerability and strengthening of early warning system to address storm surge and monsooninundation during spring tide in the coastal area at community level; the existing cyclone and storm-surge warning dissemination system is applied along the coast and not based on state-of-the-art technology to provide warning atlocal level communities.

The long-term strategy of the project is to develop new knowledge and tools required for Early Warning of Storm Surge Inundation for the Coastal community of Bangladesh and prepare inundation maps for pre, during and post disaster management programmes.

The key activities of the project are as follows:

- Cyclone Formation and Tracking Forecasting
- Meteorological Observation System:
- Hydrological Observation System
- Updating and upgrading of existing cyclone and storm surge model
- Cyclone and Storm surge Inundation Forecasting in the flood plain at community level
- Safety of coastal embankments and communities
- Warning Dissemination
- Capacity Building and Technology Transfer

4.2.2. Bangladesh Regional Climate Services Project for disaster risk reduction

The main objective of the project is to strengthen the capacity of the Government of Bangladesh to mitigate climate related hazards by improving the accuracy and lead time of weather forecasts and warnings and improving the quality of climate service in priority sectors.

Main Component of proposed project

The proposedproject has three main components:

Component (1): Strengthening Monitoring and forecasting: This component comprises of two sub-components:

Subcomponent 1a: Upgrading and Expanding Meteorological observation network

Sub Component 1b: Strengthening Weather, Cyclones, Storm Surge Forecasting and Multi-hazard Early Warning Systems

Component (2): Strengthening Climate Service Delivery

This component will help strengthen climate service delivery in Bangladesh.

Sub-component-2(a): Strengthening BMD;'s capacity for Climate service delivery:

Sub-component-2(b): Development of Sector Specific Information System ad Services

Sub-component-2(c): Regional cooperation to strengthen climate services

Component (3): Institutional Capacity Building

This component will support institutional capacity strengthening at the national and divisional level. Activities funded through the project include at the national level: (i) capacity strengthening for all Divisions and Units of BMD Dhaka in terms of staff development, provision of new hardware and software and technical assistance from international experts, study tours, strengthening local Severe Weather forecasting and research centre, strengthening meteorological centre to comply with WMO information system, Strengthening Meteorological Earth observation analysis and research centre Science Based Weather and Climate Forecast Application Research Centre (SWCARC), Strengthening Marine Meteorology Division and Common Alerting Protocol (CAAP).

At the Divisional level it includes (ii) strengthening of the six climate centres at divisional headquarters at Chittagong, Khulna, Barisal, Rajshahi, Rangpur and Sylhet all of which need to be strengthened in terms of expertise (human resources) and physical infrastructure (computing hardware and communication equipment). These divisions will be made capable of providing local level short term and seasonal weather forecast and climate service for the benefit of planners at divisional level as well as communities at large. This component will also support research and monitoring and evaluation related activities

4.2.3. Local Disaster Risk Reduction Fund

Local Disaster Risk Reduction Fund (LDRRF) is a fund-facility of CDMP II under the Ministry of Disaster Management and Relief to finance small to medium scale structural and non-structural innovative and/ or catalytic pilot interventions at the community level.This project is to provide funding opportunities directly available by local level at-risk communities to commence and scaling up effective disaster risk reduction and adaptation practices, and in developing the impetus with local administration and national authorities for recognition and effective implementation of resilience building. The fund is also expected to demonstrate to national government and donors the benefits of enabling community groups to plan, design, implement and appraise resilience building initiatives by them. The aim is to have such interventions to be sustainable enough for government to incorporate into development plans and programmes and to replicate and scale up to other locations to benefit the broader vulnerable communities.

LDRRF aims to promote pilot projects interventions that broaden and strengthen the coping capacities of communities to the impacts of natural and human induced hazards and thereby build the technical and institutional capacity of the most vulnerable to mitigate disaster threats, increase resilience and promote more sustainable livelihoods. At the same time, supporting NGOs, DMCs and other entities are done to implement small-scale innovative and strategic interventions.

4.2.4. Public-private partnership project for dissemination of forecasting and warning at Community level

Currently flood forecasting in Bangladesh is made for the river systems, which does not enable farmer and local community to assess the flood vulnerability for their crop, homesteads, livestock and other properties. A collaborative effort of Bangladesh Water Development Board/ Department of Disaster Management and local NGOs can be made to generate and disseminate forecasting and warning on daily rainfall, river water level and flood plain inundation to farmers, fishers and local traders. This will enable local community for reducing the flood disaster risk of their lives, livelihoods and properties. The project can start as a pilot program for flood prone Unions involving LGIs.

4.2.5. Improvement of Lead Time for Flood Forecast

The existing flood forecasting technology is able to provide relatively short-term (5 days)forecastssince June 2013, which are not sufficient in taking comprehensive flood preparedness/ responseactivities. Previously this capacity was limited to 38 points on 21 rivers with up to 48 hr lead time. Thismajor extension was possible by the financial support of CDMP II of the Ministry of Disaster Management and Relief given to FFWC of BWDB. The lead-time of forecasts could be extended using climate forecasts. The Climate Forecast Application Project in Bangladesh (CFAB) has paved the way and the developments made through CFAB should be carried forward.

4.2.6. Flood Proofing and Shelters:

In many areas of Bangladesh, like the *Haor* areas, ChalanBeel or the depression of south-central region, full flood protection would not be advisable because this kinds of measures are not economically viable and at the same time this could result in destruction of the ecologically sensitive wetland environment. Options for flood mitigation in these areas should focus on saving peoples life and property. Various flood proofing measures could be adopted for the purpose. One of the options may be to build clustered habitats with all the civic amenities. This may be undertaken on a pilot basis under any *Abashon* Project (Housing scheme) for the poor in Haor areas.

4.2.7. Loss and Damage assessment

Currently two types of forms are filled up in order to make disaster response in terms of relief operations and related activities. One is SOS form and the other is Form D. The form D contains 29 elements. Based on these assessments DDM considers and approves the amount of relief support and the district administration implement it.

At present there is no programme to assess baseline condition for damage assessment, which is essential for providing approval of relief assessment. There is no guideline on how to fill up the D form that reflects the reality of the disaster just occurring or has just occurred, meaning obviously there is no standard in the effort of filling up the forms. Obviously, such assessment result in wastage of resources and not properly distributed to the affected people. Therefore, standardization of damage and loss with regard to economic value is needed.It is important to conduct baseline assessment and then damage assessment.We need to follow UNFCCC guidelines for damage and loss calculation.

4.2.8. Disaster response and needassessment for relief

Past experiences of the relevant disaster management officials report that there is some kind of gap that always exists in assessing the amount of need and that is revealed after the operation is done. As a result, some affected people may be left out without relief support. Or some of them may be covered in the later round, if further resource is approved and allocated. In view of such experience, a work plan should be formulated that can be practically effective in assessing realistic amount of relief materials and timely distribution.Assessment needs sometime, but effectiveness of response depends on this time gap between actual need and time of delivery of support. Therefore, rapid assessment is necessary. A method can be developed for conductingthe rapid assessment. Currently stocking of food and other relief material is made in the district level, which delays the distribution of relief material to the affected people. In order to provide food and other relief materials in time to the affected people, there is a need for making stock of food at Upazila and Union levels.

It is important to strengthen programmes and activities to survive through post disaster situation, such as:

- Food for work
- Money for work

- Test relief
- Employment Generation Programme for the Poorest (EGPP)

It is important to motivate people to build their homes nearby big roads, not lying scattered and far apart from one home to another. Disaster management and community services can better be delivered if the homes lie along the main road, but of course keeping safe distance off the road.The state-run organization, Fire Service and Civil Defence is now under the Ministry of Home. But to meet the growing needs and better disaster management, it might be brought under the Ministry of Disaster Management and Relief.

4.2.9. Setting up of New Institution and Institutional strengthening

At upazila level, currently there is no higher level authority that can undertake roles and responsibilities necessary for overall disaster management at upazila level. Only a petty officer named PIO post is there. There is a need of revisiting the organogram considering the disaster Management.Training and Research Centreisneeded for generating data, information and knowledge. Establishment of an Emergency Response Centre would be useful.Cyclone Preparedness Programme has volunteers since 1972, now its number is as high as 49,365. In recent past urban volunteers were formed by DDM under MoDMR. Its magnitude is significant – 28,661 urban volunteers were recruited till February 2015, against the target to recruit 30,000 by April 2015.

Reportedly, more flood volunteers are in the process of recruitment. Like cyclone volunteers, the government has plan for registering flood volunteers. They can play role in two ways: in disseminating flood forecasting to community, and at the time in actual preparedness – taking people to flood shelters, preventing breaching of embankment, evacuating/rescuing people particularly from char lands and outside embankments, and discouraging people not to live on the most vulnerable areas. Since the demand is growing for volunteers in disaster risk reduction and emergency response, government has plans to make a separate volunteer organization. However, n order to bring all types of volunteers under one umbrella and to institutionalise volunteerism, enhancing community involvement, better mobilization, ensure active participation and management, it may be useful toset up a separate Volunteer Organisation.

4.2.10. Killas

Thekillas can be of much help for taking shelter at the time of emergency during cyclones and floods. Killas can be builtfor both people and livestock to take shelter on it, particularly in an area where cyclone shelters are located at a distance. Again, cyclone shelters may not provide sufficient space for livestock. It is known that for constructing killas acquisition of land involves problem. There are some suggestions in this regard:where possible khas land can be utilized in constructing killas. Road-side killas can be built every few kilometres at suitable locations with respect to location of communities and communication facilities.In addition, there are many a number of killas those were constructed in 1970's (after independence) and 1980's which have been eroded and hence not fit for the purpose of sheltering. Hence, it is suggested that these eroded/unfit killas be rehabilitated and improved by reconstructing up to a standard.

5. Building Blocks towards a Long-term Delta Vision and Decisions

5.1. Long term vision

A long-term vision for the disaster management would be based on the policy, plan, strategy and goal of the Government of Bangladesh. The Draft National Policy on Disaster Management has emphasized a group of broad-based strategies as follows:

1) Disaster management would involve the management of both risks and consequences of disasters that would include prevention emergency response and post-disaster recovery.
2) Community involvement for preparedness programmes for protecting lives and properties would be a major focus. Involvement of local government bodies would be an essential part of the strategy. Self-reliance should be the key for preparedness, response and recovery.
3) Non-structural mitigation measures such as community disaster preparedness training advocacy and public awareness must be given a high priority; this would require an integration of structural mitigation with non-structural measures.

There are inherent uncertainties on projected developments, it is essential to have policies and steering mechanisms in place that can be used when unforeseen disaster events and developments take place, where government can play important role for the safety of people and property.Likely impacts of drivers and scenarios would be assessed and then potential strategies and measures would be identified involving policy makers, planners and other relevant stakeholders.

The Vision for the BDP 2100need to provide a clear view on the characteristics of a robust andeffective disaster management system to support of the national socio-economic and policy priorities. Alternative scenarios and various combination strategies and measures would be analysed. In order to select the best suited measures and prioritization, Intensive process of stakeholder interaction would be carried out for a final agreement of the Delta Decisions the Delta Framework. After selection of measures a matrix would be made describing what will be done, by whom and when, and who will finance.

5.2. Input to 7th Five Year Plan

In order to select strategies and measures for the 7th five year plan a series of interactions with stakeholders were carried out. A number measures are outlined below as outcome of the interactions. These measures would be analysed into further details after finalization of the baseline study.

- Bangladesh Regional Climate Services Project for disaster risk reduction;
- Public-private partnership project for dissemination of forecasting and warning at community level;
- Local Disaster Risk Reduction Fund;
- Development of modelling systems for Coastal Inundation forecasting and warning at the community level for cyclonic storm surge and monsoon flooding during spring tide;
- Improvement of lead time for flood forecast;
- Ganges barrage and Brahmaputra barrage for salinity control in times of climate change and upstream withdrawal of flow;
- Loss and Damage assessment; and
- Institutional strengthening

6. Knowledge, Activity Gaps and Challenges

Though Bangladesh has recognised 32 hazards prevailing in the country, the prime and recurring disasters are caused by floods, cyclones, draughts, salinity intrusion and earthquakes. The nature and type of the disasters vary geographically within the country. On top of this, the climate change has gradually but steadily been deteriorating the situation. Relevantly, these topics and their severity have been discussed in this report. In the past, the approach of combating hazards/ disasters was mostly limited to providing relief and rehabilitation. But the priority has been shifted about a decade ago from relief distribution to a holistic approach of disaster risk reduction. This approach is made effective in all levels and at the times of disaster events (before, during and after). It is important o make sure that disaster management is comprehensive and focus on risk reduction and emergency response. The gaps in such efforts and the challenges to confront these are discussed in this section.

Flood:

Expansion of Forecasting Services: Currently forecasting is made at 54 points on 29 rivers with lead time up to 5 days since June 2013, before which this capacity was limited to 38 points on 21 rivers. This major extension was possible by the financial support from CDMP II under the Ministry of Disaster Management and Relief.There lead time is expected to be increased gradually for 10 days for better disaster management, which is yet to be developed (detail in Table B-1 under Annex B). This services need to be expanded for more river points on more rivers. Manpower resources and state-of-the-art technology are not adequate in FFWC for forecasting and warning of flood timely and efficiently; financial support is needed from CDMP and/or other sources.

Flash flood: According to progress made in 2012-13 by the development and strengthening of flood forecasting and warning system,forecasting is done with 2 days lead time on pilot basis in northwest region during April-May. This service, which started in 2013, needs to be extended to other areas – such as, northwest, north, and southeast with more lead time.

Project-structure based forecasting: From August 2013 on experimental basis flood forecasting is done by mathematical modelling with 5 days lead time for 4 large projects – Dhaka-Mawa Road, Brahmaputra Right Embankment, Embankment of Pabna Irrigation and Rural Development Project, and Embankment of Meghan-Donagodha Irrigation Project. This service can be extended for other large projects.

Flood forecasting at community level: Currently forecasting and warning is made at points on rivers by means of mathematical flood modelling. Forecasting services need to be expanded to flood plain and community level for the safety of crops, homesteads, livestock and property.

Flood shelters are not available at all high risk flood prone area: Flood shelters are being constructed. So far 99 have been completed and 156 being constructed. There is a plan to construct more shelters.

Flood shelter policy: There is a policy for cyclone shelters construction, maintenance and management (called Cyclone Shelters Construction, Maintenance and Management Policy 2011). There is no policy and plan for flood shelters. Hence, flood shelter policy should be formulated.

Embankment repair and maintenance: There are usual features such as weak points, holes, cuts, breaks, etc which are observed on the embankments. Embankment breaching is the main cause of flooding and damage for embanked areas. Also after completion of the projects, regular repair and maintenance budget is either meagre or unavailable and there is no monitor/operator posted at the regulating structures. In view of these, some suggestions are given below:

- Improvement of construction quality
- A routine monitoring and maintenance work is a must
- Placing of monitor/operator at the regulating structures
- Allocating adequate budget;some minimum budget must be there so that the embankments are kept in good shape and strength (The fact finding workshop alsoemphasizes on the budget, see Annex A).

Storm surge and tidal flooding: At present, there is no forecasting and warning of cyclonic storm surge and monsoon flood inundation during spring tide in the coastal area at local community level; strengthening of modelling system and pilot program of forecasting and warning is required (see also Sec 4.2.1).

Cyclone shelters: As for cyclone shelters – their numbers, distribution, shelters with commercial houses/buildings, with mosque; security, toilets and water supply facilities – gaps and suggestions are provided in Sec 3.2.2.

Coastal Embankment: There is no mechanism to monitor the coastal embankments and flood embankments along the main rivers to monitor and identify weak points prior to cyclones and severe floods. The problems and suggestions have been elaborated under Sec 3.2.2, which indicates the need of vegetation strip, adequate slope, monitoring weakness, maintenance budget etc.

Embankment breaching: Embankment breaching at weak points is the main cause of flooding and damage in the embankment, crop lives and livelihood. There is no minimum budget availablefor emergency repair, when it is small and easy and cost-effective to repair. If repair or filling of breach of coastal embankment is not made in time, then it becomes very difficult, complex and expensiveto repair later.

Enhancing meteorological services and strengthening institutional capacity: As mentioned earlier, the Govt's focus is on risk reduction, rather than response and relief for disasters. As such, weather-related forecasting services need to be enhanced and improved in terms of tools and methods, and enhancing human and institutional capacity. To become successful in risk reduction approach relating to hydro-meteorological hazards, forecasting services need to be improved by improving the accuracy, more lead time, data acquisition, and quality of services. In this regard, a project has been proposed as Bangladesh Regional Climate Services Project. The project has 3 (three) main components, described under section 4.2.2 and also 4.2.1.

Drought hazard: a) It is necessary to identify distribution of drought risk by assessing human vulnerability to drought; b) Physical and social factors affecting vulnerability to drought need to be identified and assessed.

Earthquake hazard: A study under the programme titled Earthquake Risk Reduction and Recovery Preparedness Programme (ERRRP) in 2007-2009 with financial assistance from the government of Japan through UNDP/BCPR, found anomalies and indiscipline in regard to landuse, construction of buildings etc;these gaps in the systems along with some recommendations were put forward to relevant authority (see Sec 3.4.1). The issues were valid for all cities and municipalities, which are briefly given below:

- Landuse plan, development control and monitoring: Cities and municipalities provide permission of building construction, but landuse is not checked, which results in haphazard development within the city/town areas. Also all hill towns are in shortage of usable land for development activities. Therefore, formulating proper landuse plan for sustainable development control is required. In addition monitoring of the activities is also needed.
- Keeping open space:*Open Space, Play Field and Natural Water Body Conservation Act* 2000has provisions in keeping these features within the municipal area. But the reality is that the Act is not followed. Therefore, the respective cities/municipalities should take steps to follow the provisions properly.
- Drainage problems: There are problems in the already developed area like water logging, shortage of water, vulnerability to landslide. Measures can be taken to mitigate these problems. Present drainage systems can be improved by widening and deepening of drains, drains can be covered by putting slabs on top so that solid waste are not dumped; regular cleaning of drains should be done particularly before starting of rainy season.
- Landuse monitoring and building height: There should be strict monitoring that no building should be erected without proper permission. Building heights need to be monitored following *Building Construction Rules 1996*.
- Following building code: Lack of following building codes is observed. Therefore, for safe and sustainable development respective municipality should follow the *Bangladesh National Building Code 1996* to design and construct earthquake-resistant buildings.
- Fault identification: There is a data shortage on fault segment information at Rangamati. It is necessary to undertake a proper study towards fault mapping with the help of field survey and satellite images.
- Epicentre study: A proper study is required on the epicentre of Borokol earthquake occurred in 2003.

Loss and Damage Assessment

- Current practice: Currently two types of forms are filled up in order to make disaster response in terms of relief operations and related activities. One is SOS form and the other is Form D. The form D contains 30 elements. Depending on these assessments DDM considers and approves the amount of relief support and the district administration implements it.
- Baseline condition: Currently no baseline condition is known. But when assessing and approving of amount of relief, not having known baseline condition (element at risk, condition of element at risk) the relevant authority faces difficulty in allocating resources for relief and rehabilitation. There is a need, therefore, to know the baseline condition.
- Guideline for filling in up Form D: Currently there is no guideline how to fill up the Form D that reflects the reality of the disaster just occurring or has just occurred, meaning obviously there is no standard in the effort of filling up the forms. Obviously, such assessment results in wastage of resource and improper distribution of relief materials to the affected people. Therefore, standardization of DNA is very much necessary.

Gaps in need-assessment for relief: Past experiences of the concerned disaster management officials indicate that some kind of gap always exists betweenassessing theamount of need and the onethat is revealed after the operation. As a result, some affected people may be left outwithout relief support. Some of them may be compensatedin the later round, if further resource is approved and allocated. In view of such experiences, a work plan shouldbe formulated that can be practically effective in assessing realistic amount of relief materials and timely distribution. Effectiveness of response depends on this time gap between actual time of need and time of delivery of support.

Rapid assessment need: Assessment needs time, but effectiveness of response depends on the time gap between actual need and time of delivery of support. Therefore, rapid assessment is necessary. A method can be developed for undertaking rapid assessment.

Institutional strengthening:

- At Upazila level: Currently there is no higher level authority that can undertake roles and responsibilities necessary for overall disaster management at upazila level. Only a petty officer named PIO is posted there. An organogram is now being formulated and a Disaster Management Officer is proposed.
- Disaster Management Training and Research Centre: Organogram for this centre is being developed. A no land is available for is premises in or around Dhaka city, the authority has planned to expand vertically the Disaster Management and Relief Bhavan by 3 floors. It is planned that two floors will be allocated for the centre, which is expected to expand and strengthen study, research and training activities.
- Emergency Response Centre: The government is actively considering toestablish an Emergency Response Centre.
- Separate Volunteer Organisation: Cyclone Preparedness Programme has volunteers since 1972, now its numbers is as high as 49,365 (around 31% is female). In recent past urban volunteers were recruited, while recruitment of flood volunteers is progressing. In order to bring all types of volunteers under one umbrella and to institutionalise volunteerism, enhancing community involvement, better mobilization, ensuring active participation and authority has plan to set up a Volunteer Organisation. Such volunteer organisation can arrange training to enhance knowledge and skills of the volunteers.

Killas: Killascan be of much help in taking shelter at the time of emergency during cyclones. The killas can be of help even for flood hazard. Killas can be built for both people and livestock to take shelter on it, particularly in an area where cyclone shelters are located at distance places. Again, cyclone shelters may not provide sufficient space for livestock. It is known that for constructing killas, acquisition of land always involves some problems. Some suggestions are given below:

- Where possible khas land can be utilized in constructing killas
- Road side killas can be built every few kilometres at suitable locations with respect to location of communities and communication facilities

Also, old killas can be rehabilitated and improved up to a certain standard so that they can serve the purpose of shelters at the time of emergency (see also Sec 4.2.10).

Relief fund: In conformity to Prime Minister's Relief Fund, a district level a relief fund can be set up permanently. The government can contribute to this fund. In addition, local people may be encouraged to extend their support to his effort. Even Bangladeshis living abroad may contribute to this fund.

Challenges: Some salient and important challenges are:

- Problem in mainstreaming: Paradigm shift from relief and rehabilitation to disaster risk reduction at every steps/level. However, success will depend on plan and action of other development ministries: For example, RAJUK appears to beinsincere in implementing building codes, monitoring of buildings according to plan etc.
- Role of administration: Administration can play more role in mainstreaming
- Landuse planning:Very important factor in mainstreaming
- Political will:Good political will needed for formulation and implementation of policies

Fire Service and Civil Defence: This department is at present under the Ministry of Home. To meet the growing needs,the department should be brought under the Ministry of Disaster Management and Relief.

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