THIRD NATIONAL COMMUNICATION OF BANGLADESH TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

Ministry of Environment, Forest and Climate Change
Government of the People's Republic of Bangladesh

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MESSAGE

Climate change is now considered to be one of the greatest challenges facing not only nations and regions but the global community and the integrity of planet earth itself. It is now scientifically proven that global warming is the direct result of massive and prolonged GHG emissions. This has led to global climatic disorder as natural disasters of various types occur more frequently and with increasing levels of devastation around the world. Consequently, the sufferings of humankind have increased remarkably, especially in least developed countries (LDCs) and in small island developing states (SIDS). All countries which are signatories to the United Nations Framework Convention on Climate Change (UNFCCC), taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, are required to periodically submit a National Communication to the Convention. Towards the fulfillment of its obligation under the Convention, Bangladesh submitted its Initial National Communication (INC) to the UNFCCC Secretariat in 2002 and the Second National Communication (SNC) in 2012. This Third National Communication reflects the firm commitment of the Government of Bangladesh to the Convention, its principles and ultimate objective.

Bangladesh's Third National Communication provides an overview of climate change issues in the country and their implications for the key stakeholders at local, national, regional and global levels. It explains national circumstances, details greenhouse gas (GHG) inventory, and highlights programmes of measures for adaptation to climate change and mitigation actions.

Bangladesh's Third National Communication Project, the preparation of which has been funded by the Global Environment Facility (GEF) through UNDP Bangladesh, has been able to create a solid foundation for further work on scientific and policy issues. It has also been able to clearly define the concerns relevant within the national context and has identified potential areas for further action. This document alerts policy makers and other key stakeholders of the urgency of mainstream climate issues in the national development policy and agenda as well as within a legal framework. The process of its preparation has helped enhance the capacity of the scientific and research communities of Bangladesh for formulating and planning adaptation and mitigation policies and options. It highlights the need for a more concerted effort to spread awareness among all stakeholders including the research community, decision-makers and those involved in implementation activities, and the need to strengthen the coordination, networking and information flows between ministries, different levels of government and civil society to have a more efficient integration of climate change issues into poverty reduction and development strategies.

I would like to take this opportunity to express my gratitude to the officials and experts of the Ministry of Environment, Forest and Climate Change including the Department of Environment, to other related ministries and government organizations, involved non-government organizations, and to the consultant team and individuals for their dedication and commitment in the preparation of this document through a participatory process, which included a series of workshops, seminars and meetings involving all key stakeholders.

Finally, I would like to request that all officials, experts and stakeholders do their utmost to utilize the information and knowledge contained in this document to work for national and global benefits.

Anisul Islam Mahmud, MP
Minister
Ministry of Environment, Forest and Climate Change

MESSAGE

Climate change is one of the greatest threats to the sustainable development of Bangladesh. The Government
Climate change is one of the greatest threats to the sustainable development of Bangladesh. The Government
of Bangladesh believes that climate change, if unmitigated, has the potential to undermine many of the positive advances that the country has made in meeting its own development goals. Escaping poverty is becoming far harder for the poor, who are worst hit by climate impacts. Extreme weather, flooding and salinity intrusion hamper the agricultural production sector and threaten long term food security. Ecosystems, biodiversity and infrastructure are all in danger.

The Paris Agreement, ratified in December 2015, represents an important milestone in the global fight against climate change. It contains considerable obligations that the international community, including Bangladesh, must assume under the principle of common but differentiated responsibilities. Parties of developed countries are to ensure that robust commitments are in place to push forward the mitigation actions and climate financing needed for adaptation and mitigation efforts, and to shape low-carbon, climate-resilient economies. Bangladesh, for its part, is working to keep its commitment; our proposals on nationally determined contributions have already been submitted.

The Third National Communication details the developments that have taken place in Bangladesh in climate change adaptation, mitigation and reporting levels. The process of preparing this report has been an opportunity for stakeholders to realize the magnitude of their accomplishments and progress since the publication of Bangladesh's Second National Communication in 2012. Through the official submission of this document, we now have the opportunity to share with the rest of the world our climate change induced vulnerability, challenges, opportunities for adaptation, and our national climate achievements that tend to be sometimes diluted in the difficult socio-political context that least developed countries like Bangladesh are faced with. Over the years, considerable efforts have been deployed in Bangladesh to create synergies between the various national activities in the environmental and sustainable development fields. Addressing climate change specifically is indeed an umbrella under which a wide range of stakeholders gather to ensure the streamlining of adaptation and mitigation within the framework of national policies and plans and to create and enhance existing channels of communications among stakeholders and relevant organizations.

The work compiled in this national communication is therefore the compilation of the vision, research outcomes, responsibilities and capacities of all concerned. I would like to take this opportunity to thank the Global Environment Facility that funded the project and the United Nations Development Programme that effectively managed it.

We remain committed to continuing to improve the quality of our reporting to the UNFCCC. We are also committed to strengthening national climate action by implementing the adaptation and mitigation targets of our nationally determined contributions with the help of the international community, by building the capacities of our experts, by strengthening our institutional arrangements and monitoring, reporting and verifying system, and by incentivizing non-state actors to mirror the government's efforts to play our part in combating climate change and managing its impacts.

Abdullah Al Islam Jakob, MP
Deputy Minister
Ministry of Environment, Forest and Climate Change

MESSAGE

As a part of the global obligation under the United Nations Framework Convention on Climate Change (UNFCCC), the Government of Bangladesh has prepared its Third National Communication in accordance with the guidelines for non-Annex I Parties adopted by the Conference of the Parties (COP). Bangladesh submitted its Initial National Communication in 2002 in which the focus was on emission inventory and the impact and vulnerability of climate change on different sectors and bio-physical systems. In the Second National Communication (SNC), submitted in 2012, emission inventory as well as impact, vulnerability, adaptation and mitigation issues were elaborated on. This Third National Communication provides an updated status of national circumstances along with greenhouse gas (GHG) inventory for 2006-2012 of different sectors, and measures to facilitate adequate adaptation and appropriate mitigation.

Climate change already adversely impacts on overall development prospects. It threatens to undermine development achievements and can slow down progress towards the achievement of the Sustainable Development Goals (SDGs), especially those related to hunger and poverty reduction and ensuring environmental sustainability. The agriculture and forestry sectors are central in this regard because while they are affected by climate change and contribute to GHG emissions on the one hand, they offer opportunities for cost-effective mitigation options with additional benefits for development and food security on the other. Given appropriate planning, mitigation initiatives and climate change adaptation, these sectors can contribute to sustainable development.

It gives me great pleasure that the Third National Communication document is ready for dissemination. This is a notable achievement. I would like to express my sincere thanks and gratitude to the Global Environmental Facility (GEF) and UNDP Bangladesh for their financial and technical assistance in preparing the document. I would also like to thank all the experts and members of different ministries, government agencies, non-government and private organizations, technical committees, consultant team, peer reviewers, lead reviewer Dr. Qazi Kholiquzzaman Ahmad, Mr. Arif Mohammad Faisal and Mr. Alamgir Hossain of UNDP Bangladesh, former Director General, Department of Environment & National Project Director Md. Raisul Alam Mondal and Project Manager Sheikh Moazzem Hossain of the TNC project for their valuable contribution and inputs for making this endeavour a success.

Abdullah Al Mohsin Chowdhury
Secretary
Ministry of Environment, Forest and Climate Change

FOREWORD

High vulnerability due to climate change is a major concern for Bangladesh. Analysis of Bangladesh's climate change projection has indicated that Bangladesh is among the most vulnerable regions in the world caused by sea level rise, drought, extreme weather and other climate-related events. Responding to the challenge of climate change is a part of priority policies for Bangladesh and that decisive actions are needed. Bangladesh has carried out a number of measures and actions at the national level, consistent with our commitments under UNFCCC. Following up the adoption of Paris Agreement, Bangladesh has deposited its instrument of ratification on 21 September 2016. Bangladesh also submitted the 'Nationally Determined Contribution' (NDC) in due time. Consistent with the COP-UNFCCC mandate, Bangladesh has prepared Third National Communication (TNC). Ministry of Environment, Forest and Climate Change of Bangladesh is currently engaged in preparing the National Adaptation plan (NAP).

The process of developing the TNC report was as important as the final report itself. It involved all national stakeholders and experts in a two year effort supported by GEF and UNDP and using the best available guidelines. The TNC was produced through the use of national expertise, with international support in the area of climate projection downscaling. The capacity building components of the TNC have helped to increase national capacity to produce national reports in a sustainable manner. The knowledge created and generated within the TNC process will drive further research and enhance the information base for all stakeholders for years to come.

Bangladesh is undergoing a rapid and effective process of enhancing its institutional and policy relevant framework for addressing climate change challenges. After developing a milestone document in the field of climate change known as Bangladesh Climate Change Strategy and Action Plan, Bangladesh created a special 'Climate Change Trust Fund' for implementing adaptation and mitigation activities from its own resources. Recently Climate Change Wing has been established at the Ministry to act as a coordinating platform for all climate change activities in the country. Despite being a most vulnerable country of the world, we are doing our best. We expect that enhanced global response to climate action would be taken by the countries that are in a position to do so.

My appreciation and wishes are for all the national experts and actors who have participated in producing this report through their relentless efforts and positive passionate attitudes. This effort was supported by both GEF and UNDP that enhances the strategic partnership between the Ministry of Environment, Forest and Climate Change and GEF-UNDP in the implementation of global environmental conventions.

Bangladesh is hereby providing its climate change document to the international community and is committed to participate in a comprehensive and fair global effort to address the challenge of climate change in parallel with the challenges of sustainable development and human well-being.

Dr. Nurul Quadir
Additional Secretary
Climate Change Wing
Ministry of Environment, Forest and Climate Change

ACKNOWLEDGEMENTS

The Third National Communication of Bangladesh has involved a series of studies that were conducted by the Department of Environment, Ministry of Environment, Forest and Climate Change. A large number of policy makers, key government officials, experts, academia, civil society organizations and NGOs were involved in preparing this important document. At the outset, I would like to express my gratitude to the Honourable Minister, Ministry of Environment, Forest and Climate Change (MoEFCC), Mr. Anisul Islam Mahmud, MP and former Honourable Minister, MoEFCC, Mr. Anwar Hossain Manju, MP and Mr. Abdullah Al Islam Jakob, MP, Honourable Deputy Minister, for their effective leadership in preparing this important document. I am also grateful to the Secretary, Ministry of Environment, Forest and Climate Change (MoEFCC), Mr. Abdullah Al Mohsin Chowdhury for his guidance in the successful implementation of the project.

I would also like to thank our former Secretaries, MoEFCC, Dr. Kamal Uddin Ahmed and Mr. Istiaque Ahmad for their support during the early and middle stages of the implementation of this project. Let me also recognize the important contributions of Md. Ziaul Haque, Director (AQM), DOE & DPD of the project and Sheikh Moazzem Hossain, Project Manager (NPC), of the project and Mr. Arif Mohammad Faisal, Programme Specialist, UNDP Bangladesh for their overall supervision and coordination. My sincere thanks also to the collective wisdom of the Center for Environmental and Geographic Information Services (CEGIS), Bangladesh Centre for Advanced Studies (BCAS), Nature Conservation Management (NACOM), Center for Climate Change and Environmental Research (C3ER), Engineering Resources International Ltd, and to experts, professionals, researchers, and environmental practitioners for their valuable contributions to the preparation of the TNC of Bangladesh. I must also thank the Global Environmental Facility (GEF) and the United Nations Development Programme (UNDP), Bangladesh for their financial and technical assistance in implementing the activities of the project.

Finally, I would like to gratefully acknowledge the contribution of all the conveners and members of the National Steering Committee, National Advisory Technical Committee, Core Sectoral Working Groups, national consultants (peer reviewers), all the professionals of the Ministry of Environment, Forests and Climate Change, the Department of Environment, and particularly the lead reviewer Dr. Qazi Kholiquzzaman Ahmad, Chairman, PKSF for providing guidance and suggestions in developing the document and preparing the final version of the Third National Communication of Bangladesh.

At this point in time, I would also like to recall and wish to extend my sincere appreciation and gratefulness to the- then National Project Director and DG, Department of Environment, now Secretary, Ministry of Fisheries and Livestock Mr. Raisul Alam Mondal for his outstanding contribution in bringing this project towards an successful completion.

Dr. Sultan Ahmed
Director General
Department of Environment

MESSAGE FROM UNDP, BANGLADSH

I am pleased to know that the Ministry of Environment, Forest and Climate Change has completed the preparation of the Third National Communication (TNC) of Bangladesh to the United Nations Framework Convention on Climate Change (UNFCCC) and we are happy that Global Environment Facility (GEF) and UNDP have been able to provide financial and technical support in preparing this nationally important document to fulfill the commitment of Bangladesh to the Conference of the Parties (COP).

We are aware that this report has been prepared through a series of consultations and meetings where officials from various government ministries, line agencies, NGOs, researchers, academicians from different universities, representative from private sectors participated. Besides, training programmes were also organized to develop capacity for managing the greenhouse gas (GHG) inventory and for preparing a high quality GHG inventory for the TNC following IPCC guidelines and good practices. We do believe that interactions with the stakeholders through the rigorous consultations process have guided the government to formulate mitigation and adaptation plans for coping climate change impacts of Bangladesh. Thus, the partnerships between the government, non-government and private sectors have been developed and strengthened through data and information sharing, technology transfer ideas, information and institutional capacity building activities. The TNC project has generated baseline data required for the assessment of climate change risks and vulnerability and impacts and adaptation options. It has also resulted in a comprehensive vulnerability and risks assessment for various sectors, in particular agriculture, water resources, forestry, fisheries, livestock, industries and infrastructure sectors.

It is praiseworthy that Bangladesh has registered a significant stability over the last 17 years in macro-economy, productivity in agricultural sector, job creation through expansion in the manufacturing, industry and the service sector and increased inward remittances. This boosted employment, food security and household income, leading to substantial alleviations in poverty in Bangladesh, primary school enrolment, gender parity in primary and secondary level education, lowering the infant and under-five mortality rate and maternal mortality ratio. Moreover, there has been a robust growth in GDP accompanied by structural transformation of the economy with greater share of manufacturing and services sectors; and declining share of agriculture.

We hope that adaptation and mitigation measures proposed in this report will be useful for government and development partners to promote resilient development and green growth and hope that the words will be turned into concrete implementation action.

I would like to extend my heartiest thanks to all those who contributed their knowledge, expertise, experience, and provided substantive inputs toward preparation of this Third National Communication.

Sudipto Mukerjee
Country Director
UNDP Bangladesh

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ACRONYMS

ADB	Asian Development Bank
AEZ	Agro Ecological Zone
ALGAS	Asia Least-Cost Greenhouse Gas Abatement Strategy
ALU	Agriculture and Land Use
ATD	Analytical Thermal Desorption
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Centre for Advanced Studies
BCCRF	Bangladesh Climate Change Resilience Fund
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BCCTF	Bangladesh Climate Change Trust Fund
BCF	Billion Cubic Feet
BCIC	Bangladesh Chemical Industries Corporation
BCCRF	Bangladesh Climate Change Resilience Fund
BCR	Biomass Conversion/Expansion Ratio
BCSIR	Bangladesh Council of Scientific and Industrial Research
BEPP	Bangladesh Energy Planning Project
BFRI	Bangladesh Forest Research Institute
BINA	Bangladesh Institute of Nuclear Agriculture
BPC	Bangladesh Petroleum Corporation
BPDB	Bangladesh Power Development Board
BRRI	Bangladesh Rice Research Institute
BSMRAU	Bangabandhu Sheikh Mujibur Rahman Agricultural University
BUET	Bangladesh University of Engineering and Technology
C- CDAT	Cluster-Capacity Development Technical Assistance
$CaCO_3$	Calcium carbonate
CAN	Climate Action Network
CaO	Calcium oxide
CCA	Climate Change Adaptation
CCC	Climate Change Cell
CCU	Climate Change Unit
CDM	Clean Development Mechanism
CEGIS	Centrer for Environmental and Geographic Information Services
CF	Correction Factor
CFC	Chlorofluorocarbon
CFD	Carbon Faction of Dry Matter
CH_4	Methane
CH_4N_2O	Urea
CIP	Country Investment Plan
CNG	Compressed natural gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COP	Conference of Parties
CV	Calorific value
DAE	Department of Agriculture Extension
DAP	Diammonium phosphate
DLS	Department of Livestock Services
DMIN	Disaster Management Information Network
DoE	Department of Environment
EF	Emission Factor

EFt	Enteric Methane Emission factor
EPA	Environmental Protection Agency of United States
FAO	Food and Agriculture Organization of the United Nation
FD	Forest Department
FFF	Forest-Fish-Fruit
FO	Furnace oil
GEF	Global Environment Facility
GFRA	Global Forest Resource Assessment
Gg	Gigagram
GHG	Green House Gas
GOB	Government of Bangladesh
GWP	Global Water Partnership
GWP	Giga watt Peak
GWP	Global Warming Potential
HA	Harvested Area
HFC	Hydrofluorocarbons
HOBC	High Octane Blending Component
ICRD	Integrated Coastal Resources Database
ICZMP	Intergrated Coastal Zone Management Plan
IIED	International Institute for Environment and Development
INC	Initial National Communication
IPCC GL	Intergovernmental Panel on Climate Change Guidelines
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial process and other product use
JFCL	Jamuna Fertilizer Co. Ltd.
KAFCO	Karnaphuli Fertilizer Company Limited
Kg	Kilogram
KT	Kilo Tonne
KW	Kilo Watt
LDC	Least Developed Countries
LPG	Liquefied Petroleum Gas
LUC	Land Use Class
LUCF	Land Use Change and Forestry
LULUCF	Land Use, Land Use Change and Forestry
MCTBK	MCBTK Movable Chimney Bull’s Trench Kilns
MDGs	Millennium Development Goals
Mha	Million hectares
MIS	Management Information System
MoA	Ministry of Agriculture
MoEFCC	Ministry of Environment, Forest and Climate Change
MS	Gas Chromatography/Mass Spectrometry
MSW	Municipal Solid Waste
Mt	Metric Tonne
MT	Million Tonnes
MW	Mega Watt
N	Nitrogen
N_2O	Nitrous Oxide
NACOM	Nature Conservation Management
NAPA	National Adaptation Programme of Action
NFA	National Forest Act
NG	Natural Gas
NGFF	Natural Gas Fertilizer Factory

NH_3	Ammonia
NMVOC	Non-methane volatile organic compounds
NOx	Nitrogen oxides
NWRD	National Water Resources Database
ODS	Ozone Depleting Substances
PFC	Per-fluorinated Compound
QA/QC	Quality Assurance/Quality Control
REED	Reducing Emissions from Deforestation and Forest Degradation
RPGCL	Rupantarita Prakritik Gas Company Limited
SANDEE	South Asian Network for Development and Environmental Economics
SDGs	Sustainable Development Goals
SF	Scaling Factor
SF_6	Sulfur hexafluoride
SGFL	Sylhet Gas Fields Limited
SHS	Solar Home System
SIEF	Seasonally Integrated Emission Factor
SKO	Superior Kerosene Oil
SNC	Second National Communication
SO_2	Sulphur Dioxide
SRDI	Soil Resource Development Institute
TACCC	Transparency, Accuracy, Consistency, Comparability and Completeness
TJ	Terajoule
TNC	Third National Communication
UNDAF	United Nations Development Assistance Framework
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
WARPO	Water Resources Planning Organization
ZFCL	Zia Fertilizer Company Ltd

Executive Summary

A National Communication is a reflection of aggregate adaptation and mitigation actions taken by a country to address climate change. The preparation of a National Communication by Non-Annex I country parties is not mandatory. Bangladesh submitted its Initial National Communication in 2002 and the Second National Communication in 2012, and prepared its Third National Communication (TNC) in June 2018 for submission to the UNFCCC.

The Government of Bangladesh (GoB), represented by the Ministry of Environment, Forest and Climate Change (MoEFCC), and its operational arm, the Department of Environment (DoE), engaged several climate experts to prepare five chapters on national circumstances, greenhouse gas (GHG) inventory, programmes containing measures to mitigate climate change, programmes analysing vulnerability to climate change and identifying measures to facilitate adaptation to climate change, and other information considered relevant to the achievement of the objectives of the UNFCCC.

National Circumstances

Location and Physical Characteristics of Bangladesh

Bangladesh is a small country in terms of its territory with an area of about 147,570 sq. km. It is located in the tropics between 20º34´ to 26º38´north and 88º01´ to 92º41´east in South Asia and is bordered by India on the west, the north and the north-east and Myanmar on the south-east. The Bay of Bengal demarcates the southern border with a long coastline and the Himalayas are close to the northern border of Bangladesh. The country consists of low and flat land, with the exception of a small proportion of hilly regions in the north-east and the south-east and some areas of highlands in the north and north-west. Floodplains occupy about 80% of the country.

The geographical characteristics of Bangladesh are heavily dependent on local and regional hydrological characteristics. These hydrological conditions again rely on climatic processes, including on the dimensions of seasonality. Flooding, cyclones and drought conditions are some phenomena resulting from the prevalent hydro-meteorological processes. Land morphology, soil conditions and river systems also play contributory roles in defining the geographical characteristics of Bangladesh.

Bangladesh is the largest deltaic region in the world with most of the country at low elevations. It is a riverine country traversed by innumerable rivers, rivulets and their tributaries. The country is divided into three major physiographic units - floodplains (occupying an area of 79% of surface land), uplifted terraces (9%) and hills (12%). The landscapes, hydrological conditions and soil characteristics are different in these physiographic regions of the country. The land is classified into six categories according to the depth of flooding that occurs: highland, medium highland, medium lowland, lowland, very lowland and bottomland.

Climatic Conditions

Bangladesh is situated in the sub-tropical regions but displays a tropical monsoon climate characterized by heavy summer rainfall and high summer temperatures. The reason for these climatic conditions is Bangladesh's geographic location; the Himalayan mountain range acts as a barrier to moisture-laden monsoon winds in the summer season which cause intense rainfall, and helps protect the country from extreme cold wind blowing towards it from the north. Hilly terrains in the eastern parts of the country cause the country to receive huge amounts of water as surface runoff during the monsoon season from June to September.

There are four distinct seasons: the cool dry winter from December to February; the hot pre-monsoon summer from March to May; the hot and humid rainy monsoon season from June to September; and the hot and humid but drier autumn from October to November, when the south-west wind retreats.

The mean annual temperature in the country is about 25°C. The mean monthly temperature ranges between 18°C in January and 30°C from April to May. The highest temperatures throughout the year range between 38°C and 41°C. The average annual rainfall in the country is about 2,200 mm. About 80% of the total rainfall occurs from May to September.

Natural Resources

Water plays a vital role in the environment and in the economy and is critical in agriculture (crops, forestry, fisheries and livestock) and in sustaining life and livelihoods.

Availability of fresh water in Bangladesh is highly seasonal and depends on monsoon rainfall both inside and outside of Bangladesh in the GBM (Ganges-Brahmaputra-Meghna) catchments. Monsoon accounts for 70 – 85% of annual rainfall, and about 92% of the annual run-off; 8% is generated by rainfall within the country. The entire water ecosystem of Bangladesh, comprised of the GBM Rivers, their tributaries and distributaries, and perennial and seasonal water bodies like *haors, baors and beels,* is characterized by this seasonality of rain and its variability. All three river systems originate outside Bangladesh. Of the 230 rivers in the country 57 are trans-boundary rivers and Bangladesh is situated at their lowest points. Of the 57, 54 come down from India and 3 from Myanmar.

The same pattern of seasonality in rainfall is applicable to river flows as well, as river flows greatly depend on monsoon rainfall and the summer snow melt in the upper Himalayas. The table below shows the peak discharge for mean and 20-year return period floods for the Ganges, Brahmaputra and Meghna, with 1994 as the reference year.

River	Mean Peak Discharge	20-year Return Period	% difference bet. mean peak & 20-yr return period
Ganges	51,050	66,354	30.0
Brahmaputra	67,200	89,025	32.5
Meghna	14,080	19,016	35.0

Agriculture and Forest Resources

Agriculture includes crops, fisheries, forestry and livestock. The sectors are inter-dependent and when one is impacted there will be a spill-over effect on to another. Understanding and identifying these cause-and-consequence links is a challenge, and links often go unnoticed.

The irrigated area available for crop cultivation in Bangladesh has increased manifold over the years and the increase in crops has led to increased demands for water. Deep tube wells, shallow tube wells and low lift pumps are widely used to extract ground water, and drought conditions have forced farmers to draw more water from groundwater aquifers. Unsustainable ground water irrigation has already caused the water table in many parts of the country to dip very low. Floods, cyclones, storm surges, river bank erosion, and salinity intrusion all affect crop production, livestock and fisheries. As a result, people become more vulnerable and turn to the extraction of natural resources including forest resources for survival. Forest resources function as a carbon sink, a safe haven for thriving biodiversity, a source of food and fuel for local people and a shield against natural disasters such as cyclone and tidal floods, but forest land now only covers 17.08% of the land.

Natural Disasters

Flood

Flooding is a common yearly phenomenon in Bangladesh that happens in the rainy season as a result of overtopping of the runoff from the rivers and canals and spreads over vast areas of floodplains. A normal flood that covers 22-30% of the country serves a useful purpose as it carries useful soil nutrients which contribute to good crop yields.

Catastrophic floods destroy or damage houses, infrastructure and livelihoods. The major forces causing floods in Bangladesh are: monsoon rainfall patterns (both within Bangladesh and upstream in India. Nepal and elsewhere); simultaneously peaking water levels in the Ganges, the Brahmaputra, and the Meghna rivers; tidal conditions (including wind) in the Bay of Bengal; and human interventions in floodplain areas. Climate change influences all of these forces and major floods are occurring with increasing frequency and with increasingly devastating consequences.

In Bangladesh rivers show markedly seasonal flows. The Brahmaputra and the Meghna rivers often begin to rise in March and April as a result of heavy pre-monsoon rainfall in north-eastern India and north-eastern Bangladesh. Conversely, the Ganges usually starts to rise in May because pre-monsoon rains start later in the Ganges basin. In June, monsoon rainfall causes all three rivers to start rising. Usually, the Brahmaputra river reaches its peak flow in July-August and the Ganges in August-September but, all three rivers may and occasionally do peak together with devastating results. Even, two peaking together spells a major disaster. It is important to note that the river levels, rainfall patterns and river flows vary from year to year meaning floods may occur when people least expect them.

Cyclonic disturbances

Depressions, storm surges and tropical cyclones are natural hazards that occur in the Bay of Bengal as a result of temperature increase causing a drop in wind pressure. Bangladesh Bureau of Statistics (BBS). in its Statistical Yearbook of Bangladesh 2014. reports that altogether 21 tropical cyclones (wind speed >117 km/hr) and severe cyclones (wind speed between 87 to 117 km/hr) struck the Bangladesh coast between 1960 and 2010. Of these cyclonic disturbances, 33.33% happened in pre-monsoon seasons, while the remaining 66.66% occurred in post-monsoon seasons.

Sea level rise and associated risks

The coastal areas of Bangladesh have witnessed changing sea levels for at least the last 11,000 years. A third of sediments carried by the three major rivers is deposited in floodplains and in the channels of the delta, and waves and tides deliver a small portion of sediment to the inactive, tidal portion of the delta at a rate about of 10mm (highest) per year. This active delta coupled with the coastal zone's low elevation (one to three metres in the south-western and central part of the country and four to seven metres in the south-eastern part) make the coastal zone vulnerable to storm surges and submergence of land by sea water.

Salinity intrusion

One of the most immediate and long-term threats of climate change is the salinity intrusion which occurs as a result of sea level rise and affects surface (i.e. river) as well as ground water systems and the soil. The nature of salinity intrusion in the coastal areas depends on a number of factors such as a reduction of fresh water flows from the Ganges, siltation in the tributaries of the Ganges and siltation in other rivers due to the impacts of polders. It was observed that between 1962 and 2008 salinity increased from 2ppt to 20ppt in the Passur river in Mongla in the south-western coastal. Study findings suggest that total soil salinity has increased to about 1.056 million hectares from 0.8333 million hectares in about four decades.

GHG Inventory

GHG Inventory is a large part of the Third National Communication (TNC) and includes the whole of Bangladesh. The inventory covers five major activities: energy (electricity generation including biomass burning, transport and energy consumed by the industrial sector); industrial processes and other product use (IPPU) (cement manufacturing and fertilizer); agriculture (ruminant livestock, livestock management and rice cultivation); land use change and forestry (changes in forest cover and woody biomass, changes in forest land use and forest resources removal); and waste and refuge management (municipal waste, domestic and industrial waste water treatment/ management).

CO_2 Emission from Energy Sector

In the energy sector, the fuels used in Bangladesh include natural gas, crude oil, diesel, kerosene, gasoline, jet fuel, furnace oil, LPG, natural gas liquids, coal and biomass. All energy consuming sectors in Bangladesh were identified and data on fuel consumption by each sector and the different fuels in use was collected from relevant sources. This was then reorganized into sub-sectors under the energy sector as specified in the IPCC 2006 Guidelines. Not all combustion activities and sectoral splits in the guidelines are relevant for Bangladesh, so the important step here was to select the appropriate ones. Emissions of CO_2, N_2O and CH4 were then calculated using the default heating values and emission factors for each type of fuel. For cross-checking purposes a reference approach was used. This involved estimating the total consumption only of each fuel, not by sector.

The table below shows the total estimated CO_2 emissions in the energy sector from reference and sectoral approaches for the years 2006 to 2012. It can be seen that the differences between these two approaches are within acceptable limits.

Summary of Energy Sector CO_2 Emission (Gigagrams)

Year (2006 -2012)	2006	2007	2008	2009	2010	2011	2012
Sectoral	45,411	48,224	51,915	57,547	64,476	65,510	69,867
Reference	50,061	52,371	55,608	58,612	63,853	68,242	74,249
Difference	4,650	4,147	3,693	1,065	(623)	2,732	4,381
% difference	10.24%	8.60%	5.96%	1.85%	-0.97%	4.17%	6.27%

Emission from Industrial Processes and Product Use

Total carbon dioxide emission from one cement factory and six fertilizer factories in the assessed inventory years was 1535,1683,1591,1311,1237,1390 and 1121 Gg respectively.

Emission from Agriculture Sector

The estimated GHG emissions from the agriculture sector are shown in the following table (Gg CO_2eq)

Source of Emission	2006	2007	2008	2009	2010	2011	2012
CH_4 emission from rice field	13583	13814	14357	14702	14686	14924	15089
Direct Nitrous Oxide (N_2O) from Fertilizer application	5375	5567	5631	5465	5563	4966	5251
Indirect Nitrous Oxide (N_2O) emissions from N based fertilizer	1746	1809	1831	1776	1808	1614	1707
Total Enteric CH_4 Emissions	12389	12562	12717	12888	13064	13233	13421
Total Manure CH_4 Emissions	2938	2963	2981	3005	3029	3051	3076
Total Direct N_2O Emissions from Manure System	4794	4847	4892	4945	5000	5050	5109
Total Indirect N_2O Emissions – Volatilization	1599	1623	1640	1662	1683	1703	1726
Total Indirect N_2O Emissions - Leaching/Runoff	450	349	465	473	481	489	498
Total	42874	43534	44514	44916	45314	45030	45877

Emission from Land Use Change and Forest

In Bangladesh there are dispersed forests, some uplands, plains and wetlands and diverse flora and fauna. Villages of Bangladesh have a long heritage of growing trees along with other perennial shrubs and herbs. Land is also used for homesteads on which crops are grown alongside trees and share land with livestock or poultry, mainly for the purpose of meeting farmers' basic needs.

Bangladesh Forest Department prepared a National Forest and Tree Resources Assessment 2005-2007, which acted as the base report for most of the carbon related assessment conducted in this sector. The changes in bio-mass carbon stocks in the inventory period were estimated and are shown in the LULUCF chapter. The total estimated CO_2 emission from LULUCF sector was 8,177 Gg in the year 2012.

Emission from Waste Sector

Methane (CH_4) emission from waste sector: Landfill sites in Bangladesh are usually unmanaged and open dumps can be optimal for landfill gas emission. Huge amounts of municipal solid waste (MSW) are dumped at the dumping sites daily, producing significant amounts of CH_4 which is then emitted into the atmosphere. A considerable amount of the generated waste remains scattered and because of aerobic conditions, the scattered waste produces little or no methane. To measure methane emission, two methodologies – that of IPCC guidelines and a Bangladesh specific methodology - were applied and the results compared. The IPCC methodology put the total annual methane (CH_4) generation from waste in six city corporation areas (Dhaka. Chittagong, Khulna, Rajshahi, Barisal and Sylhet) at about 15.513 Gg/ year. Municipalities were not included in this calculation because in most cases waste dumping is unorganized and the correction factor is taken to be zero.

Maximum average emission of CH_4 per Kg MSW under prevailing conditions in Bangladesh is 0.0276 m^3 under anaerobic conditions. In the open dumping site, as measured in Dhaka, the average CH4 production is 0.0179 m^3 per Kg of MSW. Based on this emission factor, the total emission from MSW of the six city corporation areas in the assessed inventory years was 80, 84, 87, 90, 92, 95 and 97 Gg respectively. Total CH4 emission from domestic waste water in the assessed inventory years was 695, 706, 717, 729, 740, 752 and 764 Gg respectively. Nitrous Oxide emission from domestic wastewater in the assessed inventory years was 5.0843, 5.1668, 5.2499, 5.3336, 5.4175, 5.5026 and 5.5898 Gg/year respectively and methane emission from industrial wastewater in some selected industries in the assessed inventory years was 4.14, 11.60, 14.33, 17.45, 21.55, 22.76 and 24.21 Gg respectively.

Summary of Bangladesh GHG emissions in 2012

Inventory Year: 2012			
	Emissions (Gg)		
Greenhouse gas source and sink categories	**CO_2 Emissions (Gg)**	**CH_4 Emission**	**N_2O Emission**
Total National Emissions and Removals			
1 - Energy	69867.27	93.18	3.69
1.A - Fuel Combustion Activities	69867.27	93.18	3.69
A- Electricity Generation	29130.01	0.57	0.08
B- Manufacturing Industries and Construction	20018.41	1.35	0.20
C-Transport	8441.99	89.87	3.35
D- Other Sectors	12276.85	1.40	0.06
2 - Industrial Processes and Product Use	1121.13		
2.A - Mineral Industry	674.61		
A-Cement production	674.61		
2.B - Chemical Industry	446.51		
A - Ammonia Production	446.51		
3 - Agriculture			
A - Enteric Fermentation		536.86	
B- Manure Management		123.04	17.14
C- Rice Cultivation		603.55	
D- Direct Nitrous Oxide (N_2O) from Fertilizer application			17.62
E-Indirect Nitrous Oxide (N_2O) emissions from N based fertilizer			5.73

Greenhouse gas source and sink categories	Emissions (Gg)		
	CO_2 Emissions (Gg)	CH_4 Emission	N_2O Emission
F-Total Indirect N_2O Emissions – Volatilization			5.79
G-Total Indirect N_2O Emissions - Leaching/Runoff			1.67
3.B - Land-use change and Forestry			
A- CO_2 emission from soil	3247		
B - Conversion of forest land to other land use	561.53		
C- CO_2 emission due to fuel wood removal for Consumption	4,368		
4 - Waste			
A- Solid Waste Disposal		97	
B- Methane emission from domestic waste water		764	
C- Nitrous Oxide Emission from Domestic wastewater			5.59
D- Methane emission from Industrial waste water		24.31	
Memo Items (5)			
International Bunkers	601.05	0.006	0.017
A- International Aviation (International Bunkers)	577.68	0.004	0.017
B- International water-borne navigation (International bunkers)	23.37	0.002	0.001
Memo Items			
CO_2 from Biomass burning for Energy purpose	53837.92		
Total CO_2e emission from all sources in Gigagrams	**152269**		
Total CO_2e emission from all sources in Million Tons	**152.27**		
Total Aboveground Biomass Carbon Stock in Million Tons as per Major National Land Use Categories (NLUC)	**-378.98**		

In 2012 per capita emission from all sectors is 0.98 tons CO_2 eq and 0.27 tons Carbon eq.

Mitigation Measures

Bangladesh is a country with a low level of absolute, per capita, per GDP unit of GHG emission, compared to other developing countries. As a least developed country (LDC), Bangladesh is exempt from climate change mitigation; according to the 2015 Paris Agreement mitigation should be based on nationally determined contributions (NDC) and national circumstances.

The mitigation sectors in Bangladesh include energy, industry, land use, land use change and forestry (LULUCF), waste and some others. Primary energy consumption in Bangladesh is one of the lowest in the world. In 2008, the country's per capita annual energy consumption was about 182 kgoe and per capita electricity generation was 236 kWh. Following intensive efforts to increase coverage, about 80% of the population now has access to electricity. The country's power generation installed capacity was 15000 MW as of November, 2016 and the maximum generation was 9,036 MW.

To estimate the long-term power demand and taking into consideration the future change of the daily load curve, a daily load curve up to 2041 estimated was superimposed on the maximum power demand with consideration given to the potential demand up to 2041. The transition of power demand at intervals of five years from 2015 shows a rising trend in power demand from 2015 to 2041. The maximum power demand could be 8921, 12949, 19191, 27434, 36634 and 49034 MW at five-year intervals from 2015. The government plan is that the installed capacity will be increased to around 60,000 MW by 2041. The scenario indicates that increasing amounts of GHGs will be emitted from the power sector. A strategic plan is therefore required to mitigate the emission and keep it at a level consistent with the policy of pursuing a low carbon development pathway.

A rapidly growing country like Bangladesh needs a huge amount of energy to achieve its development targets. In the past decade, primary energy consumption has increased over 100% and this trend will no doubt continue in the coming years. It is also evident in the latest sector-wise energy consumption (industrial, residential, transport, agriculture and commercial) prospects estimated in the Energy Efficiency Master Plan and recently adopted by the Power Division under the Ministry of Power, Energy and Mineral Resources. Industry is responsible for the biggest share at 47.8%, followed by residence and transportation at 30.5% and 11.5%, respectively. From the macro point of view, the amount of national energy production stands at 27,187 ktoe, while the amount of primary energy use was 33,550 ktoe, including imported fuel.

Bangladesh is developing fast, and rapid industrialization is taking place. It is expected that there will be a shift or an expansion in the industrial sector from labour-intensive industries like that of the ready-made garment (RMG) industry to energy-intensive industries. As a result, energy consumption in the industrial sector is expected to increase more rapidly. Also, as growth in GDP per capita is expected to facilitate more and more vehicle ownership and transport development in various modes, it is estimated that energy consumption in the transport sectors will increase significantly.

The business-as-usual (BAU) scenarios for all sectors were analysed during the preparation of the INDC. GHG emissions are expected to increase by 150% by 2030 from their 2011 levels, an increase from 136.14 $MtCO_2e$ in 2011 to 339.69 $MtCO_2e$ in 2030. The outcomes of the data analyses for the TNC for 2011 and 2012 are more or less the same. In the INDC, the LULUCF sector was not considered. The estimated BAU emissions for power, transport, and industry together are expected to increase by 264% between 2011 and 2030 or from 64.20$MtCO_2e$ to 233.76$MtCO_2e$. Bangladesh has the potential to address mitigation actions in a number of areas but mitigation will depend on the availability of funding from national and international sources. Potential areas are: power generation, transmission and distribution; transport – road, rail, water and aviation; energy intensive industries – public and private; residential/commercial – lighting, cooling, motors, cooking and buildings; cross-sectoral options (boilers; hollow bricks; DSM); and renewable energy (solar PV, biomass and wind).

Climate Change Vulnerability and Adaptation

Bangladesh is one of the most climate vulnerable countries in the world (German Watch, 2016) and the challenges posed by climate change make the lives and livelihoods of millions of people increasingly complex and vulnerable. Historically, Bangladesh has faced the adverse impacts of climate variability and change that threaten its economic growth and sustainable development. The country is at risk of natural disasters such as riverine floods, recurrent and flash floods, tropical cyclones and storm surges, droughts, salinity intrusion, sea-level rise, and riverbank and coastal erosions. Climate change is causing the duration, magnitude and frequency of such natural disasters to increase, making poor communities increasingly vulnerable. Despite being the ground zero of the impacts of climate change, Bangladesh has been working persistently to tackle its high level of vulnerability and at the same time, has been pursuing development objectives to improve the socio-economic conditions of its vulnerable communities. Over the last decade, Bangladesh has played a significant leadership role in the context of adaptations to climate change; it has not only introduced innovative approaches to adaptation in vulnerable communities, but has also actively mobilized resources as far as possible to tackle the challenges of climate change.

Over the last three decades, the GoB has invested over $10 billion (at 2007 constant prices) to make the country more climate resilient and less vulnerable to natural disasters. Flood management embankments, coastal polders and cyclone shelters have been built, and important lessons have been learnt on how to implement such projects successfully with the active participation of communities.

Sectoral Impacts, Vulnerability and Adaptation to Climate Change

Impacts on agriculture and food security

In Bangladesh, crops are highly vulnerable to three types of hazards: floods, droughts and cyclonic storms and associated storm surges. Annually 22-30% of the country is usually inundated. A major flood event may inundate two-thirds or more of the country. Thus, for example, the 1998 flood inundated about 70% of the country. Every year, droughts of different magnitudes affect three to four million hectares of crop land. In the drought season (usually the dry months) rainfall is sparse during the critical growth stages of crops which as a consequence suffer from soil moisture deficits. Floods cause crop losses through inundation for prolonged periods and losses may be exacerbated by the timing, magnitude and duration of the flood.. For example, a very severe drought can devastate up to 70-90% of the T.aman crop. The Rajshahi and Nawabgonj districts are prone to very severe droughts; the 1978-1979 drought affected 42% of the cultivated land and crop loss was estimated to be two million tons. Crop losses from the 1997 drought amounted to one million tons valued at $500 million (Selvaraju, 2006). The 1998 floods stayed 67 days above the danger levels at different locations in the country and caused considerable damage to agriculture. In November 2007, Cyclone Sidr affected nearly ready for harvest crops in 0.9 million hectares in the south-west region of Bangladesh (IFRC, 2010). Many households also lost their food stocks because their homes were damaged. Two years later in 2009, Cyclone Aila destroyed 0.186 million hectares of crops fully and partially destroyed 0.49 million hectares of crop (DMB, 2010).

Potential Impacts of Climate Change on Agriculture in Bangladesh

Climate Variables Temperature changes	Potential Impacts on the Agriculture Sector
Increases in very hot days and heat waves	Modification in crop suitability and productivity (heat stress) Increase in weeds, crop pests and disease outbreaks Changes in crop water requirements. The quantity and quality of yield depend on the number of days that a crop is exposed to temperatures exceeding specific thresholds during critical growth stages (i.e., flowering, pollination, fruiting, or grain filling)
Fewer cold days and nights	Increased yields in colder environments Reduction in the risk of frosts and subsequent crop failure
Increase in intense precipitation events	Damages to crops Increased water-logging, inability to cultivate lands Damage to drainage systems due to flooding Increased extent and intensity of erosion and water-logging. Increased pest incidence
Increase in drought conditions	Lower yields from crop damage, stress, and/or failure Loss of arable land as a result of land degradation Loss of arable lands Increased competition for water Increased risk of food insecurity
Increase in the frequency of floods	Crop failure and damage to crops due to flooding Yield decreases Increased risk of health hazard due to lack of nutrition
More frequent strong tropical cyclones	Damages to crops and rural infrastructure Frequent occurrence of cyclonic hazard de-motivates farmers to continue farming
Sea level rise and storm surges	Damage to crops and rural infrastructure due to flooding Seawater intrusion, loss of arable land, salinization of water supply (groundwater in particular)
Increase in CO_2 concentration	Increased biomass production and increased physiological efficiency of water use in crops and weeds Increased efficiency of water used by crops. Potentially increased weed to compete with crops

Projected Impact on Water Sector

An increase in greenhouse gases will increase net radiation on the earth's surface which will cause increases in temperature, evaporation and precipitation. Increasing temperature leads to increasing evaporation on both the land and in the ocean. Due to increased evaporation, more water vapor will be available in the atmosphere. Increased global temperature reduces moisture content in the soil. Eventually this process will affect surface runoff and groundwater recharge. The water sector in Bangladesh is highly vulnerable to changes in climatic parameters, temperature and precipitation; to the frequency, intensity and magnitude of extreme events; and to rising sea level. Human interventions in the large shared river basins may lead to further complexity. The following are the key vulnerabilities in the water sector due to climate change in Bangladesh.

Glaciers will continue to shrink in almost all parts of the world (IPCC, 2014). Accelerating melting of the Himalayan glaciers is a concern for Bangladesh's water flows, especially in the dry season. Due to the high variability of seasonal water flows, dry season water is vital to support the ecosystem, agriculture, fisheries and navigation. While glacier melting will lead to an initial increase in water flows, they will later decrease due to a shrinkage of the glacier mass. Sediment supply in the Ganges and Brahmaputra rivers could increase in the dry season which may result in increased siltation and, hence, reduced water carrying capacity of the channels.

Rate of evaporation from the soil, open water and plants would increase as temperature rises. Soil storage systems would therefore capture the larger amount of infiltrated water resulting in a reduction in deep percolation to shallow aquifers as the upper limit of infiltration is limited by soil type. As a result, groundwater recharge is likely to be reduced. In the dry season, groundwater storage is the source of base flow in the rivers in Bangladesh. Therefore, any reduction in groundwater storage would adversely affect dry season river flows.

All models and all scenarios project an increase in both the mean and extreme precipitation in the summer monsoon period due to increase in supply of moisture from the ocean to the land despite a weakening of monsoon winds (IPCC AR5 WGI, 2013). The onset of monsoon could be earlier and its withdrawal, later. This implies a longer flooding season in Bangladesh. Increased temperature and higher rates of soil moisture loss could lead to longer and high impact droughts in the country.

Impacts on Health Sector

Climatic activity has a significant influence on human health. A changing climate impacts health and well-being, but it is difficult to determine the degree of complexity, scale and directness to which it does so. Consequently, given geographical and environmental realities and the vulnerability of the local population, particularly in rural areas of Bangladesh, impacts would also vary. In view of interactions between ecological and social processes, it is difficult to determine the contribution of environmental and biological influences of climate change on health. The changes in exposure to heat waves, winter cold, increases in floods, cyclones, storm surges, droughts, increased air pollutants and aeroallergens like spores and molds are all considered to have direct impacts on the health sector of this country in terms of lives lost, injuries, and disease outbreaks (Michael, 2003).

Impacts on Fisheries sector

Climate change is likely to adversely affect fish production and diversity; fish habitat; fish physiology; fish reproduction systems, growth, and migration; fishery and aquaculture related infrastructure; and the lives and livelihoods of people dependent on fishing. Some effects such as prolonged high floods may be beneficial to certain aspects of fishery; increased area and depth of inland open waters with sufficient nutrients may stimulate breeding, growth and migration.

Impacts on livestock sector

Effects of air temperature, humidity, rainfall, heat and cold waves, wind speed and other climatic factors have a direct influence on animal growth, milk and wool production and reproduction. Indirect effects include climatic influences on the quantity and quality of feed such as fodder, grain and pasture and the outbreak and on the severity of livestock diseases and parasites. Global climate change is expected to alter temperature, precipitation, atmospheric carbon dioxide levels and water availability in ways that will affect crop yields and livestock productivity. Like human beings, livestock and poultry may suffer due to natural disasters, higher temperatures, salinity intrusions and floods. As compared to other sectors, there are very few economic analyses available on the climatic effects on the livestock sector worldwide.

The most important impacts of climate change on the livestock sector are reduced grazing areas, fodder crises, reduced growth and decreases in the production of milk, meat and eggs. The livestock sector of Bangladesh is dominated by homestead rearing and vulnerable to natural hazards such as cyclones, storm surge, and floods. Animals and poultry, ill-protected in their habitats, are often the first victims of natural disasters.

Impacts on Livelihood

As noted earlier, because of its geographic location, geomorphological conditions, demographic and socio-economic features, Bangladesh is highly vulnerable to climate change. Both rapid onset and slow onset climatic hazards and disasters cause serious havoc to the socio-economic fabric of the country. Climate change induced vulnerabilities are likely to be exacerbated further in the future with heightened changes in the climate. Given that different climatic events are likely to be more frequent and more severe in the future, the increasing adverse impacts thereof will increasingly jeopardize livelihoods, especially of the poor who are mostly dependent on natural resources. There is also a threat to the consolidation of the socio-economic achievements Bangladesh has made in relation to poverty reduction and improvement in the population's living standards.

Impacts on the Coast of Bangladesh

Around one-third of the total population (over 150 million) of Bangladesh live in the coastal districts. The coastal population increased from 35.1 million in 2001 to about 50 million in 2011. The coast of Bangladesh, comprising 19 of 64 districts, while extremely fertile, is exposed to multiple vulnerabilities. Rich with natural and mineral resources, including gas and oil, the coastal zone accounts for 1.95 million ha or 41% of the total national agricultural land. However, it is particularly exposed to cyclone, storm surge, tidal flood, coastal erosion, water logging, variations in temperature and rainfall, salinity intrusion and sea level rise. People living in these low-lying coastal areas often suffer the impacts of the above mentioned natural disasters and the poverty rate in the coastal zone is higher than the national average (World Bank, 2014).

The IPCC has reported that increases of 2°C and 4.5°C of sea surface temperature (SST) would cause an increase of 10% and 25% in the wind speed of cyclones, respectively (IPCC, 2007). This means that the intensity of cyclones will increase with an increase in temperature. A total of 149 cyclones hit Bangladesh's coasts between 1891 and 1998. There are a recorded 38 cyclonic events that struck the south-western coast of the country between 1877 and 2010. (Islam and Peterson, 2008). With regard to the frequency of cyclonic events in the last 200 years, available evidence indicates that only three major cyclones hit the coasts of the country in the first and second fifty years (1795-1845 and 1846-1896), while 13 and 51 major cyclones affected the coasts in the third (1897-1945) and fourth fifty year (1948-1998) periods respectively (BBS, 1993; BBS, 2002d). World Bank reports (2010) that Bangladesh is located at the receiving end of at least 40% of the impacts of total storm surges in the world because of a number of geographical factors including its funnel shaped structure, shallow continental shelf, low elevation and location in a high tidal zone. Cyclones and storms are deadly (and their victims are often women and children) and have devastating effects on ecosystmes such as that of the fragile Sundarbans. The severe cyclone that struck Bangladesh in 1991 killed about 140,000 people, mostly from the Chittagong, Noakhali and Cox's Bazar districts, destroyed 1.75 million houses and damaged 6,500 schools and embankments of about 470 km. Salt water intrusion occupied rice crops of about 72,000 ha. Cyclones Sidr (2007) and Cyclone Aila (2009) were accompanied by 3-5.5 metre high storm surges, which brought saline water into agricultural lands and inundated the dwellings of many coastal communities. Cyclone induced saline intrusion in surface water and soil resources has become a serious challenge and the World Bank estimates that the adaptation deficit of Bangladesh in relation to cyclones is $25 billion.

Bangladesh has however made significant advancements in cyclone impact management, substantially reducing both impact risks and actual impacts through timely warning, evacuation of people, and improved relief and rehabilitation. Compared to the 1991 cyclone, the number of human lives lost due to cyclones is now a fraction of what it was.

Impacts on Urban Areas

The urban population of Bangladesh will exceed 50% of its projected total population by 2050. The annual growth rate of the urban population in Bangladesh during the last decade of population census (2001-2011) was 3.5%, while for the greater Dhaka area it was 4.7%. Rapid population growth and mass urbanization are putting severe pressure on agricultural lands, water bodies, forest, wetlands and municipal services (drinking water and sanitation facilities, drainage, education, health). The pressure is greater in larger cities as more and more people, lured by employment prospects, move to them. As demand for land has increased, encroachment on and changes in land usage have been rampant. The urbanization impact, compounded by unplanned industrialization, unplanned settlement formations such as slums, haphazard transportation and infrastructural development and climate change pose tremendous challenges in the context of developing and implementing planned and sustainable urban development.

The potential impacts of climate change on urban cities and their populations were identified by examining the cities' vulnerabilities and capacity for adaptation. City dwellers face high levels of risk with regard to damages to and loss of property and in terms of consequences for their health.

Priority Areas for Climate Change Adaptation

The Government of Bangladesh has identified the following areas of intervention to address the adverse impacts of climate change.

Key areas of intervention to address adverse impacts of climate change	
1	Food security, livelihood and health protection (including water security)
2	Comprehensive disaster management
3	Coastal zone management including salinity intrusion control
4	Flood control and erosion protection
5	Building climate resilient infrastructure
6	Increased rural electricity
7	Enhanced urban resilience
8	Increasing resilience of vulnerable groups
9	Development of climate resilient cropping systems
10	Development of surveillance systems for existing and new disease risks
11	Ecosystem based adaptation (including forestry co-management)
12	Community based conservation of wetlands and coastal areas
13	Implementing drinking water and sanitation programmes in areas (e.g., coastal areas, flood- and drought-prone areas) move at risk from climate change
14	Policy and institutional capacity building

Based on the above-mentioned areas, the following adaptation actions are priorities for Bangladesh.

Adaptation priorities for Bangladesh	
1	Improved early warning systems for tropical cyclones, floods, flash floods and drought
2	Disaster preparedness and construction of flood and cyclone shelters
3	Protection against tropical cyclones and storm surge
4	Inland monsoon flood-proofing and protection
5	Climate resilient infrastructure and communication
6	Climate resilient housing
7	Repair and rehabilitate existing infrastructure (including coastal embankments, river embankments and drainage systems, urban drainage systems)
8	Plan, design and construction of urgently needed new infrastructure (various types of shelters, low cost disaster resilient housing, protection schemes, water management structures, etc.)
9	Improvement of urban resilience through improvement of drainage systems to address urban flooding

10	River training and dredging (including excavation of water bodies, canals and drains)
11	Development and dissemination of stress tolerant (salinity, drought and flood) varieties of rice; improved varieties of livestock and fisheries
12	Research and knowledge management
13	Adaptation based on local-level perspectives
14	Adaptation to climate change impacts on health
15	Biodiversity and ecosystem conservation
16	Capacity building at individual and institutional level to plan and implement adaptation programmes and projects in Bangladesh

Economy-Wide Damages and Losses

An ADB study (2014) conducted an economy-wide climate change impact assessment based on the Integrated Assessment Models for the South Asia region. The assessment shows that the average temperature could rise by 2ºC by 2050. By 2100, the average temperature is expected to rise by around 4ºC under the business as usual scenario. The rise in temperature will cause significant damages and losses to the economy. Bangladesh would face an annual GDP loss of around 2% by 2050. There is a 10% chance that losses will be over 4%.

In the long term, if no action is taken to adapt to or mitigate global climate change, the average total economic losses are projected to be 9.4% by 2100. The projected average losses do not include impacts of extreme events such as cyclones, storms, floods and droughts. The GDP losses would be lower at around 1.5% by 2050 and roughly 2.5% by 2100 if GHG emission and consequent temperature rise is kept below 2ºC.

Tropical Cyclone and Storm Surges

A World Bank Study (EACC, 2010) estimates that under the baseline scenario, the damages and losses stand at $4.6 billion from a single cyclone/storm surge of a ten year return period. With climate change, the damages and losses would increase to $9.16 billion, including $4.5 billion attributable to climate change.

The housing sector would suffer the worst damages and losses due to cyclonic storms accounting for 43% of the total damages and losses. Industry, commerce and tourism combined come next with 26%, followed by agriculture with 20% of the damages and losses due to climate change induced storm surges. Damages and losses due to tropical cyclones and storm surges that accounted for 0.3% of the GDP under the baseline scenario would rise to 0.06% of GDP in 2050.

Inland Flooding

Bangladesh historically incurs substantial damages and losses due to devastating inland flooding. However, relatively speaking, damages and losses have decreased over the years as a result of improved macroeconomic management, increased resilience of the poor, improvement in disaster management and flood protection infrastructure. The 1974 flood, a 1-in-99-year event, resulted in damages of 7.5% of the GDP. The 1998 flood, a 1-in-99-year event, caused damages equivalent to 4.5% of the GDP. In absolute terms, the damages of major floods were $0.9 billion in 1974, $1.4 billion in 1988, $2.2 billion in 1998, $1.8 billion in 2004 and $1.1 billion in 2007.

Agriculture

The EACCA study by the World Bank provides estimated damages and losses in agriculture, especially in rice and wheat production due to climate change. The study estimates the change in production of three seasonal rice varieties (*aus, aman* and *boro*) as well as wheat due to climate change (CO2, temperature and precipitation only are considered). It was found that the production of *aus* and *aman* would increase by 2% and 4% by 2030 and 2050 respectively. Wheat production would also increase by 4% by 2050. *Boro* production, however, would decline annually by 8% by 2080.

Production changes due to flood damages as estimated by the study show that *aus* and *aman* would fall by 2.4% and 4% respectively by 2050. *Boro* and wheat are assumed to be unaffected by floods. However, *boro* can be affected by flash floods in areas like haor.

Considering all climate change impacts (CO_2 fertilization, temperature and precipitation changes, flood changes, and sea level rise), the median of all rice crop shows a declining production. *Boro* will undergo the worst decline with median loss of 3% in 2030 and 5% in 2050 (ECCA, 2010). The losses in *aus* and *aman* production would range between 0.6 to 1.5%.

The study estimates that cumulative production will be reduced by 80 million tons in the 45-year period between 2005-2050 as the negative impacts of climate change will significantly outweigh any positive effects.

It is further projected that agricultural GDP will be 3.1 percent lower each year as a result of climate change. This will cost Bangladesh $129 billion in total GDP equivalent to a $2.9 billion overall loss each year. The annual loss may increase to $5.1 billion with the worst climate scenario.

The ADB 2014 study on costs of climate change and adaptation in South Asia shows that climate change would lead to a substantial yield reduction in rice crop in Bangladesh. Among the different climatic regions, maximum yield reduction will happen in the south-eastern and south-western regions of Bangladesh. Rice yield would decline by 5.3% for *aus,* 4.9% for *aman* and 4.6% for *boro* in the south-eastern regions by 2030. Further deterioration of rice yield would occur beyond 2030. Rice yield in the south-eastern region would decline by 10.3% for *aus*, 9.5% for *aman* and 5.5% for *boro* by 2050. The decline in rice yield in the south-west region is projected at 6.2% for *aus*, 5.6% for *aman* and 4.9% for *boro* by 2050.

Infrastructure

The 2014 ADB study also highlights that climate change and the resultant more frequent and devastating floods and cyclones will have a significant adverse impact on the infrastructure sector of Bangladesh. It is projected that due to the impact of climate change, the capital stock in the construction sector would be depleted by 0.05% annually until 2100. The magnitude of these negative impacts would intensify beyond the end of the century. The study points out that a negative stock on infrastructure as a result of climate change will have serious adverse effects on the overall economy of Bangladesh. Different economic sectors linked to infrastructure services would experience large falls in production. It is projected that real GDP would continue to fall by 0.62% by 2030 and 1.07% by 2100. The poor status of infrastructure is a serious constraint to the country's development efforts. Improving the country's infrastructure system will be essential for achieving a higher ratio of economic growth.

Cost of Adaptation

Adaptation and improving climate resilience are important to reduce damages and losses from climatic disasters to address climate change. Therefore, more investments would be required in early warning systems, improved irrigation and water management, improved operation and maintenance upgrading of coastal embankments and polders and upgrading of flood protection embankments/drainage systems. Adaptation cost estimates for all key economic sectors have not been made for Bangladesh but the World Bank (2010) estimated that, by 2050, adaptation costs in relation to tropical cyclones and storm surges will be $5,516 million with an annual recurrent cost of $112 million, while for inland monsoon flooding the cost will be $2,671 million with an annual recurrent cost of $54 million. Adaptation costs in respect of climate related diseases: diarrhea, kalazar, filariasis, dengue/malaria, chikungunya and chronic obstructive pulmonary diseases would be $4.01 billion for the 15-year period (1915-2030) which is equivalent to $272.1 million per annum.

Implementation of identified priority adaptation measures is critical to increase the resilience of the country to climate change and Bangladesh has already implemented or is implementing some key adaptation activities as urgent and immediate. It is estimated that an investment of $44 billion will be needed from 2015 to 2030 in order to implement identified adaptation measures to address the adverse impacts of climate change from tropical cyclones, monsoon flooding and climate related diseases.

Mainstreaming Climate Change

The Outline of the Perspective Plan: Vision 2021 is a strategic document which includes mitigation of the impact of climate change as one of the strategic cornerstones towards ensuring sustainable development. The 2009 Bangladesh Climate Change Strategy and Action Plan (BCCSAP) proposes 44 programmes under six thematic pillars related to adaptation and mitigation to be implemented within a ten year period. Bangladesh achieved significant successes with regard to goal 7 of the Millennium Development Goals (MDGs) which was to ensure environmental sustainability.

Bangladesh's Sixth Five Year Plan (2011-2015) emphasizes the importance of managing climate change and indicates the priorities for implementing the BCCSAP, 2009. Additionally, a National Plan for Disaster Management has been adopted, which addresses key natural disaster-related issues such as risk reduction, capacity building, climate change adaptation, livelihood security, gender mainstreaming, community empowerment, and response and recovery management. In May 2010, with the support of its development partners, Bangladesh established a Climate Change Resilient Fund. To date, $130 million has been disbursed through this fund to implement some of the programmes under BCCSAP. Moreover, the Government of Bangladesh (GoB) has allocated about $400 million from its annual national budget to the Bangladesh Climate Change Trust Fund to implement the BCCSAP.

Climate Change Research and Systematic Observation

The Bangladesh Meteorological Department (BMD) is the forerunner in generating, acquiring and handling meteorological data as it collects data from its 37 climate data stations all over the country. This climatic data includes evaporation, humidity, solar radiation, rainfall, sunshine hours, temperature and wind speed. The Bangladesh Water Development Board (BWDB) collects hydrologic information such as water level and discharge data as well as meteorological information. The Bangladesh Inland Water Transport Authority (BIWTA) collects water level data from its 43 tidal stations. The Flood Forecast and Warning Centre (FFWC) is an organization under BWDB that generates and provides flood forecast and warning information to enhance the disaster management capacity of national agencies and communities, using best scientific principles, real time data, weather forecast information and mathematical models. It functions as a centre of emergency response through Flood Forecasting and Warning Services (FFWS) to minimize or mitigate loss of life and damages to properties in the most effective manner possible within the framework of the national policy of disaster risk reduction. Currently, FFWC provides forecasts through its 54 forecast stations throughout the country.

Research Initiatives on Climate Change Scenario Generation and Physical Processes

Many research programmes on the climate change issues faced by Bangladesh have been conducted by a number of national and international organizations in recent years. Gobeshona, a knowledge sharing platform for climate change research in Bangladesh, shares information about completed publications, ongoing research, upcoming events and research opportunities relevant to climate change in Bangladesh through its web portal. As of October 2016, some 1,360 publications based on research works conducted since the 1970s, with direct or indirect links to climate change issues in Bangladesh had been published in this web portal, and of these, around 900 publications were published between 2012 and 2016.

Education, Training and Public Awareness

The formal education system, under the Ministry of Education and Ministry of Primary and Mass Education, has adopted a syllabus accommodating the study of climate change at primary, secondary and tertiary levels. A number of public and private universities have introduced undergraduate, postgraduate, and/or diploma courses on climate change related subjects including adaptation to climate change-induced disasters and risk reduction.

The Institute of Water and Flood Management (IWFM) at the Bangladesh University of Engineering and Technology (BUET) provides both diploma and master's courses on climate change, climate hazard and disaster risk management and climate change adaptation. The Dhaka School of Economics (DScE), a constituent institution of the University of Dhaka, teaches environmental and resources economics at undergraduate, diploma, and master's levels. The Institute of Disaster Management and Vulnerability Studies at the University of Dhaka (DU) is an academic and research institute that shares disaster and vulnerability related experiences and knowledge through training and regular curricula. The Bangladesh Public Administration Training Centre (BPATC) has initiated training programmes on climate change for public service cadres.

In addition, some of the universities in Bangladesh have joint progammes with foreign universities to introduce climate change intensive research and training at the post-graduate level.

Efforts to Facilitate Information Sharing

Several web-based networks have been developed in the country for information sharing. The Disaster Management Information Network (DMIN) Portal has been established under the Ministry of Disaster Management and Relief to share, coordinate and disseminate disaster management information, programmes and guidelines. The Water Resources Planning Organization (WARPO) has developed a National Water Resources Database (NWRD) to meet the demand for authentic data and information related to the water sector. As part of its mandated functions, WARPO maintains, updates and disseminates the NWRD continuously. An Integrated Coastal Resources Database (ICRD) has been set up to formulate and implement the Integrated Coastal Zone Management Plan (ICZMP) of Bangladesh. Initial tasks of the database were: to perform needs assessments; to prepare existing data inventory and interim reports; to co-ordinate with the NWRD; to install hardware and software; and to implement a database structure.

Chapter 1

Third National Communication: Rationale, Process and Structure

1.1 National Communication

Bangladesh became party to the United Nations Framework Convention on Climate Change (UNFCCC) after its ratification in March 1994. Upon ratification, Bangladesh decisively committed itself to pursuing coordinated efforts to reduce climate change impacts on the most vulnerable of its population, and to take appropriate actions on mitigation while continuing to advance national economic development. Article 4, paragraph 1, and Article 12, paragraph 1, of the UNFCCC requests that the parties to the convention periodically provide information to the Conference of Parties (COP) on sources and sinks of greenhouse gases (GHGs), mitigation measures, vulnerability to climate change, adaptation measures and programmes undertaken. National Communication (NC) reports have been prepared and submitted by many parties, including the Non-Annex 1 countries. Bangladesh prepared and submitted its Initial National Communication (INC) in 2002, and its Second National Communication (SNC) in 2012. The present report is the Third National Communication (TNC), which will be submitted to the UNFCCC in due process. The TNC follows the revised guidelines and the associated user manual as far as practicable.

1.2 The process

The Government of Bangladesh (GoB), represented by the Ministry of Environment, Forest and Climate Change (MoEFCC), and its operational arm, the Department of Environment (DoE), enlisted the services of several climate experts to prepare five reports/chapters on five activities/components of the TNC. These were as follows:

Activity 1: National Circumstances;

Activity 2: Greenhouse Gas (GHG) Inventory;

Activity 3: Programmes containing measures to mitigate climate change;

Activity 4: Programmes analyzing vulnerability to climate change and containing measures to facilitate adaptation to climate change; and

Activity 5: Other information considered relevant to the achievement of the objectives of the UNFCCC/crosscutting issues.

In each case, the relevant consultant discussed the Terms of Reference (ToR) under each activity with a wide group of stakeholders, had inception and follow-up workshops when preliminary drafts were ready, used comments and observations received for revising the drafts, and submitted them to the Department of Environment (DoE). These reports were then peer-reviewed and revised taking into account further comments and observations from reviewers. The TNC is based largely upon these final reports under the activities. However, whenever the relevant consultant thought it desirable, s/he has supplemented information in activity reports with further information and analysis. Once the TNC was prepared, it was further discussed by a group of stakeholders, including representatives from ministries, experts and civil society groups. Comments and observations received during this meeting were further considered in the finalization of this document.

1.3 Structure

The TNC is organized in line with the activityrReports. Thus, the chapters bear the same titles as the activity reports and are arranged accordingly. The TNC also contains an executive summary, figures and tables. It may be noted that while the GHG inventory refers essentially to the year 2012, many measures and programmes nonetheless refer to the pre- or post-2012 situation in the country in light of various ongoing trends. For comparability purposes, the situation in 2012 has been shown wherever applicable.

Chapter 2

National Circumstances

2.1 Introduction

This chapter outlines national circumstances on the basis of available data and narrative assessments. It addresses the first of the five activities conducted in the context of preparing the TNC, and seeks to:

1. Update information needs and ensure necessary updated data collection from relevant sources;
2. Analyse all available national and sectoral strategies, plans, programmes and studies relevant to the formulation of the TNC, including national development blueprints and poverty reduction policies and strategies;
3. Update the information base on geographical characteristics including climate, forests, land use and other environmental characteristics, population, economy and social and other services, which may affect the country's ability to deal with mitigating and adapting to climate change.
4. Conduct studies on how the different roles of men and women in Bangladesh's social and economic circumstances may affect the country's ability to deal with mitigating and adapting to climate change.
5. Analyse poverty-climate links.

2.2 Geographical Characteristics of the Country

Geographical characteristics of Bangladesh are heavily dependent on local and regional hydrological characteristics. These hydrological conditions rely on climatic processes, including on seasonality dimensions. Flooding of various types (e.g. seasonal normal inundation, severe and prolonged flood conditions, flash floods, floods associated with high tides in the coastal regions etc.), cyclones, and drought conditions are some of the phenomena resulting from hydro-meteorological processes. Land morphology, soil conditions and river systems also play contributory roles in defining the geographical characteristics of Bangladesh. Information on these and related issues has been gathered from such sources as the Survey of Bangladesh (SoB), the Ministry of Disaster Management and Relief (MoDMR), the Ministry of Environment, Forest and Climate Change (MoEFCC), the Ministry of Land, the Bangladesh Water Development Board (BWDB), and the Flood Forecasting Warning Centre (FFWC) to outline the geographical characteristics of the country.

2.2.1 Topography of Bangladesh

Bangladesh is the largest deltaic region in the world with most of the country at low elevations. It is a riverine country criss-crossed by innumerable rivers, their tributaries and rivulets. The country is divided into three major physiographic units. These are floodplains (occupying 79% of land surface), uplifted terraces (9%) and hills (12%) (Brammer, 2014). The landscapes, hydrological conditions and soil associations are different in these physiographic regions of the country. Based on depth-of-flooding, the land in Bangladesh is divided into six categories: highland, medium highland, medium lowland, lowland, very lowland and bottomland (Table 2.1).

Table 2.1: Depth-of-flooding, land types and traditional cropping pattern

Land type	Flooding description	Normal flooding depth	Traditional land use
Highland (H), F0	Not flooded	Above flood level	Aus-rabi crops; t.aman-fallow
Medium Highland (MH), F1	Shallowly	Up to 90 cm	Aus-rabi crops; aus-t.aman
Lowland (ML), F2	Moderately deeply	c. 90 – 180 cm	Mixed aus+deep water aman+/-rabi crops
Lowland (L), F3	Deeply	d. 180 – e. 300 cm	Deep water amsn-Khesari/fallow
Very Lowland (VL), F4	Very deeply	f. >300 cm	Grassland; irrigated boro
Bottomland (B)	Shallowly to deeply	Wet all year	Boro (local varieties); wetlands

Table 2.2 indicates that lowlands (including settlements) of the country cover about 35% of the total land area of the country (columns 4, 5 and 6). It also shows that 58% of total floodplains falls in highland categories (columns 2, 3) indicating the remaining 42% are in low elevation areas which are susceptible to flooding. These three major physiographic units are further sub-divided into 18 physiographic regions (Figure 2.1). Table 2.2 indicates that lowlands (including settlements) of the country cover about 35% of the total land area of the country (columns 4, 5 and 6). It also shows that 58% of total floodplains falls in highland categories (columns 2, 3) indicating the remaining 42% are in low elevation areas which are susceptible to flooding. These three major physiographic units are further sub-divided into 18 physiographic regions (Figure 2.1).

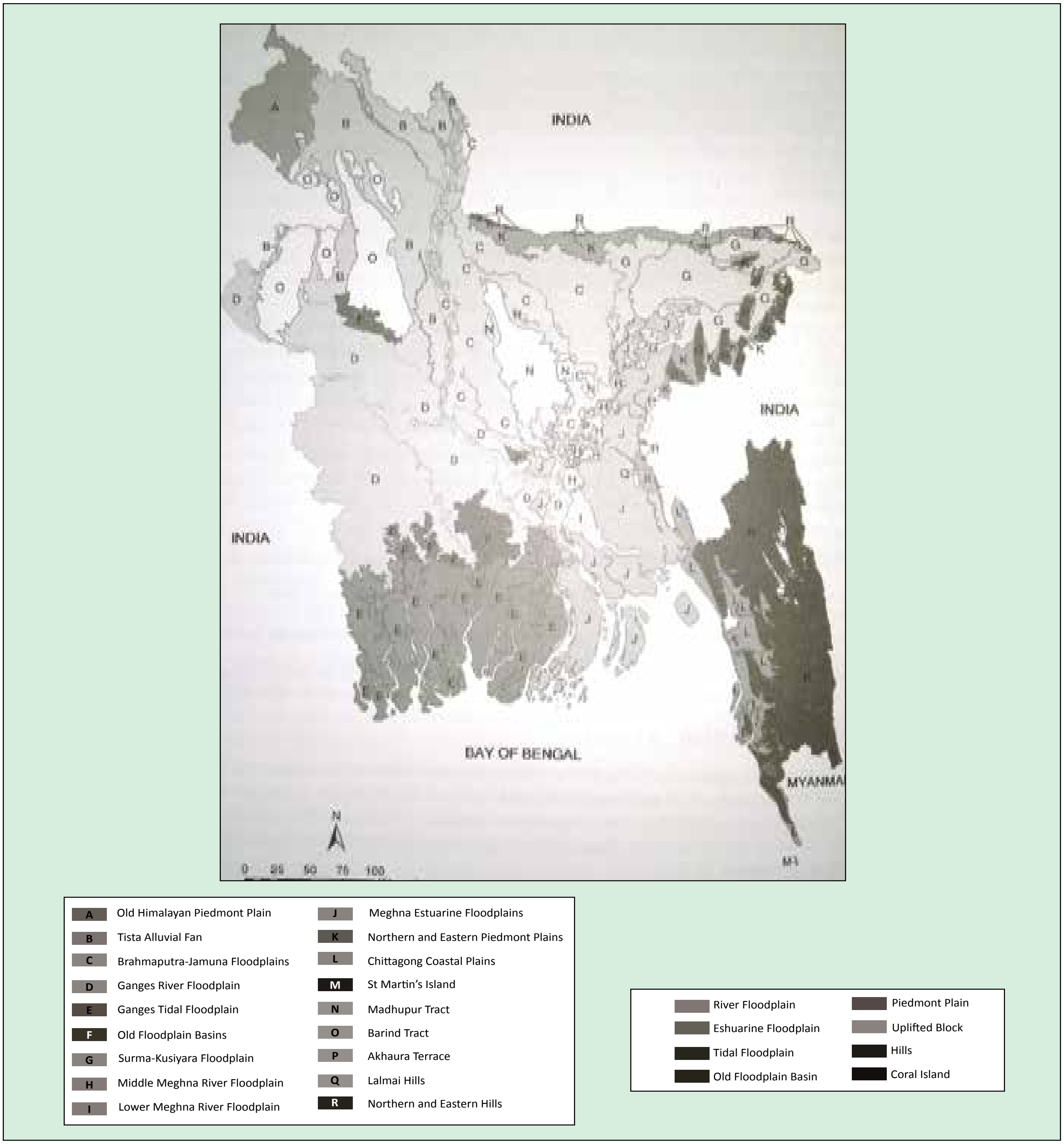


Figure 2.1: Physiography of Bangladesh (Source: Brammer, H. (2014)

Table 2.2: Proportions of depth-of-flooding land types in physiographic regions (Brammer, 2014)

Region	Land area (km^2) 1	Highland (%) 2	Medium Highland (%) 3	Medium Lowland (%) 4	Lowland + very lowland (%) 5	Settlements and water (%) 6
Floodplains (79% of total land area)						
A	3931	58	35	1	-	6
B	12963	29	50	8	4	9
C	15472	12	33	31	15	9
D	23069	26	31	21	12	10
E	15073	2	87	3	<0.5	8
F	3472	2	10	31	51	5
G	8779	<0.5	17	18	54	10
H	1296	-	7	45	38	10
I	912	27	15	29	<0.5	29
J	12944	1	45	26	14	14
K	547	28	39	15	8	10
L	3592	22	46	14	<0.5	19
M	8	56	32	34	-	2
Average of A-M		**16**	**42**	**18**	**14**	**10**
Uplifted Terraces (9%)						
N	4146	32	18	7	29	7
O	7687	47	40	3	2	8
P	171	40	9	15	30	5
Q	38	59	37	-	-	3
Average of N-Q		**50**	**32**	**5**	**6**	**8**
Hills (12%)						
Northern and Eastern hills	16274	95	3	<0.5	-	2
Total hills		**95**	**3**	**<0.5**	**-**	**2**
Bangladesh	**123244**	**28**	**36**	**15**	**11**	**9**
Proportions in the regions are of the land area, excluding rivers. National figures are for the land area excluding rivers, *Kaptai* lake and Dhaka and Chittagong urban areas.						

2.2.2 Climatic conditions

Although Bangladesh is situated in the sub-tropical region, it displays a tropical monsoon climate characterized by heavy summer rainfall and high summer temperatures. The reason for this is its location in South Asia where the Himalayas act as a barrier (Figure 2.2, 2.3) to moisture laden monsoon winds in the summer season causing occurrence of heavy rainfall. This Himalayan mountain range also helps to protect the country from extremely cool winds blowing from the extreme north (i.e. Siberian regions). In addition, uplands in the central Indian regions and hilly terrains in the eastern parts of the country cause the country to receive huge amounts of water as surface runoff during monsoon times that start in June and last until October.

From the climatic point of view, four distinct seasons can be identified although some experts even recognize only three, despite the proverbial six Bangla seasons. These four seasons are: the cool dry winter from December to February; the hot pre-monsoon summer from March to May; the hot, humid and rainy season from June to September; and the hot and humid but drier autumn from October to November, when the south-west wind retreats.

The cool winter dry season (December to February) is characterized by an anti-cyclonic pressure system, very light northerly winds, mild temperatures and dry weather with clear but occasionally cloudy skies. The prevailing air mass is dry with low humidity. However, continuous evaporation from the numerous rivers, lakes and other natural water bodies during clear sunny days accounts for high humidity during the late evening and early morning. This contributes to the build-up of late night and early morning fog. The winter begins first in the west-central part of Bangladesh by mid-December, where it lasts about four months. From there, it advances towards the east and south. January is the coldest month, with the cold winter air moving into the country from the north-western part of India. Average temperatures in January vary from about 17^{o}C in the north-western and north-eastern parts to 20^{o}-21^{o}C in the coastal areas. The minimum temperature may reach 4^{o} to 7^{o}C in the extreme north-western and north-eastern parts of the country. The average winter rainfall varies from 20 mm in the west and south to slightly over 40 mm in the north-east. Rainfall in this season accounts for only 2- 4% of the total annual rainfall. Relative humidity is below 60% and cloud cover during winter is the lowest, about 10% country-wide. This is due to the cold dry winds from the north-western part of India during the winter season.

The pre-monsoon hot summer season (March to May) begins as the winter anti-cyclonic pressure regimes start changing to summer heat from March onwards. Seasonal rainfall varies from year to year, and from place to place, and drought is not unusual.

Table 2.3: Mean annual rainfall and variability at Rajshahi, Dhaka, Sylhet and Chittagong. (Brammer, 2014)

Station	Mean rainfall (mm)	Standard Deviation (mm)	Coefficient of Variation (%)	Pe riod	Number of years
Rajshahi	1517	301	20	1964 -2008	42
Dhaka	2112	391	18	1959 -2008	44
Sylhet	4090	657	20	1959 -2008	45
Chittagong	2869	524	18	1959 -2008	42

*** Rajshahi represents the north-western region, Dhaka the central region, Sylhet the north-eastern region and Chittagong the south-eastern region of Bangladesh.**

The rainfall in this season accounts for about 15 - 20% of the annual total. Rainfall from the thunderstorms of this season (known as the nor'westers, an important climatic event of the season) is copious, varying from 150 to 200 mm in the west central part to more than 800 mm in the north-east. This reflects the effect of the hill ranges in the north-eastern part of Bangladesh and adjoining parts of India that triggers the uplift of the air and convectional overturning of the moist air from the Bay of Bengal. This season's rainfall has implications for two crops: the harvesting of the rabi crop and the planting of the kharif-I crop. The season is characterized by high temperatures and convective rainfall. April is the hottest month when the average temperature varies from 27^{o}C in the north-east to 32^{o}C in the west central region, often going up to as high as 40^{o}C. Humidity varies from 57 - 56%. The cloud cover is 50 – 60%.

The season is marked by cyclonic storms formed in the Bay of Bengal which have the potential to strike the Bangladesh coast with storm surges, often with devastating effects on the people living in the coastal region of Bangladesh.

The **rainy or monsoon season** (June to September) coincides with the summer season when the country's weather is dominated by the south-westerly winds from the Bay of Bengal. The average temperature varies from 27^{o}C – 290C with mean minimum at about 25^{o}C and the mean maximum at about 31^{o} C. The humidity is more than 80% with 80 – 90% cloud cover. This season accounts for about 70 – 85 % of the total annual rainfall. Rainfall in this season is caused by the tropical depressions coming from the Bay of Bengal. Rainfall varies widely, from about 1220 mm in Rajshahi to 1490 mm in Narayanganj, to 3380 mm in Cox's Bazar to as high as 5000 mm in the northern part of Sylhet. The average rainy days vary from 60 in the west-central part to 95 days in the south-eastern and over 100 days in the north-eastern part. The arrival date of the summer monsoon is very important from an agricultural point of view because it has implications for two crops: the harvesting of aus *(kharif-I)* and planting of aman *(kharif-II)*. Moreover, severe floods may occur in this season causing extensive damage to crops, livestock, human life and infrastructure. Sometimes floods may reach calamity proportions as in 1987, 1988 and 1998. The summer monsoon has an enormous influence on the agriculture, hydrology and drainage systems of Bangladesh, all of which in turn influence the economy of the country.

The post-monsoon or autumn is the transitional season from the summer monsoon to the winter. The south-west monsoon begins to withdraw from the country in early October, and the season sets in gradually as by mid-October the monsoon rainfall peters away rapidly (October to November). In the western half of the country and in the central Bangladesh the rains are normally over by the last week of October, whereas in the east and south-east they may continue up to about the second week of November. Very little rain then falls until the middle of January. The cloud cover is about 25% in the northern and eastern region and about 40 – 50 % in the southern and eastern region. The rainfall varies from 2 – 10%. The winds are variable in October, but there is a definite strengthening of the northerly winds at the expense of the south easterlies. The post-monsoon season is characterized by the occurrences of cyclonic storms, particularly between September and November. Some of these cyclonic storms form in the Bay of Bengal, at about 100 N latitude or even near the equatorial belt, initially move north-west and when near about 200 N latitude they turn north-east and hit the Bangladesh coast. Near the eye of the cyclone, there is a heavy swell known as the storm surge which can be devastating to lives and properties.

The major characteristics of the Bangladesh climate are as follows:

- Seasonality of temperature and rainfall: four seasons are characteristically distinct;
- Variability of temperature and rainfall, particularly that of rainfall. There are variabilities in the arrival and departure of monsoon rainfall, and also variability in the amount of rainfall received during pre- and post-monsoon periods;
- Regional variations, called climatic sub-zones within Bangladesh. The five sub-regions have rainfall and temperature characteristics that are essentially different.

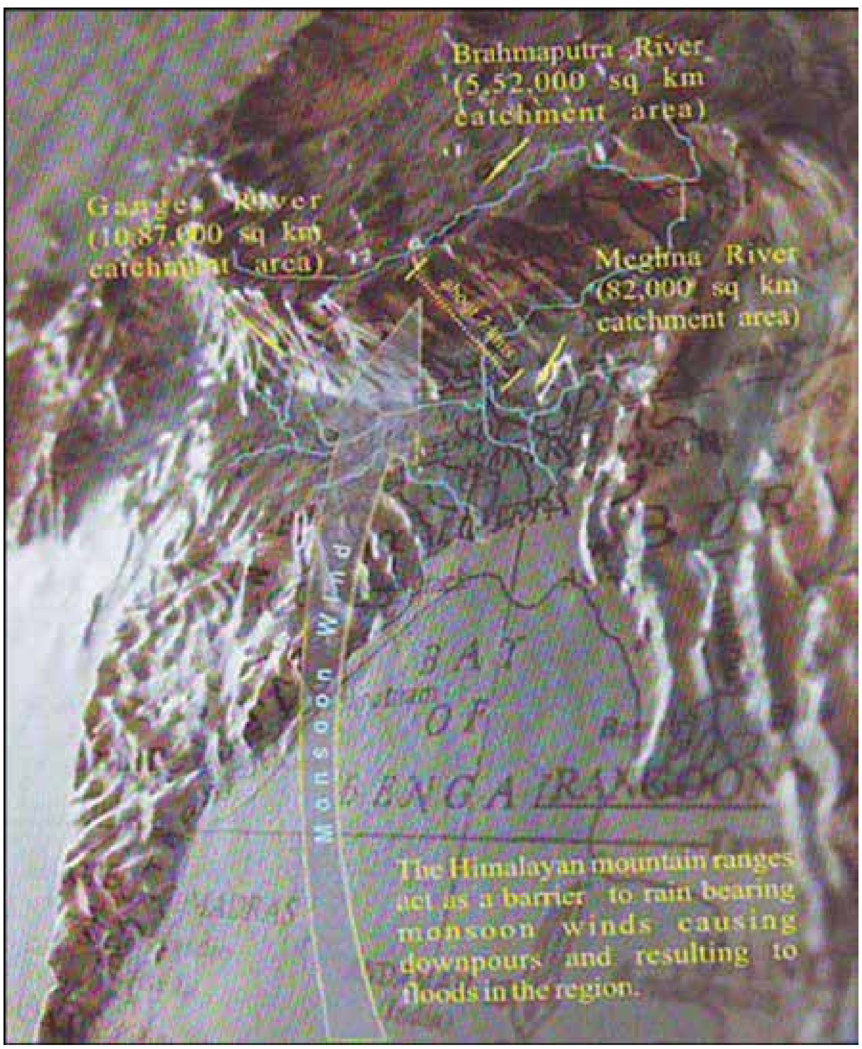


Figure 2.2: Model showing regional topography of South Asia (Source: Islam, S.T. and Neelim, A., 2010)

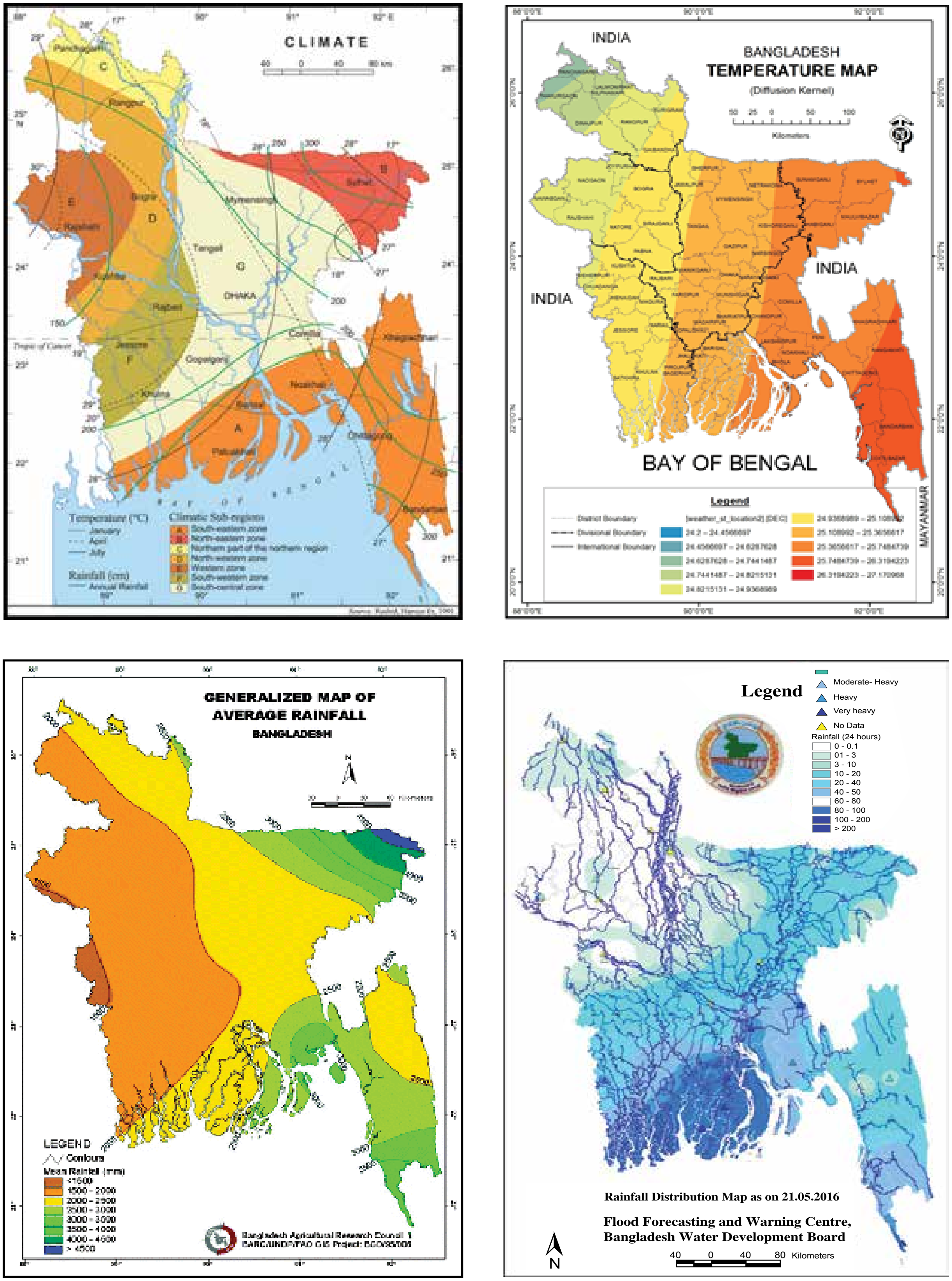


Figure 2.3: Maps showing general climatic conditions (upper left), temperature (upper right), rainfall (lower left) and real time convection rainfall due to cyclone Roanu (made landfall in Bangladesh on 22nd May 2016) produced using satellite altimetry by FFWC (lower right) (Source: BARC (Bangladesh Agricultural Research Council) and FFWC (Flood Forecasting Warning Center)

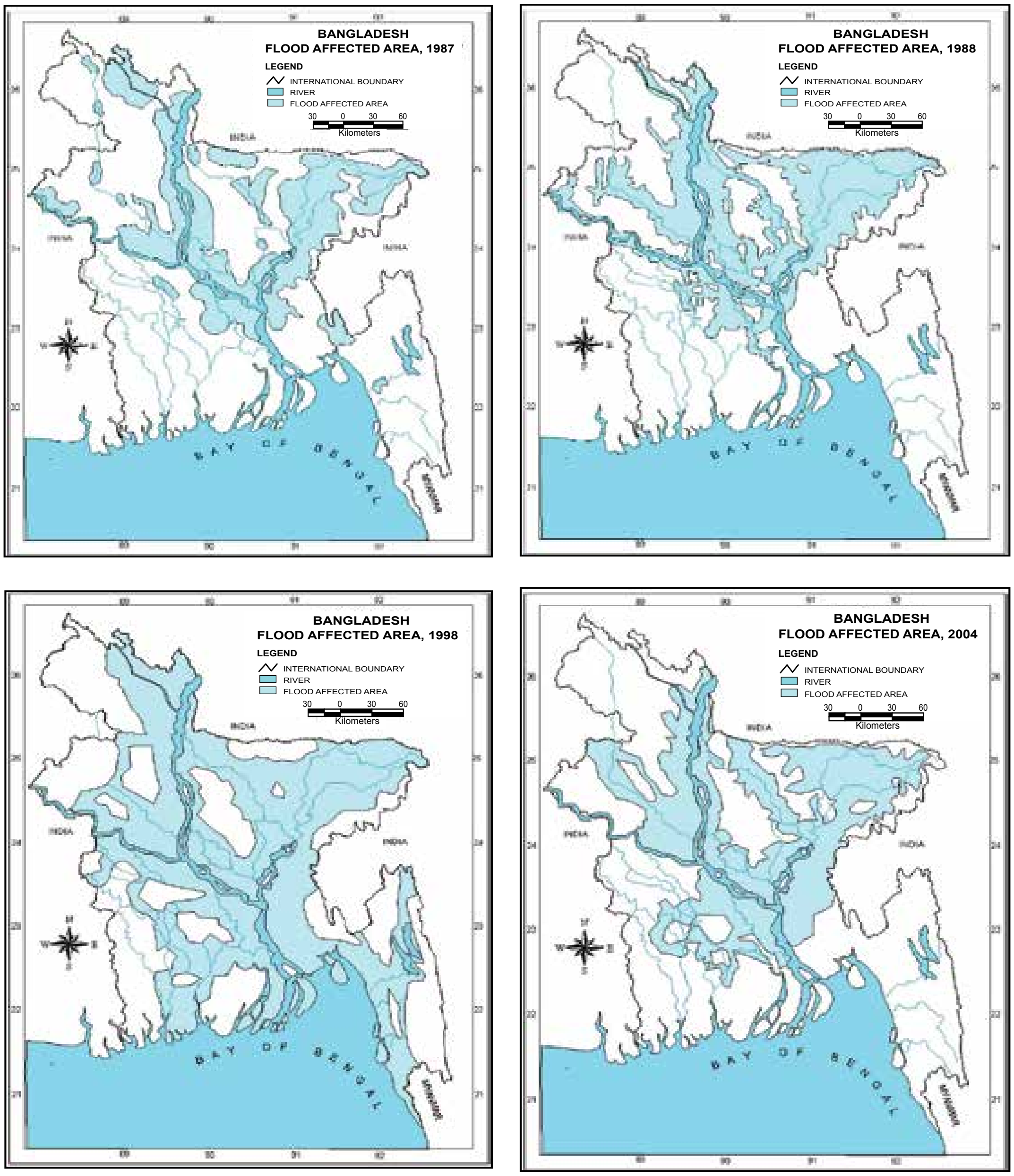


Figure 2.4: Flood affected areas of Bangladesh in different major flood years

2.2.3 Water resources

Water plays a vital role in the economy of Bangladesh. Its role in agriculture, fisheries and livestock is very significant, and access to drinking water and water for domestic uses is of social importance. Water is needed in industries and it supports sanitation and health systems. Unfavourable changes in water regimes caused by climate change will adversely affect all these sectors.

The availability of fresh water in Bangladesh is highly seasonal and depends on monsoon rainfall both inside and outside of Bangladesh in the GBM (Ganges-Brahmaputra-Meghna) catchments. Some 80% of annual rainfall will fall in the monsoon period. The entire water ecosystems of Bangladesh, comprised of the GBM Rivers, their tributaries and distributaries, the perennial and seasonal water bodies like haors, baors and beels, are characterized by this seasonality of rain and its variability. It is also important to note that all three river systems originate outside Bangladesh. Out of 230 rivers in the country, 57 are trans-boundary rivers, 54 coming down from India and three from Myanmar.

The same pattern of seasonality is applicable to the river flows as well, as the river flows greatly depend on monsoon rainfall and the summer snow melt in the upper Himalayas. The table below shows the peak discharge for the mean and 20-year return period floods for the Ganges, Brahmaputra and Meghna, with 1994 as the reference year.

Table 2.4: Discharge for the Mean and 20-year return period floods for the Ganges, Brahmaputra and Meghna (INC, 2002)

River	Mean Peak Discharge	20-year Return Period	% difference between mean peak & 20-yr return period
The Ganges	51,050	66,354	30.0
The Brahmaputra	67,200	89,025	32.5
The Meghna	14,080	19,016	35.0

2.2.4 Agriculture and forest resources

In Bangladesh, agriculture systems include crops, livestock, forestry and fisheries. These sectors primarily depend on the same kinds of natural resources such as water/irrigation, land/soil, and the support of biodiversity/ ecosystem services such as enabling a flowering environment through pollination services for better crop yield etc. These sectors also support each other. For example, agriculture is heavily dependent on services provided by livestock resources and forests support different types of biological diversity (e.g. habitat, ecosystem, genetic). Hence impacts on any sector gradually spill over onto other sectors. Understanding and identifying these cause-and-consequence links is not always easy, and some may go unnoticed.

Irrigation areas for crop cultivation have increased manifold over the years in Bangladesh. For irrigation, deep tube wells, shallow tube wells, low lift pumps and various means of conveying surface water are used. Unsustainable ground water irrigation has already affected aquifers as water levels have dipped in many parts of the country. Drought conditions mean farmers are drawing more groundwater from aquifers to offset the water shortages and make the existing situation worse. Flood, cyclone, and associated risks like river bank erosion and salinity intrusion all equally affect crop production, livestock and fishery resources. The impacts of these stresses make people more vulnerable and poverty stricken, forcing them to draw on natural, including forest, resources. Forest resources are a carbon sink, a safe haven for thriving biodiversity, work as a shield from natural disasters such as cyclones and tidal floods and are a source of food and fuel for the local population. The country now has 17.08 percent of total land area as forest, but by and large density is sparse.

Table 2.5: Important agricultural attributes of Bangladesh (BBS, 2014)

Items	Estimates are for 2008 for rural areas
Number of total agricultural farm holdings (2008)	14,870,576 (59%)
Number of total non-farm holdings (2008)	10,480,930 (41%)
Cropping intensity (2008)	172.84%
Production of rice (2013-14)	34356000 Mi llion Tons (MT)
Production of wheat (2013-14)	13, 03,000 Million Tons(MT)
Total agriculture operated areas	22,944,236 Acres
Total irrigated lands (2013-14)	18,116,000 Acres (79% of total agricultural lands)
Area under production of rice (2009-2010)	12, 574,000 Acres (55% of total agricultural lands and 69% of total irrigated areas)
Internal procurement of food grain (2013-14)	1,405,000 M T (About 4% of yearly total grain production)
Public food distribution (2013-14)	2,220,000 (158% against the procurement of that year)
Cold storages for crops and the number of total storage capacity (2014)	368; 2,531,441,000 M T
Forestlands under the control of Forest Department (2013-14)	2,574,486.79 square kilometers
Fish production (2012-13)	3,410,254 M T; 83% from inland water sources (culture and copter) and 17% from marine fisheries

2.2.5 Human health

The health sector in Bangladesh has made significant progress since the country's independence in 1971 through a number of reforms and through the development of extensive health infrastructure in both the public and the private sectors (Table 2.6). With regard to the target for reducing child death under MDG Goal 4, by the end of 2015 significant improvements had been achieved in reducing maternal deaths, infectious diseases like malaria, tuberculosis and diarrhea and in increasing immunization coverage. Currently patients can receive treatments from 592 government managed hospitals and 2,983 registered private hospitals, community health sectors and clinics (BBS, 2014) with total bed facilities of about 94,318. Despite these improvements, the health sector in Bangladesh still faces multiple challenges such as a shortage of trained health professionals, low annual allocation of funds from government sources, high cost to receive health-related private sector services, and inequitable access to health services between urban and rural areas (Ahmed *et al.*, 2015).

Table 2.6: Major achievements in health sector in Bangladesh from 1973 to 2016

Planning Periods	Milestones
1st Five Year Plan (1973-1978)	Putting emphasis on prevention by providing basic curative services Building health infrastructure in rural areas Recruiting and training primary health care providers
2nd Five Year Plan (1980-1985)	Adoption of Alma Ata and Primary Health Care as the Key approach Continued infrastructure development and training Introduction of union level health facilities – Health and Family Welfare Centers
3rd Five Year Plan (1985-1990)	Expansion of EPI and satellite clinic services Specialized services at Thana Health Complex Modernization of district hospitals
4th Five Year Plan (1990-1995)	Integrated services in rural areas through merger of EPI outreach and satellite clinics Improving quality and coverage Improving health of disadvantaged populations Encouraging NGO involvement in service delivery
5th Five Year Plan (1997-2002)	Strengthening urban health services Health and Population Sector Strategy (HPSS) 1997 Health and Population Sector Programme (HPSP) 1998 – 2003 National Health Policy 2000
6th Five Year Plan (2011-2016)	Health Population and Nutrition Sector Development Programme (HPNSDP) National Health Policy 2011 National Population Policy 2012

2.3 Natural Disasters

2.3.1 Impacts of floods

Flooding is a common annual phenomenon in Bangladesh that happens in the rainy season as a result of an overtopping of the runoff from rivers and canals spreading over vast areas of floodplains. This normal flood carries useful soil nutrients which contribute to an improvement in yields of agricultural crops and farmers expect it. However, at times and in certain areas, normal floods turn catastrophic in terms of the volume of water, and of the duration and timing of the flood. The main factors behind flooding in Bangladesh are: patterns of monsoon rainfall (both in Bangladesh and regionally); characteristics of water levels in the Ganges, the Brahmaputra and the Meghna rivers; simultaneity of peaking of the three river systems; tidal (including wind) conditions in the Bay of Bengal; and human interventions in floodplain areas resulting in ponding effects. Climate change influences all of these factors and thus influences the pattern and magnitudes of floods.

In Bangladesh, rivers are characterized by markedly seasonal flows. The Brahmaputra and the Meghna rivers often begin to rise in March and April as a result of heavy pre-monsoon rainfall in north-eastern India and north-eastern Bangladesh. The Ganges usually starts to rise in May because pre-monsoon rains start later in the Ganges basin. In June, all these rivers start rising simultaneously due to the occurrence of monsoon rainfall. Usually, the Brahmaputra reaches peak flow in July-August and the Ganges in August-September. The worst case scenario for Bangladesh is when all these rivers rise and peak together. Even if two of the three rise and peak together, the consequent flooding is enormously devastating (e.g. the floods of 1998). It is important to note that the flood flows and river levels vary from year to year, and hence untimely floods (maybe early or late) may occur in some parts of the country as well.

2.3.2 Cyclonic disturbances

Depressions, cyclonic storms and tropical cyclones are different categories of natural hazards occurring in the Bay of Bengal as a result of temperature increase causing a decrease of wind pressure in the surface of the Bay. In its Statistical Yearbook of Bangladesh 2014, the Bangladesh Bureau of Statistics (BBS) reports that altogether 21 tropical cyclones (wind speed >117 km/hr) and severe cyclones (wind speed between 87 to 117 km/hr) hit the Bangladesh coast in the period 1960-2010). Among these, 33.33% cyclonic episodes took place in pre-monsoon times while the remaining 66.66% occurred in post-monsoon times (Table 2.7).

Table 2.7: Frequency distribution of tropical cyclones and severe cyclonic storms

Pre-monsoon			Post-monsoon		
Time of occurrence		No	Time of occurrence		No
April	11-20	0	**September**	**21-30**	1
	21-30	1	**October**	**1-10**	1
May	1-10	1		11-21	1
	11-20	2		22-31	2
	21-30	3	**November**	**1-10**	3
June	1-10	0		11-20	3
				21-30	2
			December	1-10	1
* Cyclones included are those that occurred in pre-monsoon and post-monsoon seasons from 1960 to 2010.					

Most of the casualties/fatalities and destruction associated with cyclones happen as a result of the accompanying water surge and high storm waves that sweep away and drown people. The degree of destruction and the number of casualties/fatalities depend on the time when a cyclone occurs and on the topography and geomorphological conditions of where it strikes. It is observed that areas close to the Meghna estuary face more cyclonic disturbances because of the estuary's funnel-shaped morphological conditions and because tidal characteristics such as tide levels are generally higher in the Meghna estuary areas than in adjoining areas. The impacts are generally high if the cyclone makes landfall on the coast when high tide conditions prevail.

2.3.3 Drought conditions

Drought is a water stress condition at a time when rainfall is generally expected for plant growth. Incidence of drought in north-western regions of Bangladesh is quite common where rainfall occurrence is almost half of that occurring in north-eastern regions of the country. June is the month when drought usually occurs as rainfall in June has always been less in north-western parts of the country compared to other parts. Studies carried out in the 1980s by BARC (Bangladesh Agricultural Research Council) in order to develop an AEZ (Agro-ecological Zone) database for the country show that monsoon rainfall in Bangladesh starts in the first week of June but standard deviation was found to be 26 days in Rajshahi district located in the north-western regions of the country (Brammer, 2014). It indicates that the late start of monsoon in the drought-prone north-western region is not the abnormal phenomenon which was observed in 2009. This drought occurred when rainfall of 146mm was recorded against a 45-year mean of 271mm. It is also important to note that most of the rainfall (105 mm against a total of 146mm, 72%) in that year (2009) occurred on 29th and 30th June. It suggests that understanding the drought phenomenon needs a more rigorous study using daily rainfall data (not monthly or yearly averages) including associated daily temperature records so that the PET (Potential Evapotranspiration) rates could be calculated.

2.3.4 Sea level rise and associated risks

The coastal areas of Bangladesh have been adjusting to Sea Level Rise (SLR) in the Bay of Bengal during the last at least 11,000 years (Kuehl *et al.,* 2005; Mikhailov and Dotsenko, 2007). SLR happens as a result of the deposition of sediments carried by the three major rivers, i.e. the Ganges, the Brahmaputra and the Meghna, one third of which is deposited on the active floodplain areas and in the channels of the delta (Goodbred and Kuehl, 1999). A small portion of sediment is delivered via waves and tides to the inactive, tidal portion of the delta at a rate of about 10mm (highest) per year (Rogers *et al.* 2013). However, the coastal areas are still subject to adjustments since their average elevation ranges from -3 metres in the south-western and central coastal regions (about 80% of the coastal areas) allowing dynamic variables like incoming sediments, SLR and land subsidence to play roles. The elevation of south-eastern coastal zones is about 4 to 7 metres. This low elevation, active delta and dynamic morphology play significant roles in making the region vulnerable to hazards like cyclone induced water surges and the submergence of lands by the rising levels of sea water. The area is also vulnerable to coastal land erosion and salinity intrusion affecting surface water, groundwater and soil.

The coastal areas of Bangladesh are generally divided into three categories - the Ganges Tidal Plain or the Western Coastal Region, the Meghna Deltaic Plain or the Central Coastal Region and the Chittagong Coastal Plain or Eastern Coastal Region. These three coastal regions experience different SLR scenarios; water level increase is happening at a rate of 5 to 7 mm per year in the south-western coastal regions, around 10 mm per year in the central coastal regions and about 14 to 23 mm per year in the south-eastern coastal regions (CEGIS, 2016).

Table 2.8: Areas of different elevation in the coastal area of Bangladesh

Elevation (m)	Area (square kilometer)	Area (in percentage)
0-1	16941	26.58
1-2	19941	31.29
2-3	13545	21.25
3-4	8545	13.41
4-5	4756	7.46
Total	63728	100

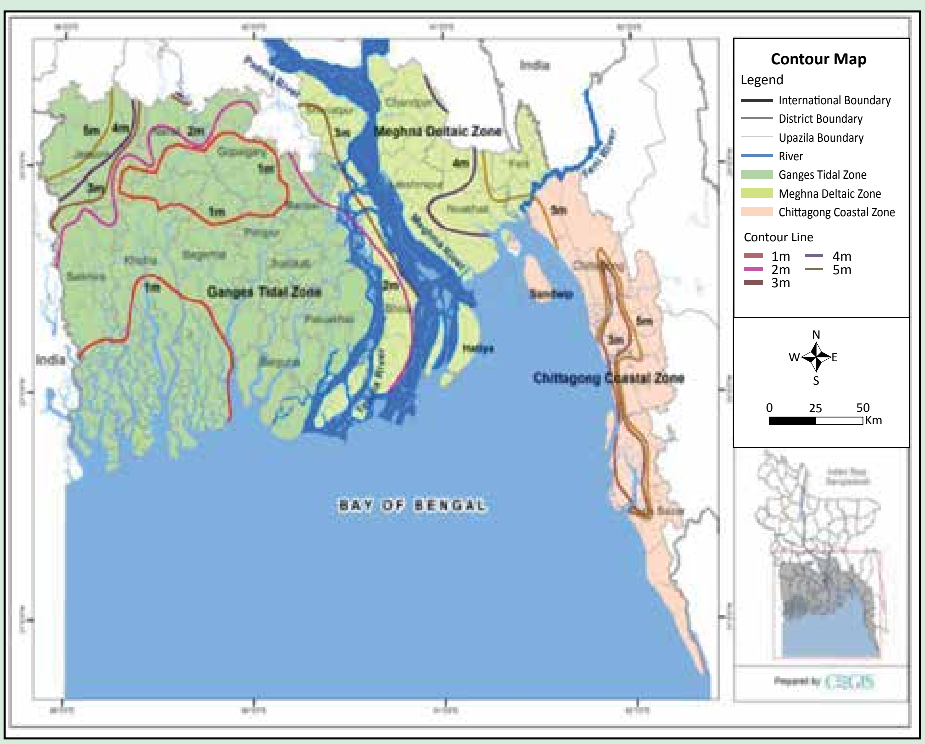


Figure 2.5: Map showing coastal elevation (Source: CDMP, 2009)

Land subsidence is an important factor in the context of understanding SLR in Bangladesh. Different authors have given different estimates (see CEGIS, 2016) of the land subsidence in the coastal areas of Bangladesh. This subsidence occurs as a result of: (i) accumulation of about 1.6 billion tons of sediment load delivered by the Ganges and the Brahmaputra rivers; (ii) sediment compaction from the removal of oil, gas and water from the inland delta's underlying sediments; (iii) trapping of sediment in upstream reservoirs due to floodplain engineering; and (iv) rising sea levels. It is important to note here that due to human interventions in the floodplain areas, about 37% of the river distributaries have dried up in the south-western and central coastal regions of Bangladesh (Syvitski *et al.*, 2009). Therefore, the sediment budgeting process may need to be readjusted among the regions, and needs more studies for a clear understanding.

2.3.5 Salinity intrusion

One of the immediate and long-term threats of climate change is the ingress of salinity into surface (i.e. river) and groundwater systems and the soil. Salinity intrusion in the coastal areas is due to a number of factors such as a reduction of fresh water flows from the Ganges, siltation in the tributaries of the Ganges river systems, and siltation in many other rivers due to the impacts of polders. Dasgupta *et al.* (2014) found that salinity increased from 2ppt to 20ppt at Mongla (south-western coastal regions) in the Passur river from 1962 to 2008.

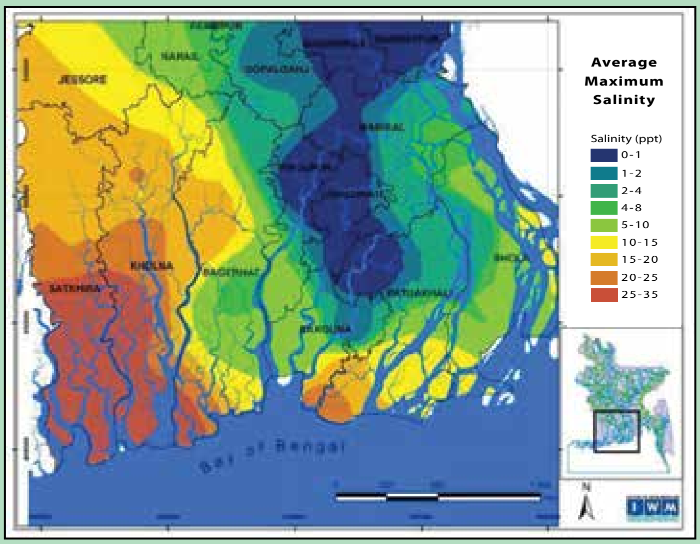


Figure 2.6: Salinity intrusion in coastal areas of Bangladesh (Dasgupta *et al.*, 2014)

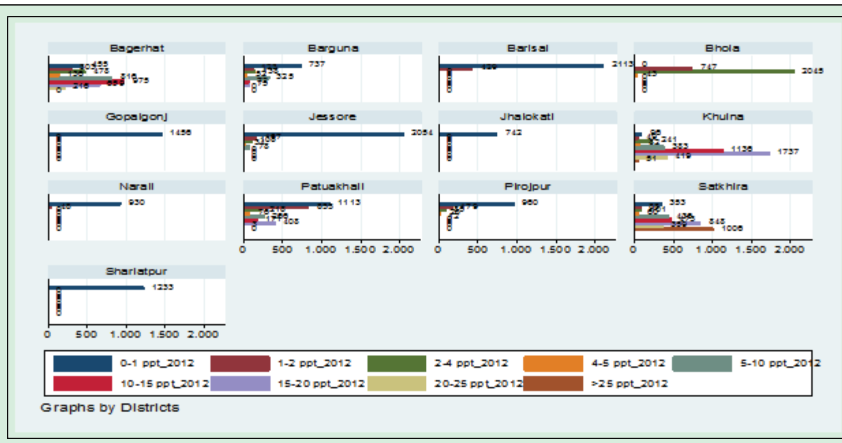


Figure 2.7: Surface Water salinity (in square kilometers) for base year 2012 (above) and best future (B1 emission scenario) in 2025 (below). Graph produced using data from Dasgupta et al. (2014)

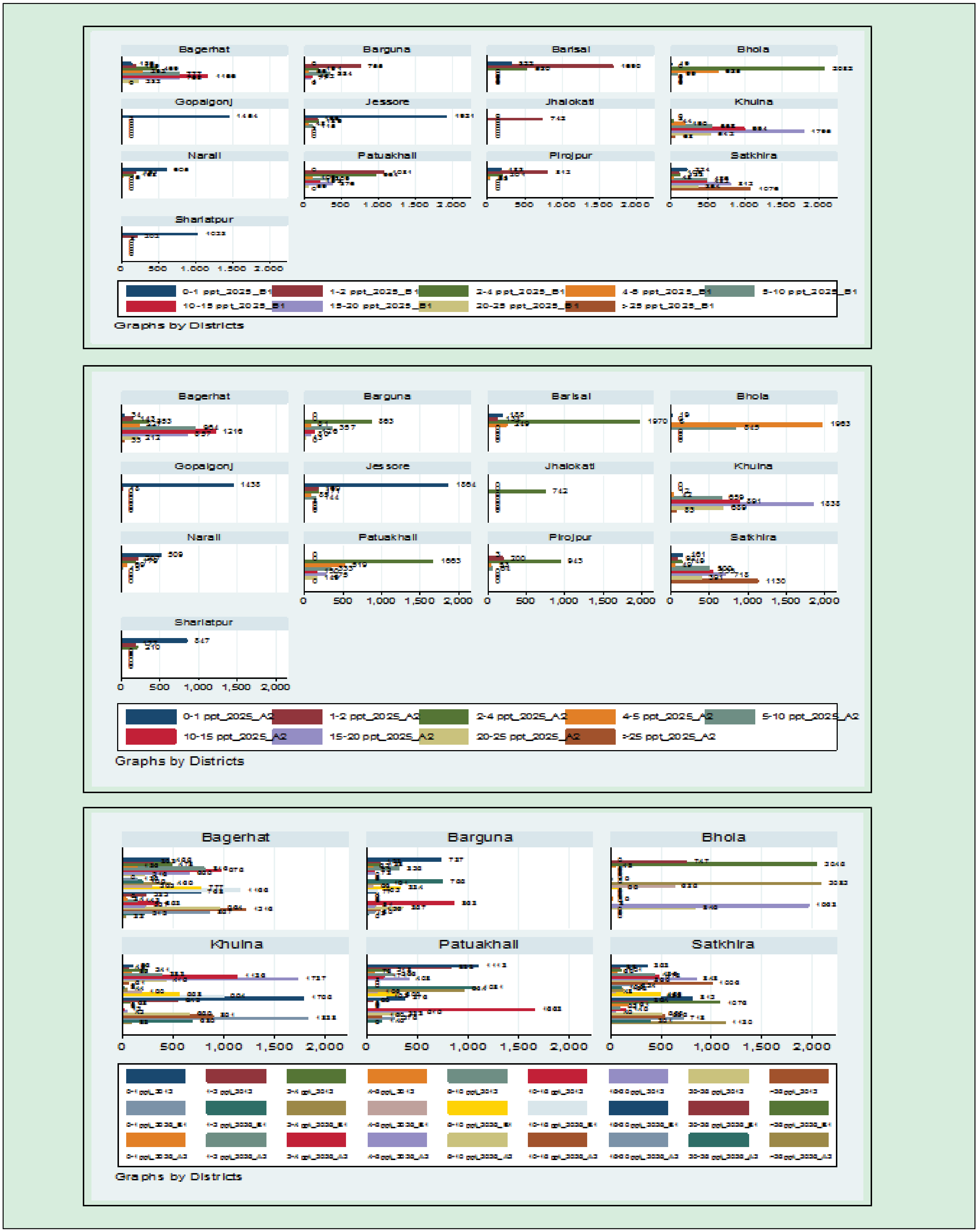


Figure 2.8: Surface Water future (A2 emission scenario) in 2025 (above) and district-wise salinity (in square kilometers) for worst comparison of surface water salinity (below). Graph produced using data from Dasgupta et al. (2014)

Surface and ground water salinity combined with soil salinity has serious negative impacts on agricultural productivity and production. SRDI periodically estimates soil salinity for coastal regions of Bangladesh. The third such report was published in 2010. The study findings suggest that total soil salinity has increased to about 1.056 million hectares from 0.8333 million hectares in about four decades. As of 2010 out of about 1.689 million hectares of coastal land 1.056 million hectares (about 63%) were affected by soil salinity of various degrees. About 0.328, 0.274, 0.189, 0.161 and 0.101 million hectares of land are affected by very slight (S1; 2 – 4 dS/m), slight (S2; 4.1 – 8 dS/m), moderate (S3; 8.1 – 16 dS/m), strong (S4; >16 dS/m) and very strong salinity (S5) respectively. A comparative study of the salt affected area during 1973 to 2009 showed that about 0.223 million ha (26.7%) of new land has been affected by various degrees of salinity during approximately the last four decades (Table 2.9).

Table 2.9: Soil salinity in coastal Bangladesh (SRDI, 2010)

Region*	Salt affected area (000 ha)			Soil salinity: degree and area (000 ha)													Salinity increase over 4 decades	
				S1 2 – 4 dS/m			S2 4.1 – 8 dS/m			S3** 8.1–16 dS/m			S4 >16 dS/m			Area (000 ha)	%
	1973	2000	2009	1973	2000	2009	1973	2000	2009	1973	2000	2009	1973	2000	2009		
1	374	417	432	48	93	87	255	119	102	52	161	169	20	48	68	57	15
2	78	78	76	18	24	25	53	27	19	3	19	27	0	7	1	-	-
3	100	106	106	25	16	21	31	33	29	24	46	50	19	72	6	6	6
4	0	26	33	0	10	22	0	5	8	0	1	2	0	0	0	33	100
Bangladesh	833	1020	1056	287	289	238	426	307	274	79	336	351	36	87	101	222	26

**1 - South-western regions (Khulna, Bagerhat, Satkhira)*
2 Central coastal regions (Laxmipur, Feni, Noakhali)
3 South-eastern regions (Chittagong, Cox's Bazar)
4 Mature delta regions (Jessore, Narail)
*** S3 = S3+S4; S3 = 8.1 -12 dS/m; S4 = 12.1 – 16 dS/m. Survey conducted in May 2009.*

2.4 Information on Population, Economy and other Service Sectors

Bangladesh has successfully managed population-related challenges generated from its sheer density (152.7 million estimated in Population Census 2011) given the size of the country. Total size and population increased to about 160 million in 2017. Successful management of population-related challenges can be seen in indicators such as a decrease in the annual growth rate (1.36, BBS, 2014), reducing poverty incidence in both urban and rural areas (poverty is now <25%, Planning Commission, 2015), a reduced unemployment rate (current unemployment rate is 4.5%, BBS, 2014) and significant improvements in human health-related indicators like reduced child mortality and maternal deaths. The Government of Bangladesh has also created employment opportunities for large numbers of people (Table 2.10). It must be recognized though, that under-employment in general and unemployment of educated youth in particular remains an ongoing problem.

Table 2.10: Major attributes of demographic and economic situations of Bangladesh

Attribute	Value/ Estimate
Area (square kilometers)	147,570
Total population (million),	152.7
Total male and female (million),	78.2, 74.5
Total urban and rural population (million),	41.7, 111.6
Annual population growth rate (2014)	1.36
Gender ratio (males per 100 females)	104.9
Population density per sq. km	1035

Attribute	Value/ Estimate
Life expectancy at birth	69.4
Persons per physicians (number)	3297
Per capita income (USD)	1190
Economically active population/labour force (million, 15 year+)	56.7
Youth labour force (million, 15 – 29 years),2010	20.9
Female labour force (million)	17.2
Employed population, self-employed (million),	54.1, 22
Unemployment rate (%),	4.5
Employment in agriculture, non-agriculture sectors (%),	47.3, 52.7
Unpaid family worker (million),	11.8

Source: All data refers to 2010, except population growth rate

It is important to note that the Bangladesh Bureau of Statistics (BBS) has played a significant role in supplying useful information to monitor and assess the changes/successes happening in different sectors. The Population and Housing Census 2011, the Household Income and Expenditure Survey 2010, the Multiple Indicator Cluster Survey 2012-13, the Report of Sample Vital Registration System 2013, the Labour Survey 2010, and the 2015 Report on MDG achievements are some of the important reports that BBS has produced and which supply useful information in the demographic characteristics of Bangladesh including issues related to the economy and various service sectors. In addition, data provided by the Ministry of Finance and Bangladesh Bank Data and Planning Commission reports are also useful in the context of developing states and scenarios related to population and relevant socio-economic aspects of the country.

2.4.1 Climate change education and technical research institutions in Bangladesh

The Ministry of Disaster Management and Relief (MoDMR) (through their CDMP II activities) has developed partnerships with a number of academic institutions in Bangladesh to help create an enabling atmosphere for generating disaster management professionals. The goal is that these professionals will play important roles in generating data and information and will undertake critical analytical works on more clearly understanding climate change vulnerability and risks. Through their different departments and institutes, partner universities are running programmes such as certificate courses, undergraduate bachelor programmes, master's and post graduate diplomas. Higher level research-based degrees on disaster management related fields such as PhD and MPhil are also being offered by these institutes.

<u>Universities and related agencies offering disaster management courses</u>

- University of Dhaka (DU), Dhaka.
- University of Rajshahi (RU), Rajshahi.
- Jahangirnagar University (JU), Dhaka.
- Bangladesh Agricultural University (BAU), Mymensingh.
- Khulna University (KU), Khulna.
- Patuakhali Science and Technology University (PSTU), Patuakhali.
- Mawlana Bhashani Science and Technology University (MBSTU), Tangail.
- Shahjalal University of Science and Technology (SUST), Sylhet.
- Chittagong University of Engineering and Technology (CUET), Chittagong.
- Independent University Bangladesh (IUB), Dhaka.
- BRAC University (BRAC-U), Dhaka.
- North South University, Dhaka.
- National Curriculum and Text Book Board (NCTB), Ministry of Education, Dhaka.
- Armed Forces Division (AFD), Prime Minister's Office.
- Dhaka School of Economics, Dhaka (a constituent Institution of the University of Dhaka)

Inclusion of disaster risk reduction and climate change adaptation issues has been accomplished in the primary, secondary and higher secondary education through a partnership between MoDMR and National Curriculum and

Textbook Board (NCTB) of Bangladesh. By 2014, NCTB had distributed 320 million books among 30.68 million students and disaster management issues were incorporated in 31 subjects - 9 at primary level, 14 at secondary level and 8 at higher secondary level. NCTB has also facilitated the distribution of supplementary learning materials e.g. stories, poems, and novels, focusing on disaster risk reduction issues.

2.4.2 Climate change governance and mainstreaming activities

Climate change impacts are cross-sectoral and thus different ministries in Bangladesh are concerned with both the immediate and the far-reaching consequences of climate change. These consequences are dealt with mainly by incorporating climate change challenges into sector policies and ensuring institutions deliver necessary services. The Ministry of Environment and Forests (MoEF) has been playing the leading role in managing climate change and the challenges Bangladesh faces.

The 2013 CPEIR (Climate Public Expenditure and Institutional Review) Study provides details on climate change governance structure and processes by focusing on related policies and institutional frameworks. The policy frameworks provide strategic planning and the proposed necessary institutional architecture to implement climate actions. Initially, an attempt was made to mainstream climate change issues within a disaster risk management framework, namely the Comprehensive Disaster Management Programme (CDMP I, under the auspices of MoDMR) framework, i.e. Component 4b. It aimed to establish a mechanism that would facilitate the management of long-term climate risks as an integral part of national development planning. Later, with the addition of the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009, a gradual transfer of climate change-related risk management took place from MoDMR to MoEF (Ministry of Environment and Forests). Currently, MoDMR with its sub-agencies such as the Department of Disaster Management (DDM) and the Cyclone Preparedness Programme (CPP) is focusing on Disaster Risk Reduction (DRR) aspects. Simultaneously, MoEF with its major sub-agencies such as the Department of Environment (DoE) and the Forest Department has as its primary focus Climate Change Adaptation (CCA) issues. It is important to note that there are academic debates regarding synergies and differences between DRR and CCA, and in practice these are often considered rather overlapping. In this respect, the Planning Commission, while developing the 7th Five Year Plan, tried to distinguish the thin boundaries between the definitions of the two concepts.

The recently completed multi-donor funded CDMP II (implemented under the supervision of MoDMR) invested in climate change aspects and implemented partnership programmes with 12 Ministries, 13 agencies and also with some non-government organizations. These partnership action programmes could also be considered as mainstreaming relevant climate change issues into the regular development programmes of the respective ministries. Major achievements of the partnership activities have been in the following areas:

Mobile phone operators: 115 million cell-phone users now have direct access to early warnings of approaching hydro meteorological disasters by dialing 10941;

Partnership with Bangladesh Metrological Department (BMD): About 70% of weather forecast processing time has been reduced as a result of installing a Weather Research and Forecasting simulation system with BMD. A total of 593 BMD officials have been trained on meteorological services and ICT. The Storm Warning Centre has been strengthened with a high-speed communication system and solar powered electricity backup;

Flood Forecasting Warning Centre: Flood forecasting lead time has been extended to five days, which is saving the lives, livelihoods and assets of some 88 million people living in four river basin areas of Bangladesh. Communities can save more than 70% of their movable resources/capital goods with the introduction of the five day lead time flood forecasting. The extended lead time has the potential to reduce the loss of moveable assets by 20% in the case of severe flooding. Over 100,000 people have visited the redesigned FFWC website for flood forecasts since July 2014;

Training of professionals: A total of 300 government officials have received training and orientation on preparing climate resilient development projects. In addition, to date, 30,011 urban community volunteers including 6,970 female volunteers, 6,342 farmers, 1,017 officials and 3,900 Climate Field School members, 250

Department of Fisheries (DoF) officials have received the training. About 1,350 fishermen have been trained through 110 demonstration ponds. A Disaster Risk Reduction Action Plan for the Department of Fisheries has been prepared. Farmers have been trained through model villages in a cross-sectoral collaborative effort by the DoF, DAE and DLS. A total of 250 DWA (Department of Women Affairs) officials have received training on disaster and climate change from training programmes organized in ten districts;

Climate change in educational curricula: CCA and DRR issues have been incorporated in 35 text books from primary to higher secondary levels of education. Over 22 million students from classes III to XII of every academic year now have access to DRR and CCA knowledge. Bangladesh Technical Education Board has incorporated 'Climate and Disaster Management' in the curriculum of the Agriculture Training Institute;

Field level demonstration of climate smart technology: Short-term safe aquaculture has been demonstrated in 110 ponds. A training module on short-term safe aquaculture has been developed for farmers and has been adopted and used by the Department of Fisheries. So far 2,500 demonstrations for farmers and 500 farmer meetings have been conducted. In addition, 600 officers have received training on bio-security measures; WASH facilities in saline affected areas: A total of 50 deep tube wells, 38 rainwater harvesting units, and one underground water reservoir have been installed in salinity affected coastal area;.

DGHS (Director General of Health Services): National Health Crisis Management and Archive Centre have been established;

Partnership with Planning Commission: Development planning is being aligned with DRR and CCA in the DPP format;

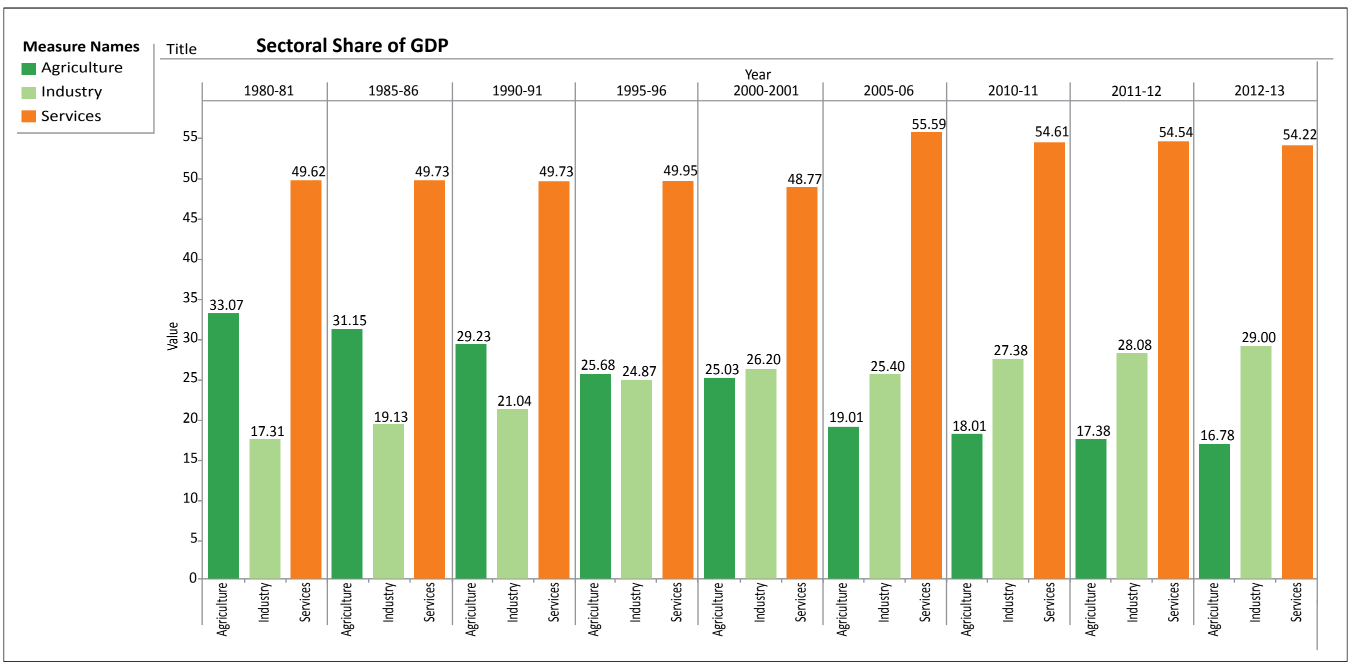


Figure 2.9: Sectoral Share of GDP in Bangladesh (Source: MOF, 2005; MOF, 2008; MOF, 2012; MOF, 2014, BBS, 2014)

2.5 Analysis of National and Sectoral Strategies, Plans, Programmes and Studies

Different ministries, departments and agencies have been undertaking projects for addressing climate change in relation to adaptation and mitigation. Some agencies, such as the Ministry MoDMR) and the Ministry of Environment, Forest and Climate Change (MoEFCC), work primarily as regulatory bodies while others, such as the Bangladesh Water Development Board (BWDB) under the Ministry of Water Resources (MoWR) have the responsibility to implement programmes. In many cases, the same agency carries out both types of activities simultaneously through different sub-agencies. For example, the Department of Disaster Management (DDM) also delivers programmes under the auspices of MoDMR. A thorough review of those activities has been undertaken and the results are given in the following sections.

Table 2.11: Key Activities Related to Climate Change Carried Out by Different Agencies

Government Agencies	Key Activities Related to Climate Change Adaptation and Mitigation
Department of Environment (DoE):	Market Development Initiative for Bondhu Chula Clean Development Mechanism (CDM) Using Municipal Organic Waste of Towns (City Corporation/Municipalities) throughout Bangladesh Community Based Adaptation in the Ecologically Critical Areas through Biodiversity Conservation and Social Protection (CBA-ECA) Project
Bangladesh Climate Change Resilience Fund	Emergency 2007 Cyclone Recovery and Restoration Project (Multipurpose Cyclone Shelter Construction Project) Community Climate Change Project Supporting Agriculture Adaptation to Climate Change Climate-Resilient Participatory Afforestation and Reforestation Project Rural Electrification and Renewable Energy Development Project II (Solar Irrigation Project) Modern Food Storage Facilities Project Impacts of Climate Change on Climate-Sensitive Diseases and Implications for the Health Sector Waterlogging of Urban Areas in a Changing Climate: Potential Damage and Adaptation Scaling up Innovation in Disaster Risk Management in Bangladesh: A Proposal to Support Human and Financial Resilience to Natural Hazards Making Climate Data Relevant to Decision Making in Bangladesh: Spatial and Temporal Downscaling
Bangladesh Climate Change Trust Fund (BCCTF)	Created in 2009-2010 by the Gpvernment of Bangladesh (GoB) to finance the implementation of projects under BCCSAP 2009. The projects undertaken so far include building cyclone resilient houses, afforestation, excavation/re-excavation of canals, introduction and dissemination of stress tolerant crop varieties and seeds, construction of embankments and river bank protective work, waste management and drainage infrastructure, and installation of solar panels. A total of 282 projects, with an estimated cost of 19,97.04 crore Taka, have been approved so far. Among these projects, 219 have been implemented by different government ministries, departments and agencies and 63 projects are being implemented by NGOs
Department of Forestry	Climate Resilient Afforestation and Reforestation Project Reduction of Carbon Emission through Establishment of Sonaichari Botanical Garden, Bhatiary, Chittagong Plantation for massive forestation across Bangladesh to address negative effects of climate change Revegetation of Madhupur Forests through Rehabilitation of Forest Dependent Local and Ethnic Communities (Phase-2)
Institute of Water Modeling (IWM)	Trust established by the GoB working in the fields of Computational Hydraulics, Water Modeling and Allied Sciences. River Engineering Division (REN) of IWM has completed many river modeling research projects. So far, it has completed a number of nationally important projects, such as ‘Land-use Change upon Storm Water Drainage in Eastern Dhaka’, ‘Causes and Remedies of Southwest Flood 2000’, ‘Decision Support System for Irrigation Management’, ‘Bangladesh Flood Hydrology Viewer’— an Internet based GIS Application, ‘Prediction of Erosion around Hatia & Sandwip with University of Tohuku, Japan’, ‘Improvement of Cyclone induced Coastal Flood Forecasting Tools with DHI Water and Environment’ and a climate forecasting application in Bangladesh with the Georgia Institute of Technology. Some of the ongoing works are: Urban Growth Modeling to Determine City Run-off in the Future, Determination of Hydro-geological parameters for SW and SE regions of Bangladesh, Phase-II, Data Collection, and General, Regional & BoB Models Updating, and A Study on the Effect of Oblique Flow and Char Movement in River Bank and Bank Protection Work
Bangladesh Water Development Board (BWDB)	Works primarily in the water sector inspecting the impact of climate change on the Ganges river basin. Under the funding of the Bangladesh Climate Change Trust Fund (BCCTF), the BWDB has also completed a number of projects related to drainage and river issues.

Government Agencies	Key Activities Related to Climate Change Adaptation and Mitigation
Bangladesh Rice Research Institute (BRRI)	Has conducted research works on finding high-yielding rice varieties and on the development of improved production technologies. The BRRI has already developed many high-yielding and salt tolerant varieties of rice. BRRI dhan58, BRRI dhan59 and BRRI dhan60 are some examples from a long list of high-yielding rice varieties developed by BRRI. The BRRI dhan61 is a salt-tolerant rice that can lead to an increase in rice production in coastal areas. Further, research is also ongoing to develop more varieties of salt tolerant rice. BRRI has already made inroads into making a submergence-tolerant variety of rice. Other significant ongoing research projects include the development of rainfed lowland rice (RLR), of varieties of rice tolerant of shallow floods, tidal submergences, water stagnation, cold and drought and of insect resistant rice.
The Department of Public Health Engineering (DPHE)	The DPHE has already achieved significant success in addressing a declining water table by introducing the Tara pump, Mini Tara & extended piston in 1.5- inch diametre shallow wells. This has helped people living in northern Bangladesh to fetch water from much lower water table areas. This institution also updated coastal belt mapping in 1993-95, allowing the identification of excess salinity intruded areas and areas with some other problems. Later, alternative technologies were introduced in those affected areas where salinity level was found to be high. DPHE has also designed and piloted a community- based Rain Water Harvesting System (RWHS) to serve three to five families (25 to 30 users) for drinking and cooking purposes. Perhaps the most successful activity in terms of emergency preparedness was the establishment, following the 1994 flood, of a water source with raised platform in flood shelters or strategic locations. In a study carried out by CEGIS after the 2007 flood, it was found to be very effective and this technology has been incorporated into the UNICEF assisted Post Flood Rehabilitation project. In addition to these projects, DPHE has also pioneered various water treatment technologies such as Pond Sand Filters (PSF). Right now, the DPPHE is involved with a number of water and sanitation projects concerning water supply, sanitation and drainage in both rural and urban areas of Bangladesh.
Department of Agricultural Extension (DAE)	DAE has been undertaking different agricultural projects, some of which are also addressing climate change alongside agricultural production issues. For example, the Disaster and Climate Risk Management in Agriculture (DCRMA) project promotes agricultural adaptation practices and enhances disaster risk reduction opportunities in four hazard prone regions of Bangladesh. The DAE has also been implementing a project in flood and water-logging prone areas, which promotes floating bed agriculture. It has also undertaken projects to ensure environment-friendly food security through the strengthening of a round-the-clock monitoring, forecasting and advanced warning system (July, 2013 – June, 2015).
Department of Disaster Management (DDM)	DDM has already completed a number of projects for addressing and managing disaster risk. For promoting awareness on disaster related information, the DDM has pioneered Interactive Voice Response (IVR) technology which allows people to access a pre-recorded weather advisory and disaster early warning around-the-clock. To communicate with disaster management personnel working in the field regarding early warning and post-disaster management directives, a mobile phone SMS based system has been developed. Further, cyclone shelter and flood shelter projects are now underway in flood prone and river erosion areas. For increasing institutional capacity, the 'Strengthening of the Ministry of Disaster Management and Relief Programme Administration' (SMoDMRPA) project is now being implemented.
Bangladesh Bureau of Statistics (BBS)	The BBS is entrusted with generating and maintaining statistical information concerning various sectors including the economy, society, health, and environment. The BBS has conducted a survey entitled 'Impact of *Climate* Change *on Human Life* (*ICCHL) Survey-2013-16'*. This work will identify climate change induced disaster prone areas, provide information on socio-economic characteristics of disaster prone areas, calculate agricultural loss due to natural disasters, collect information on land affected by natural disasters, generate information on affected houses in areas hit by natural disasters, and identify the water and sanitation conditions in disaster hit areas.
Local Government Engineering Department (LGED)	The LGED is involved with the development, maintenance and management of transport, trading and small-scale water resources infrastructure at the local level. It has invented a number of technologies that are less costly and more user and environment friendly than earlier ones. Noteworthy are: a. the development of low-cost sustainable model houses; b. Buried Pipe Irrigation, which allows total use of the command area of deep tube well irrigation; and c. Briquette as Fuel, which is a substitute for firewood and reduces fuel cost by 20-25%.

2.6 National Policies to Address Gender Issues in the context of Climate Change in Bangladesh

Some of the significant initiatives related to gender, climate change and disasters have been put in place through policy instruments like Vision 2021, Perspective Plan, Sixth and Seventh Five Year Plan, BCCSAP (2009), NAPA (2009), Climate Change and Gender Action Plan (CCGAP, 2015), National Women's Advancement Policy (2011), Standing Order on Disaster (SoD 1997, revised in 2010), National Water Policy 1999 and National Water Act 2013, National Plan for Disaster Management (NPDM, 2010-2015), Coastal Zone Policy (2005), and Agriculture Policy (2010). Vision 2021, which provides political directions for all national policy documents, states: *"All measures will be taken to protect Bangladesh, from the adverse effects of climate change and global warming including planned migration abroad."* The Perspective Plan (PP) is the *'Blue Print that advances a more inclusive and holistic picture of development that considers climate change in devising strategies for overall and sectoral development plans and proposed 'Climate Change Response Options'.* Other national sectoral policy documents such as the Coastal Zone Policy, 2005 and the Agriculture Policy, 2010 are currently being reviewed taking into account the effects of climate change and policy directions to combat those. Bangladesh Sixth FYP-2011-2015 provides strategic directions and a policy framework as well as sectoral strategies, programmes and policies for accelerating growth and reducing poverty. The Sixth FYP has identified benchmarks, targets and implementation strategies for the period it covers. The Seventh FYP (2016-2020) has reviewed Climate Change and Disaster Risk Reduction, taking into account gender issues (Background document 17 of Seventh FYP).

The BCCSAP (MoEF, 2009) and corresponding Climate Change and Gender Action Plan (CCGAP) developed in 2015, revised Standing Orders on Disaster Management (MoDMR, 2010), and the Disaster Management Act, 2012 include various gender-focused stakeholders such as the Ministry of Women's and Children's Affairs (MOWCA), civil society and academics in climate change and disaster risk reduction activities. Responsibilities include responses to pre- (awareness, warning), during (disaster period) and post-disaster (rehabilitation) situations. The Department of Women's Affairs (DWA) assumes responsibility for specific activities such as ensuring participation of DWA representatives in different disaster management committees (DMC), ensuring women's participation in preparedness and disaster management activities and providing livelihood support to women and children affected by natural disasters. It also plays an active role in identifying gender gaps and ensuring that these are addressed in all disaster management activities. In 2011 and for the first time in Bangladesh, the National Policy for Women's Advancement endorsed women in disaster as a separate theme. From 2010 to 2012 the DWA completed a programme on gender and disaster in 413 *upazilas,* involving 1,500 organizations. In 2015 a gender toolkit on DRR was produced for DWA to provide orientation to officials of the DWA and women at the level of grassroots organizations. Bangladesh is actively addressing the issues related to the 2030 Sustainable Development Agenda involving 17 goals and 169 targets. Number 5 of the Sustainable Development Goals (SDGs) focuses on women's advancement with specific targets, and gender perspectives are inherent in other SDGs.

2.7 Analysis of Poverty-Climate Links/Nexus

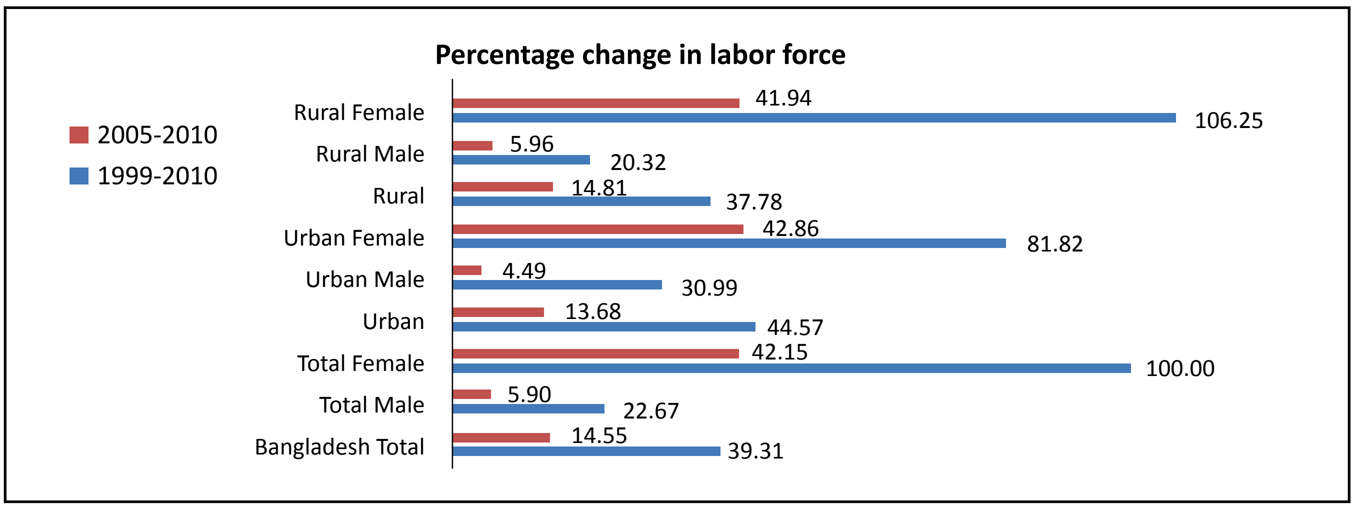
2.7.1 Contextual settings of climate change induced vulnerability in Bangladesh

Climate change induced disasters have an impact on employment and on the livelihoods and security aspects particularly of people living in areas prone to natural disasters. People living in cyclone prone and saline affected coastal areas, and in areas prone to floods and river bank erosion or in floodplains, river island areas, or haor-wetlands where water inundation stands for about half of the year, experience crop and property loss almost every year. Loss of income leads to increased poverty and can disproportionately affect the most vulnerable members of society - women, children, the elderly and the disabled. Risks spread to different aspects of living, for example food security, schooling, health conditions and WaSH facilities. Studies show that the number of unemployed people increased from the year 2000 to 2010, although percentage-wise the employment rate increased significantly for the same period of time. Percentage change data shows that the number of employed people increased manifold (about 100% for women, 22% for men and overall about 39%). However, the unemployment that still remained resulted mainly from the impacts of disasters that hit in different disaster hot-spots of the country. River bank erosion, frequent occurrence of floods and cyclones, drought conditions and climatic anomalies which show increasing trends in the wake of worsening climate change have been disturbing primary production processes resulting in people affected losing their crops, while others who sell physical labour lose employment opportunities. These conditions are illustrated in the following sections.

Table 2.12: Unemployment in Bangladesh from 1999-2010

Characteristics	1999-2000	2005-2006	2010
Bangladesh: Total	1.7	2.1	2.6
Total Male	1.1	1.2	1.6
Total Female	0.7	0.9	1
Urban	0.5	0.5	0.9
Urban Male	0.4	0.3	0.5
Urban Female	0.8	0.2	0.4
Rural	1.3	1.6	1.7
Rural Male	0.7	0.9	1.1
Rural Female	0.5	0.7	0.6

Source: Labour Force Survey 2005-06 and 2010 (Bangladesh Bureau of Statistics 2007 and 2011)



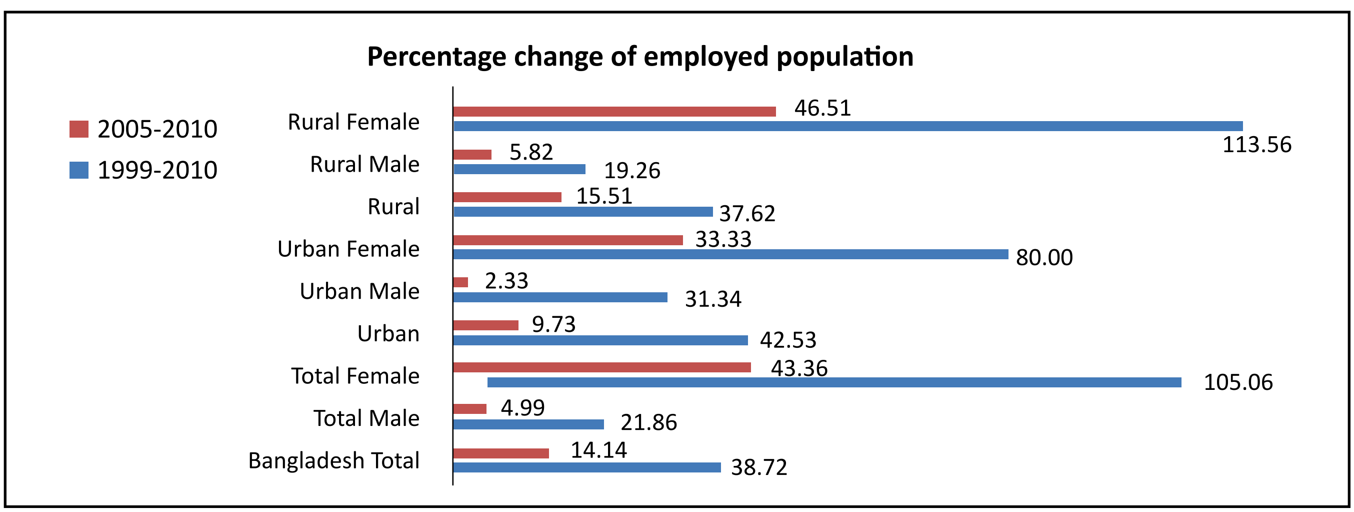


Figure 2.10: Characteristics of Labour Force in Bangladesh (Bangladesh Labour Force Surveys 2005-06 and 2010)

2.7.2 The nexus between climate change impacts and poverty

The majority of people in Bangladesh are heavily dependent on access to natural resources for their food security. Natural resources include: (i) land with favorable properties such as fertility, moisture holding capacity, and drainage systems; (ii) biological diversity and availability of resources that provide alternative choices to the farmers; (iii) water resources that ensure rainwater or irrigation facilities and supply important nutrients for plants and animals; and (iv) climatic conditions like optimum temperature, sufficient occurrence of rainfall, wind direction and flow pattern and necessary sunshine. These create an enabling environment suitable for natural resources based, agriculture, forestry and fishery primary production systems in the country. The effect of climate change on these processes needs to be understood in order to recognize the adverse effects of climate change on people's economic and food security.

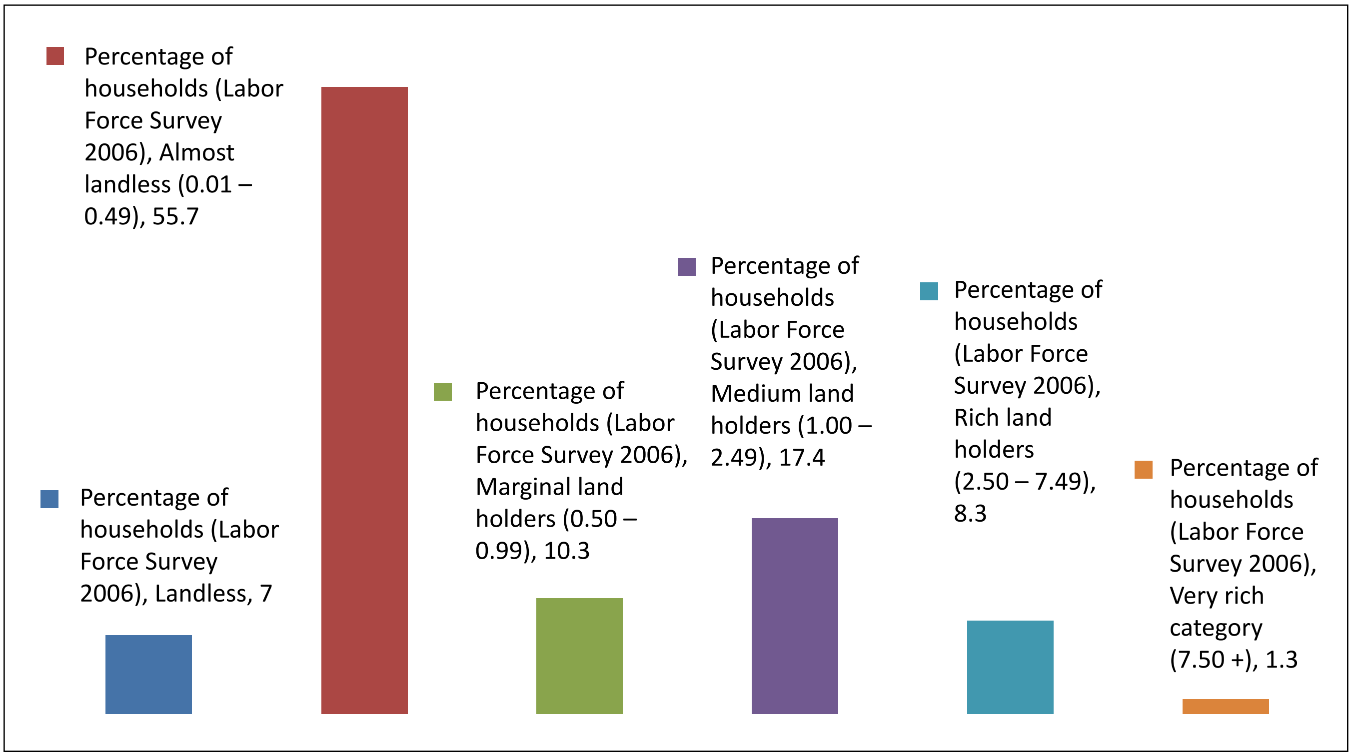


Figure 2.11: Percentage of Land Ownership by Households in Bangladesh

Source: Bangladesh Bureau of Statistics, 2007

The Bangladesh Bureau of Statistics (BBS, 2011a) puts the labour force of the country at 56.7 million of whom 39.5 million (70%) are male and 17.2 million (30%) female. About 25.7 million (47%) are directly engaged in the agriculture and fisheries sector and of these, almost 62.7% are functionally landless poor (when the bottom two categories are combined); about 27.7% own land between 0.5 to 2.49 acres and only 9.6% fall in the rich category in terms of land ownership. This indicates that the people who are engaged in primary production systems are generally poor. In these sectors some people are owners of small businesses or employers and some are self-employed, but the majority work as day labourers (agricultural and non-agricultural), small traders, crop processors and transportation workers. It is important to note that about 95% of Bangladesh's day labourers come from the agricultural sector (BBS, 2011a), that there are 5.53 million day laborers in Bangladesh and when all sectors are combined, about 25 million people are dependent on them. This suggests that the occurrence of any natural disasters, whether sudden or as a result of slow onset climate change, puts marginalised people who are in harm's way as the disaster strikes, in serious poverty ridden conditions. These people have little or no land and disasters rob them of their modest means of earning livelihoods including the collapse of possible employment opportunities. These conditions create the grounds of poverty climate change nexus.

Table 2.13: Status of Employment (in 000)

Occupation Category	Status Employment (in 000)									
	Total	Regular paid employee	Employer	Self-employed (agri)	Self-employed (non-agri)	Unpaid family worker	Regular paid worker	Day laborer (agri)	Day laborer (non-agri)	Servant
All professional categories combined	54,084	7,876	119	1,2308	9,714	11787	1486	5792	4,838	455
Agriculture, forest and fishing (% against all categories combined)	25679 (47.47%)	748 (9.5%)	23 (19.32%)	7982 (64.85%)	1518 (15.62%)	9559 (81.09%)	116 (7.8%)	5526 (95.40%)	383 (7.91%)	31 (6.81%)

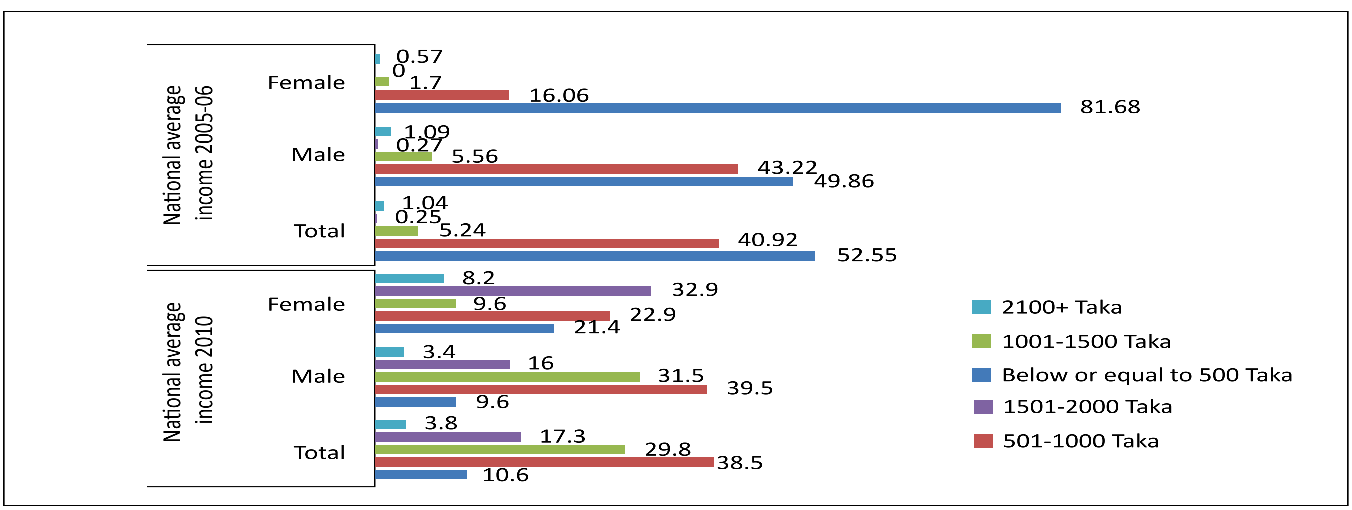
Source: BBS, 2011a

In rural Bangladesh people take up different occupations simultaneously to minimise risks to their livelihoods.. However, people have traditionally given more importance to one type of occupation than others and it is generally observed that people allocate 60-70% of their time to one occupation and the rest to minor ones. The secondary or minor income sources play important supportive roles when the primary occupation is in jeopardy due, for example, to natural disasters over which they have least control; in this way many farmers take up certain non-farming activities. People are usually classified into different occupational groups, according to their primary occupation but given the tendency for secondary occupations, classification can be problematic.

In recent times, climate change has posed a threat to physical processes (e.g. geo-chemical properties of soil, hydrological regimes, meteorological properties, etc.) and changes in their properties, availability and quality have been observed (Climate Change Cell, 2009; CDMP II, 2013). Changes also occur, consequentially, in the characteristics of land, forest and water based natural resources and dependent social systems. The effects of climate change are felt both directly and also through a complex process of impact, spill-over and multiplication issues. Climate change impacts and the poverty nexus are not linear and straightforward; major impacts fall on specific sectors but also cause scars on supportive and related sectors. The impacts of major disaster may be widespread but it is most often the case that small communities are those whose livelihoods are devastated and economic recovery is extremely difficult. It has been observed that as climate change intensifies and major natural disasters occur with increased frequency and devastation, destroying or damaging crops, other economic activities and infrastructure, many non-poor are becoming poor, many poor are becoming extremely poor and many extremely poor are becoming destitute. The challenge of poverty reduction is enormous.

2.7.3 Poverty eradication efforts in the context of climate change in Bangladesh

Bangladesh has achieved notable progress in reducing poverty and hunger in recent years. The Bangladesh MDG Progress Report 2015 (General Economics Division, 2015a) suggests that a sustained GDP of over six percent has contributed significantly to eradicating poverty. Improvements have been made in life expectancy and fertility rates as well as in education and health indicators, gender disparity and employment rates. In 1991-92 about 56.7% of the population was defined as poor, and this figure was reduced to 31.5% by 2010. This represents a 25.2 percent point or 55.5% reduction of poverty in only two decades. The poverty headcount ratio for 2015 is estimated to be 24.8 percent (General Economics Division, 2015b).



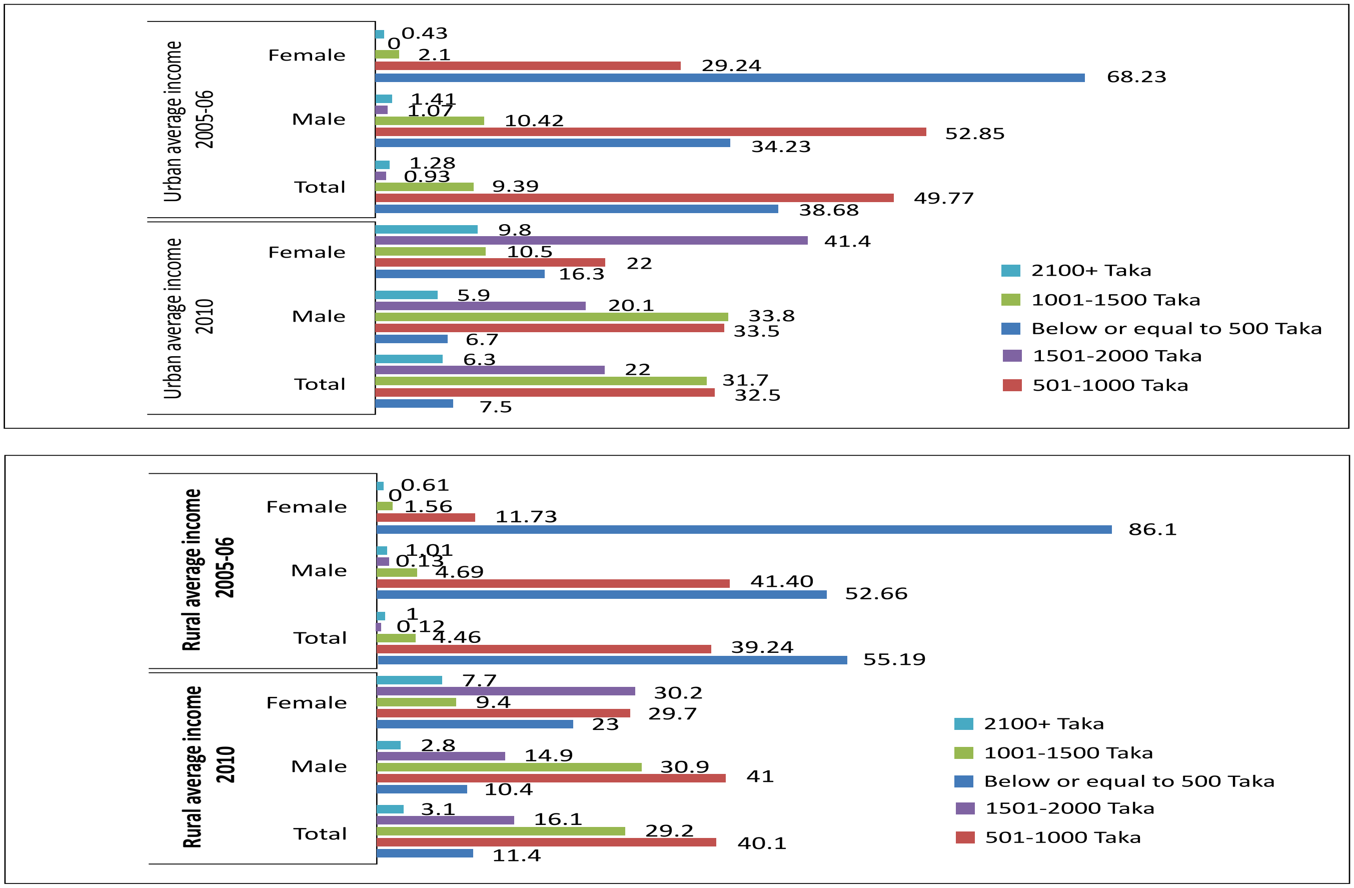


Figure 2.12: Weekly Income of People (National Average, Urban and Rural)

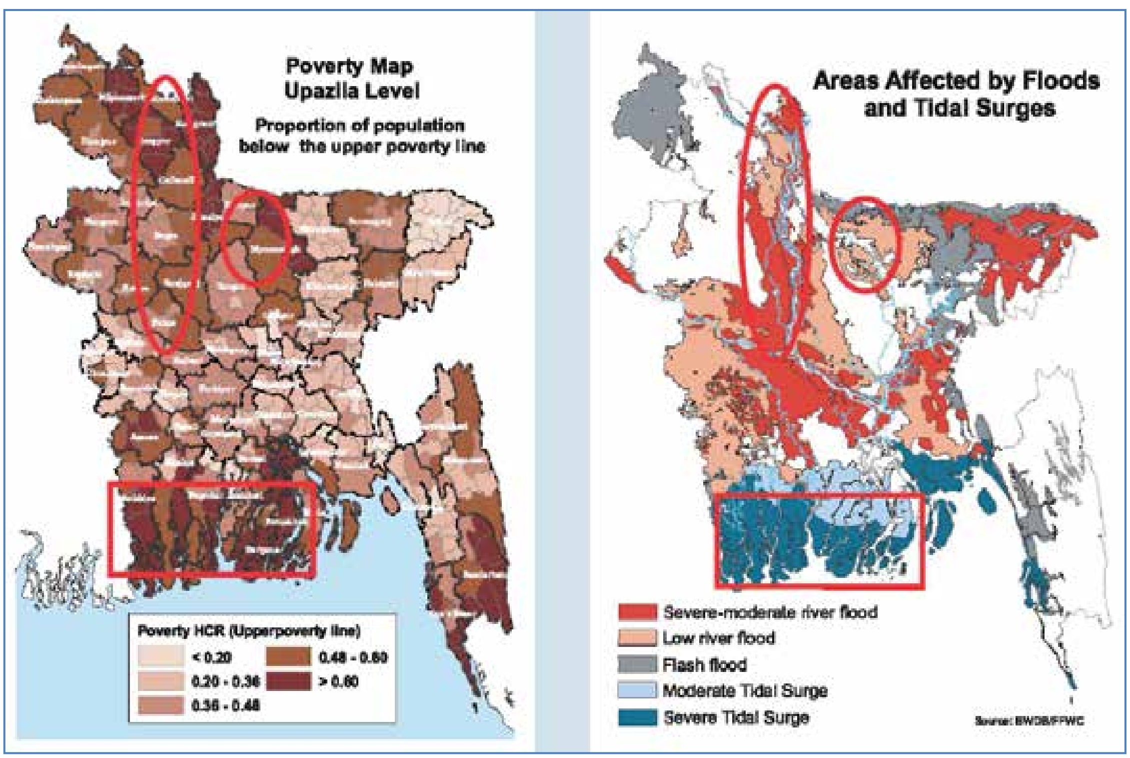


Figure 2.13: PovertyDisaster Nexus (BBS, World Bank, World Food Programme: Updating Poverty Maps of Bangladesh, 2005)

However, despite a significant reduction of poverty in terms of proportion, the absolute number of poor people is still 38 to 40 million. Poverty is concentrated in certain areas of the country, those which are particularly affected by cyclones, floods, erosion of river beds, water-logging and salinity intrusion and also in urban slums. The urban slum dwellers are migrants from rural areas who have lost whatever assets they may have had and who face bleak employment prospects. Thus poverty pockets preponderate in haor regions of the country where river erosion and riverbank spillovers cause frequent disastrous impacts and where flash floods are common, and in south-western coastal areas where cyclonic impacts and inundation threats are frequent (Khandker and Mahzab, 2010). A background paper prepared for the Seventh Five Year Plan of Bangladesh entitled 'Lagging Districts Development', identified fifteen districts which lag behind in development opportunities based on a deprivation matrix[1]. Among the 15 districts, three belong to the Chittagong Hill Tracts region, seven to south-western coastal regions and five to north-eastern haor regions. These conditions adversely impact different production sectors and employment markets, resulting in poverty and unemployment.

Table 2.14: Lagging Districts of Bangladesh (GED, 2015b)

Districts/Indicators	Road	Electricity	Credit	Education	Health	Water Supply	Overseas Employment	Total
CHT								***14***
Bandarban	1				1	1	1	4
Rangamati	1		1	1		1	1	5
Khagrachhari			1	1	1	1	1	5
South-West								***15***
Narail				1		1		2
Meherpur			1	1		1		3
Shariatpur						1		1
Rajbari		1			1	1		3
Barguna		1						1
Madaripur					1	1		2
Jhalakathi	1		1				1	3
North-West								***14***
Magura				1				1
Lalmonirhat		1			1	1	1	4
Chuadanga			1					1
Panchagar		1		1	1	1	1	5
Joypurhat			1	1			1	3
Total	3	4	6	7	6	10	7	43

Unemployment and under-employment tend to be dominant among young people 24 and under; this group comprises about 8.5% of the country's total population and 22% of the total labour force (BBS, 2011). Overall and as is to be expected, there is a significant difference in income between rural and urban areas. Thus, income per capita nationally and then broken down to urban and rural areas was Tk 2,553, 3,740 and 2,130 respectively as of 2010 (Bangladesh, Report of the Household Income and Expenditure Survey, 2011b). This means that someone living in an urban setting earns 176% what a person living in a rural setting earns. This rural-urban divide needs to be addressed by way of efforts to eradicate rural poverty and improve resilience and opportunities for rural people to move on to sustainable development.

1 Khandkher and Mahzab, 2010. used Principal Component Analysis (PCA) using 21 indicators; please see http://www.plancomm.gov.bd/

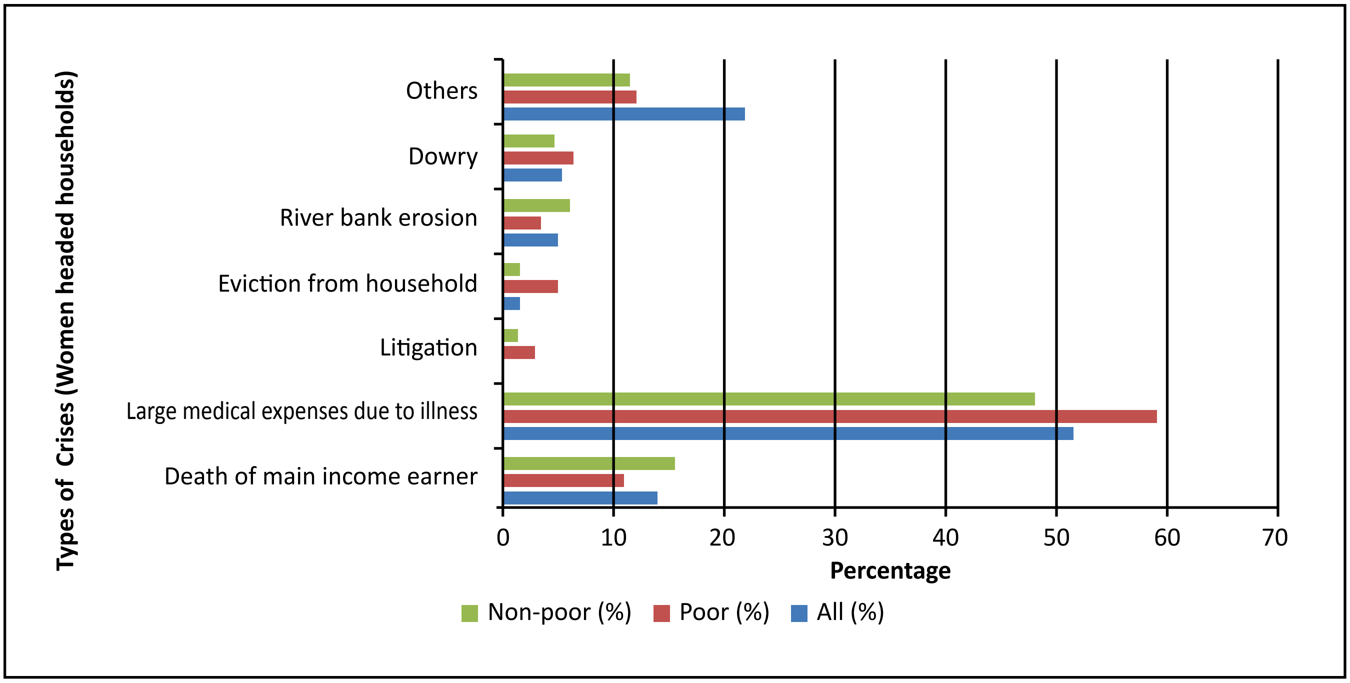


Figure 2.14: Reasons for Expenditure (Bangladesh Bureau of Statistics, 2004)

2.8 Gender Dimensions of Climate Change in Bangladesh

The sections above have illustrated the state of poverty and inequality in employment opportunities, including their geographical dimensions, and have looked at how climate change has contributed to exacerbating disparities and deprivations. Women are the biggest victims of these disparities and deprivations. Nationally both urban and rural males are more engaged in service sectors (43.05%), followed by agriculture (41.81%), while females are mostly engaged in agricultural employment (68.13%) followed by employment in the service sectors (19.35%) and the industrial sector (12.52%). It emerges therefore, that females are more engaged in agricultural activities (26.32 percent points or 63% more than their male counterparts). This high level of engagement of women in agricultural activities means that they are forced to contend with the various challenges that the agriculture sector faces (see impacts of climate change on agriculture in Bangladesh: CCC, 2009) and have to take on additional workloads to keep the sector moving and at the same time protect their own employment opportunities. On the other hand, males who are primarily engaged in service sectors are less vulnerable since service sectors are mainly located in urban areas where amenities and security/protection are more robust than in rural areas. In addition, health, education and communication services in rural areas are not as abundant as in urban areas and are often more costly despite people having less income from which to pay for them. Figure 2.14 shows that in rural areas people, including those with less disposable income, spend more on health services. Moreover, in relation to wage rates for the same work, the gender pay gap is more prevalent in rural areas than in urban areas (Table 2.15). Discrimination extends to working hours too; women find fewer working hours of paid employment opportunities compared to their male counterparts. Table 2.15 shows that 45,000 females work for 15-29 hours per week (among whom 42,000 i.e. 93% come from rural areas), while 279,000 males work in this category per week - 14% females as opposed to 86% males. Other categories also indicate similar inequalities in terms of the availability of working hours in the context of which earnings are determined. There are two dimensions to consider in the scope of fewer working hours for women; firstly employment opportunities are less in rural areas because of gaps in infrastructural and other support facilities and in certain cases climate change and disaster impacts destabilize the employment sectors, which in turn reduces employment opportunities as a whole in rural areas; and secondly, employers prefer to employ males rather than females.

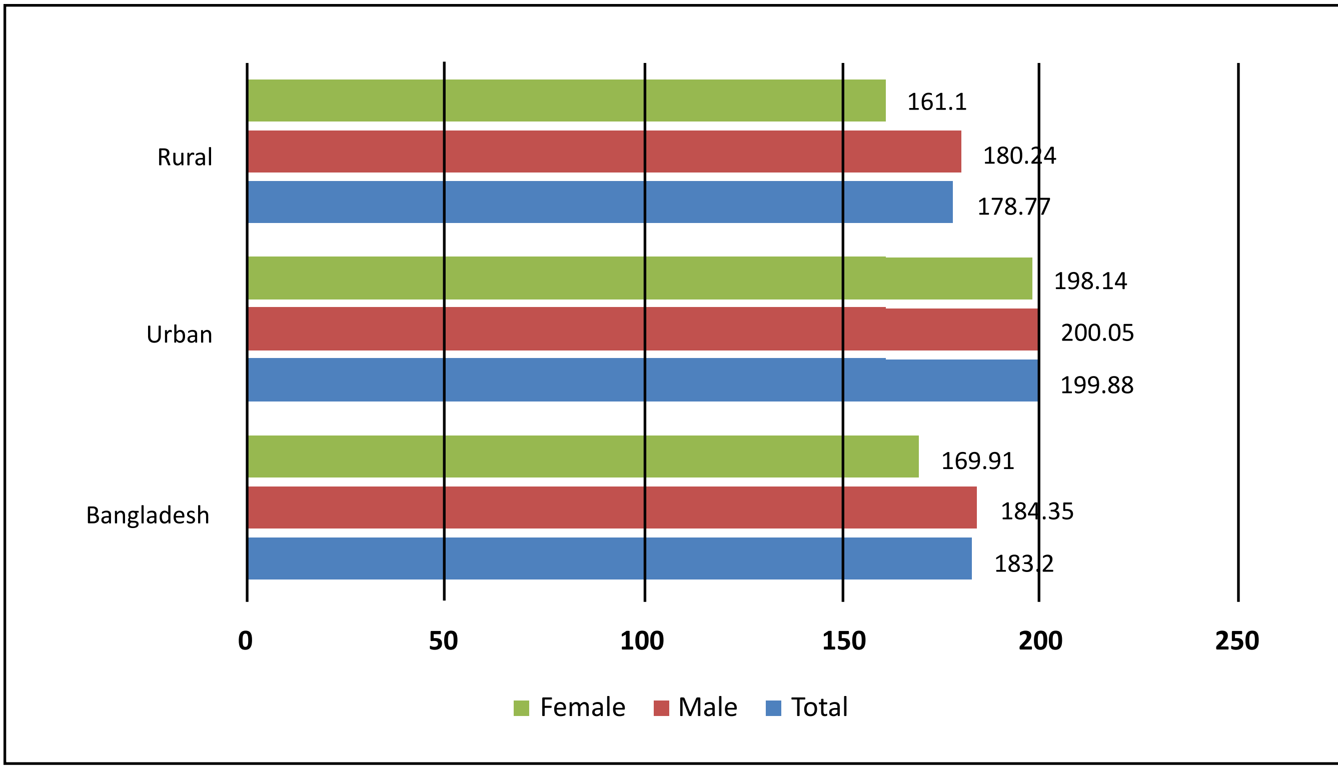


Figure 2.15: Daily Wage Rate in taka (Bangladesh Bureau of Statistics, 2010)

It is evident that during and after disaster situations people move elsewhere due to fewer employment opportunities (for example agricultural land is flooded or otherwise destroyed) and women shoulder the responsibility of sustaining the household (Nasreen, 1995, 2012). Women take on the responsibility of procuring and processing food and fuel, collecting drinking water, maintaining health and sanitation, and looking after children and the elderly as well as livestock and poultry. Despite some improvements in recent years, women continue to suffer from some discrimination in relation to their human rights in ownership of land and other assets, access to employment, participation in decision making at home and freedom from violence and sexual abuse. When natural disasters strike, they suffer from further disadvantages given that they have to shoulder additional household and other burdens. A thorough analysis of available documents on climate change in Bangladesh highlights a lack of gender analysis and sensitivity in adaptation design and delivery (Neelormi, 2014). Establishing linkages between gender and mitigation has also been largely absent.

Table 2.15: Employment of youth (15-29) and over by major occupation and sex, weekly hours worked

Occupation Category		Hours Worked Group						
		Total	<15 hours	15-29	30-39	40-49	50-59	60+ hours
Bangladesh (covers 10 major occupational categories*)		19342	255	4416	1007	6468	4550	2645
Skilled agri and fisher workers	Total	1354	83	324	224	343	269	111
	Male	1248	63	279	219	318	258	110
	Female	106 (89 rural)	20 (16 rural)	45 (42 rural)	5 (5 rural)	24 (17 rural)	11 (10 rural)	01 (0 rural)
Other categories are: Special Occupations, Legislators, Senior Officials and Managers, Professionals, Technicians and Associated Professionals, Clerks, Service workers and Shop and Market Sales Workers, Craft and Related Trade Workers, Plant and Machine Operators and Assemblers and Elementary Occupations.								

The assessment indicates that: (i) women are more likely to be employed in climate sensitive sectors like agriculture as compared to men; (ii) women are mainly confined to rural areas where deprivations and insecurities are more prominent; and (iii) women endure unfavourable conditions in terms of wages, availability of working hours and receiving basic service facilities.

The Government of Bangladesh has been trying to address women's vulnerability arising from various factors in rural areas, some of which have been discussed above, by implementing a number of social safety net programmes. The VGD (Vulnerable Group Development) is one such programme through which the Ministry of Women and Children Affairs (MoWCA) is supporting 750,000 ultra-poor women across all 64 districts of the country, a programme which was originally designed and implemented by the World Food Programme immediately after the 1974 famine conditions in Bangladesh. Initially the programme aimed at addressing household level food security through the Vulnerable Group Feeding programme. Gradually its coverage has been extended and currently the programme addresses climate change related impacts in many ways. The government's annual allocation to climate sensitive sectors currently stands at about one billion dollars (CPEIR, 2013; Box 1) which plays a role in reducing climate change related impacts and vulnerabilities. This allocation is distributed across the sectors and thus contributes to raising the adaptive capacities of other sectors[2] that are also vulnerable to climate change impacts.

Table 2.16: VGD support of the government to protect ultra poor women in the context of climate change

Period		Programme features
1974-84	Operated as a relief programme targeted at most vulnerable households	Relief and feeding Targeted at disaster affected most vulnerable households A programme of the Ministry of Relief Both men and women were beneficiaries Fully donor funded
1985-90	Experimental phase to re-orient the programme from relief to development	Relief and feeding as focus but rethinking on achieving development goals through the programme Targeted at disaster affected most vulnerable households A programme of the Ministry of Relief Both men and women were beneficiaries Mostly donor funded
1991-2004	Expansion phase as a development programme	Focus on development of vulnerable households through food transfer NGOs get involved for capacity (skills) building of beneficiaries Ministry of Disaster Management and Ministry of Women and Children Affairs worked jointly Women were considered sole beneficiaries Mostly donor funded
2005-09	Phasing out as development programme	GoB fully owns the programme and starts investing from own resources Targeted at women from extreme poor households A programme of the Ministry of Women and Children Affairs (MoWCA) Strictly women focused programme Strategic donor engagement
2010-16	Capacity enhancement phase as a safety net programme	GoB retains ownership of the programme and continues to invest from own resources Targeted at women from extreme poor households A programme of MoWCA Strictly women focused programme Stronger focus on livelihoods Limited donor engagements (only in capacity building)

2 After agriculture, the labour force is Bangladesh are employed in the services sector (37.4%) and in the industrial sector (14.52%, among whom 11.03% are engaged in manufacturing sector).

These government protection programmes play useful roles in securing and growing employment sectors in urban and rural areas, where both females and males might benefit. However, the degree of improvements that this public expenditure has generated in different sectors remains neither clearly known nor estimated.

Box 1: Higher Government Expenditures are happening in Climate Sensitive Sectors in Bangladesh.

Government is the largest funder of climate actions in Bangladesh – around three quarters of government expenditure is funded from domestic sources. The Government typically spends around 6% to 7% of its annual combined development and non-development budget on climate sensitive activity which equates to an annual sum in the region of US$1bn at current exchange rates.

CPEIR Study 2013, Planning Commission, Bangladesh.

2.9 Conclusions

Major actions in reducing disaster and climate change impacts have been taken by the DDM (Department of Disaster Management) under the auspices of the MoDMR (Ministry of Disaster Management and Relief). Policy formulation (e.g. SoD, Disaster Management Act, 2012), implementing social safety net programmes (e.g. TR, EGPP, FFW), infrastructure development (e.g. the development and maintenance of approximately 3,850 cyclone shelters) and working towards disaster impacts recovery are some of the areas the DDM has focused on. In addition, the DDM has developed partnerships with donors and non-government agencies (including INGOs) to implement a number of projects that have contributed to reducing disaster risks induced from climate change in different parts of the country. The European Commission (EC) supported DIPECHO programme, implemented mainly through NAARI alliance and the multi-donor supported project CDMP (Phase I and II, from 2003 to 2014) are two examples. In parallel, international and national NGOs have supported and implemented a number of programmes in different disaster hot spots of the country in areas of risk assessment, capacity development, early warning, better disaster response and recovery and so on. These action programmes have created opportunities for different national (e.g. DDM) and field level agencies such as the Fire Service and Civil Defense (FSCD), different local government agencies such as the city corporation and municipalities to develop their equipment and human resource capacities to better deal with disaster risks and uncertainties. The major achievements related to disaster risk reduction in Bangladesh can be categorized as follows:

- Capacity development of institutions for better climate change and disaster preparedness including response (e.g. policy, institutions, human resource, tools and equipment);
- Alignment of sectoral policies with DRR (Disaster Risk Reduction) objectives (e.g. at least 10 out of 24 supportive studies carried out for 7th FYP have elements of DRR, aligning social safety net programmes with DRR objectives;
- Introduction of systematic impact and risk assessment procedures (e.g. CRA) to produce RRAP (Risk Reduction Action Plan);
- Risk identification and early warning (FFWC, BBS's ICCHL project, UNESCO supported climate change and education evaluation study);
- Knowledge management through information generation, information dissemination gateway (BARC's climate information management systems, FFWC, BBS); and
- Partnership development for innovative programme design and delivery aiming at reducing underlying risks (major projects include CDMP phase I and II, poverty reduction focused CLP, SHIREE, NARRI, and Shifting the Power project.)

3

Chapter 3

Emission of Greenhouse Gases: An inventory for Bangladesh

3.1 Background

Bangladesh is a party to the United Nations Framework Convention on Climate Change (UNFCCC). One of the objectives of this Convention is to achieve stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level needs to be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, ensure food security, and enable economic development in a sustainable manner.

One of the key elements of the National Communication is the preparation of inventory of the greenhouse gases (GHGs) sources and sinks. Under the UNFCCC, parties, with the exception of least developed parties and small island states, are expected to submit reports every two years, which should contain, among other input, a recent inventory of national GHG emissions and removals.

3.2 Introduction

The information provided in the Initial National Communication was according to the guidelines provided in decision 10/CP.2 for the year 1994 for the gases CO_2, CH_4 and N_2O. The estimates of emissions were made in the Second National Communication and Third National Communication for the years 2005 and 2006-2012 respectively, in accordance with the guidelines provided in decision 17/CP.8.

This Third National Communication (TNC) details a comprehensive national GHG emission inventory by sources and removals by sinks for the base years 2006 and 2012 using comparable methodologies of IPCC 2006. The scope of improvement with reference to the inventories presented in TNC include: (i) adherence to the TACCC (Transparency, Accuracy, Consistency, Comparability and Completeness) principle for developing a National GHG Inventory; (ii) development of different inventory life cycle documents such as institutional arrangement (IA) and the template methods and data documentation (MDD), detailed QA/QC procedures to ensure the highest quality of GHG Inventory; (iii) identification of data gaps on different sectors and addressing those with proper explanation in light of IPCC GL; (iv) the development for the first time, of an archiving system in DoE to preserve and regularly update the necessary inventory works and data-base; (v) a national inventory improvement plan with a focus on addressing the data gaps and sustainable inventory development capacities within and outside of the nodal agency, i.e. DoE; (vi) inclusion of additional GHG pools identified in IPCC 2006 guidelines (IPCC 2006) for the preparation of national greenhouse gas emission inventories that were not included in INC and SNC; (vii) a strong emphasis on QA/QC procedures as identified in IPCC Good Practices Guidance 2000 and 2003 (GPG 2000, 2003).

3.3 Objectives

Main Objective

The main objective of this task is to assess the level of GHG estimation each year between 2006 and 2012, and to develop and compile the national GHG inventories in Bangladesh.

Other Objectives

a) To establish emission baselines for the applicable sectors as per IPCC 2006 guidelines
b) To establish a GHG data base management system and archive that contains information for future reference.

Scope of the Work

Geographic: The entire territory of the People's Republic of Bangladesh

Activities: Five major activities are covered under the GHG inventory, as follows:

- Energy (including electricity generation, biomass burning, transport and energy consuming industrial sector etc.);
- Industrial process and other product use (IPPU) (mainly cement manufacturing and fertilizer);
- Agriculture (ruminant livestock, livestock management, rice cultivation, etc.);
- Land use change and forestry (change in forest cover and woody biomass, change in forest land use, etc.);
- Waste and refuge management (municipal waste, domestic and industrial waste water treatment/ management, etc.).

3.4 Task List

- Identify relevant national institutions from where activity data will be gathered and develop generic and sector specific data collection format for the data providing agencies.
- Familiarization of the effective use of the inventory related software like IPCC inventory and ALU to input activity data and develop GHG estimation on all the applicable sectors in a credible manner.
- Calculate percentage share of emissions of each of the greenhouse gases in Bangladesh. Global Warming Potential of 2006 IPCC Guideline may be used. The data was tabulated following the format below:

GAS	Emission Gg	GWPs	CO_2 Equ Gg	% of total emission.
CO_2				
CH_4				
N_20				
Total				

- Identify priority GHGs and analysze key source categories. The idea of key sources is based on a measure of which sources contribute the most GHGs. The results are being tabulated as follows:

Sector Emissions in CO_2**-eq.**	% of total emissions	Sector Emissions in CO_2-eq.
All Energy		
IPPU		
LULUCF		
Agriculture		
Wastes		
Total		

- Collect activity data from nationally available statistics along with necessary expert judgement and comments to fill inventory data gaps;
- Review and select appropriate emissions factor;
- Identify the contribution of the stationary sources (such as energy industries, manufacturing industries, commercial, residential, fishery/agriculture/forestry) and mobile sources (such as civil aviation, road transportation, railways, navigation, international bunker fuels) to GHG emissions;
- Prepare the GHG inventory for the years 2006, 2007, 2008, 2009, 2010, 2011 and 2012;
- Build national capacity on inventory preparation by offering short training sessions and workshops for relevant institutional representatives;
- Carry out an uncertainty assessment in relation to emission coefficient and activity data, as well as an assessment of the reliability of currently available data in the IPCC software platform; and
- Conduct stakeholder consultations on nationally relevant key emission factors and data gaps and devise cost effective modalities to generate such data in the near future.

3.4.1. Emissions from Energy Sector

3.4.1.1 Introduction

The energy sector is the single largest source of CO_2 emission, as well as of other gases like CH_4, and N_2O. In this report, greenhouse gases (GHG) from the energy sector are presented covering all the activities that contribute GHGs in this sector. The assessment for the Third National Communication (TNC) covers seven years, starting from the period 2006 to 2012. Emissions of CO_2, CH_4 and N_2O were estimated. The IPCC 2006 Guidelines were followed to conduct the estimation.

Comprehensive estimations of GHG emissions for Bangladesh were performed on three other occasions. The first time was in 1995 under the Asia Least Cost Greenhouse Gas Abatement Study (ALGAS) project. The inventory was for the year 1990. Following that, GHG inventory was performed for the year 1994 under the Initial National Communication (INC) in 2002 and for the Second National Communication in 2012. The growth of GHG emissions as reflected in comparison with the previous inventory is presented in terms of per capita CO_2 emission.

Methodology

In the TNC, GHG inventory was performed following the reference as well as sectoral approaches as per IPCC Tier 1 methodology. Default values of conversion and emission factors were used for all fuels and activities. The first step was to identify all energy consuming sub-sectors in Bangladesh. Identification of fuels was the next step, followed by identification of the data sources. Fuel consumption by each sector was collected from relevant sources. These were then reorganized into the sub-sectors under the energy sector as specified in the IPCC 2006 Guidelines. Not all combustion activities and sectoral splits in the guidelines are relevant for Bangladesh. Therefore, only the relevant sub-sectors were selected for reporting. A comparison of the Reference Approach and Sectoral Approach inventories on each year has been presented and annexed.

There are no reliable national estimates of calorific values of different fuels. Moreover, there is no data available on national emission factors. Thus, IPCC Tier 2 methodology inventory was not attempted.

Data Sources

For the collection of reliable data as per IPCC guidelines, a generic template was developed on all the applicable sectors and communicated to the chiefs of those respective agencies through a letter of data request duly signed by the Director General of the Department of Environment.

In Bangladesh, natural gas is the most important fuel both in terms of primary energy supply and usages. Bangladesh Oil, Gas and Mineral Resources Corporation, or Petrobangla as it is more commonly known, is assigned with the responsibilities of handling the gas and coal sectors of Bangladesh. Subsidiaries under Petrobangla are responsible for the exploration, production, transmission and marketing of natural gas. Thus, Petrobangla is an obvious choice for a good and reliable source of data on natural gas and coal consumption. It was possible to obtain a breakdown of consumer types by major categories, even down to major industry categories.

Bangladesh Petroleum Corporation (BPC) is responsible for the importing, refining and marketing of all liquid fuels consumed in Bangladesh. Thus, it is the most reliable single point of data source. Unfortunately, the complete breakdown of consuming sectors by fuel type for the reporting time was not available. The sector-wise and fuel-wise breakdown, had to be estimated from data for previous years following the trend of growth and expert judgement, especially on the spilt of usages between international and national aviation fuel usages. BPC provided annual data on fuel usages by international and national marine vessels. Since LPG and lubricants are imported by the private sector, collection of data proved to be rather difficult.

Petrobangla provided coal consumption data on the only government owned power generating station, the Barapukuria 250 MW coal power plant. Apart from power generation, coal has significant usages for making bricks and unfortunately, we do not have a well-structured accounting system despite large amounts of coal being imported every year for the production of bricks. To address this issue of data unavailability, an assessment was carried out based on the secondary information available. Reference was taken from the World Bank report while carrying out that assessment and activity data accordingly inputted to arrive at a rationale estimation on coal consumption particularly for brick making. Further discussion on this is presented in the Completeness and Uncertainty sections.

Fuel Supply and Consumption in Bangladesh

Definitions of Fuel Types were obtained from Table 1.1: Definitions of Fuel Types Used in the 2006 IPCC Guidelines. The local names of the fuels vary from the IPCC nomenclature. Table-3.1: shows the local names of petroleum products and the comparable IPCC names, together with units, conversion factors and IPCC default emission factors used in this reporting.

Table-3.1: Fuels, conversion and emission factors

FUEL TYPES			Local Name	Unit	Conversion Factor	Unit	Carbon Emission Factor (TC/TJ)
Liquid Fossil	Primary Fuels	Crude Oil	Crude Oil	MT	42.3	TJ/MT	20
		Natural Gas Liquids	Natural Gas Condensate	MT	44.2	TJ/MT	17.5
	Secondary Fuels	Gasoline	MS, HOBC, Octane	MT	44.3	TJ/MT	18.9
		Jet Kerosene	JP-1	MT	44.1	TJ/MT	19.5
		Other Kerosene	SKO	MT	43.8	TJ/MT	19.6
		Gas / Diesel Oil	HSD, LDO	MT	43	TJ/MT	20.2
		Residual Fuel Oil/Furnace Oil	RFO/FO	MT	40.4	TJ/MT	21.1
		LPG	LPG	MT	47.3	TJ/MT	17.2
		Naphtha	Naphtha	MT	44.5	TJ/MT	20
		Bitumen	Bitumen	MT	40.2	TJ/MT	22
		Lubricants	Lubricants	MT	40.2	TJ/MT	20
		Other Oil	SBP, MTT, JBO	MT	40.2	TJ/MT	20
Solid Fossil	Primary Fuels	Sub-bit. Coal	Sub-bit. Coal	MT	1000	Gg/MT	25.8
Gaseous Fossil		Natural Gas (Dry)	Natural Gas	TJ	1	MJ/M^3	16.1
Biomass		Solid Biomass	Cow dung	KT	8.76	TJ/KT	29.9
			Firewood	KT	15.39	TJ/KT	29.9
			Agricultural Waste	KT	5.61	TJ/KT	29.9
			Other Waste	KT	14.15	TJ/KT	29.9

3.4.1.2 Natural Gas

For the reporting period, there were fifteen gas producing fields in Bangladesh, operated by three state-owned and three international companies. The gas is marketed to the end users by four distribution companies of Petrobangla. Table 3.2 shows the production of gas and condensate (natural gas liquid) for the years 2006 to 2012.

Table 3.2: Gas and condensate production in Bangladesh

Year	Gas (BCF)	Condensate (Tonne)
2006	527	**156788**
2007	562	**167987**
2008	601	**168915**
2009	654	**173245**
2010	704	**176543**
2011	709	**178654**
2012	**744**	**179654**

Natural gas is the most consumed fuel in Bangladesh. Accurate data on natural gas is therefore imperative for a good quality GHG inventory report. Fortunately, data on the production and consumption of natural gas by various sectors is found in relatively complete form from Petrobangla in their MIS data received from the distribution companies. With respect to consumption by different consumption categories under each gas consuming sector especially in the context of CNG consumptions by different vehicle mix and natural gas consumption by different industry mix, data is not available. Expert judgment and vehicle numbers are being considered to sort out this issue in a rational way.

In Bangladesh, natural gas is used for electricity generation, in industrial processes like urea fertilizer and clinker to cement production, in industrial heating, captive power generation and household cooking. It has also been used in the transportation sector in the form of CNG since 2005. Figure 3.1 shows natural gas consumption by various sub-sectors of the energy sector as per data recorded in Petrobangla. Apart from the gas requirement in the industrial processes of urea and cement production, we have considered their gas requirement for running their auxiliaries and system and place those consumptions in the IPCC recommended sub-sector split, under the 'chemical' group.

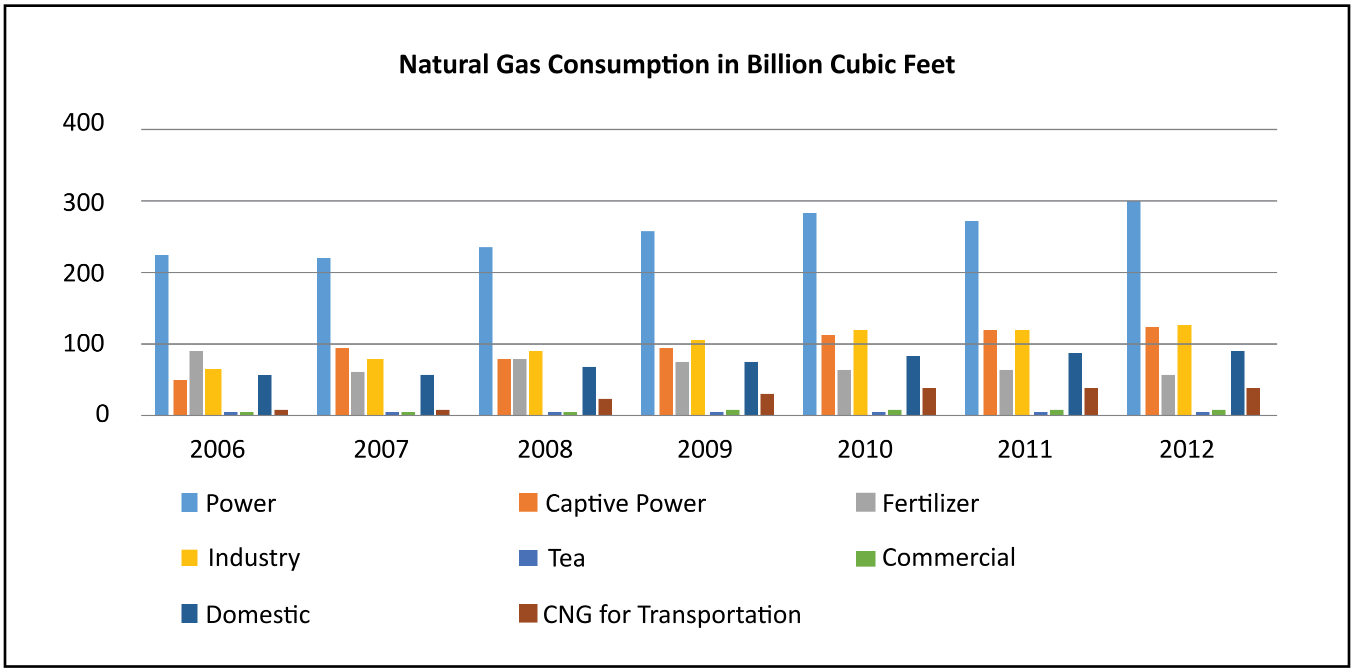


Figure 3.1: Natural gas consumed by the Energy Sector

It can be clearly seen from Figure 3.1 that the largest consumer sector is electricity generation. It is interesting to note from Figure 3.1 that the 'Fertilizer' sector is losing its dominance as the industry, domestic and commercial sector requirement for gas grows.

3.4.1.3 Liquid Fuels

There are no oil fields so far supplying crude oil in Bangladesh. The country therefore, has to rely solely on imports for liquid fuels. Import, refining and marketing of liquid fuels is carried out through BPC and its subsidiaries, the oil companies like Padma, Meghna and Jamuna. The following liquid fuels are important for Bangladesh:

Crude Oil: It is imported and refined into various products in the sole state-owned refinery The Eastern Refinery Limited (ERL). Two major grades of crude oils are imported – the Murban Crude and the Arabian Light Crude. BPC also imports finished petroleum products such as diesel, kerosene, jet fuel, gasoline, and base oil for lubricants.

These products are marketed through the three distribution companies under BPC (Padma Oil Co. Ltd., Jamuna Oil Co. Ltd., and Meghna Petroleum Ltd.).

Diesel: The highest consumed liquid fuel in Bangladesh. The bulk of it is imported; crude oil refining supplies only a small portion of the total. As expected, the main use of diesel is in the transportation sector, but diesel is also used in the agriculture sector for irrigation pumps and agricultural equipment, and by an unknown number of standby generators varying in size from 2 kW to 500 kW in industries, commercial establishments and households. No statistics on such usages are available. Moreover, BPC diesel data on different mode of usages is based on lumped diesel sales data on road transportation, rail and marine and agricultural purposes and data was not available for the reporting period. To complete the sectoral inventory, consumption of diesel by the IPCC categories was assumed to have the same breakdowns as the average of the previous five years. The largest share was allocated to heavy-duty trucks and buses. In the agriculture sector, 33% was allocated to irrigation pumps, 33% to farm equipment and the remaining 33% to fishing boats. It was not possible to estimate the quantity of diesel consumed by stand-by electricity generators in the industrial, commercial and residential sectors.

Kerosene: It is imported as a finished product as well as obtained from crude oil refining. It is mostly used in the residential sector for lighting and cooking purposes. Some of it is used in the agriculture sector for unspecified purposes.

Gasoline: petrol, octane, HOBC, MS, etc. are all grouped together as gasoline. These are imported as well as refined from crude oil. Gasoline is used mostly in the transportation sector, but a small quantity is also used by small electricity generators. In the absence of data, the total quantity was allocated to the transportation sector, largely to cars and only 10% to motorbikes.

Jet Fuel: Both imported and refined from crude oil, it is used exclusively in aviation. Data on domestic aviation and international bunkers was not available, hence expert comments on the rational spilt were considered for the estimation.

Furnace Oil: It is refined from crude oil. This is another major fuel which is used for electricity generation, furnaces in various industries, and navigation. The data on electricity generation was available in both the BPDB system planning as well as in the BPC yearly sales reporting.

LPG: It is obtained mainly from refining crude oil. It is bottled and marketed by state owned subsidiaries of BPC and Petrobangla. In addition, a significant amount of LPG is imported by the private sector. BPC reports the total sales figure and its own production. LPG is used for cooking in households and hotels/restaurants. In the absence of any detailed data, the total sales quantity was allocated to the Residential sector.

Natural Gas Liquids: The production of natural gas liquids (or condensate) is reported by Petrobangla. It is refined to produce diesel, gasoline, kerosene and solvents by ERL, LP Gas Ltd., RPGCL, SGFL, and Super Refinery (a private company).

3.4.1.4 Solid Fuel

Coal: Coal is mainly consumed by two industries, power generation and brick making. While estimating the coal consumption of the brick making sector, data on the number of kilns based on technologies like Fixed Chimney Kiln (FCK), Zigzag, MCBTK (drum chimney), Hybrid Hoffman Kiln (HHK both fueled by coal and gas) and also the modern and most efficient tunnel kilns are being accounted annually from reliable sources such as the World Bank Report and DoE publications. Standard coal consumption and the number of bricks produced each year were also estimated to come up with total coal consumptions in this sector. Tables 3.3 & 3.4 below show the detailed data used to obtain the coal consumption by this sector. An increasing trend in coal usages from 2006 is seen; over 4 million tons of coal were used in 2012.

Table 3.3: Total Brick Kilns Data 2006-2012

Type of kiln	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014
FCK	3,123	3,467	3,812	4,156	4,500	4,461	4,423	4,384	4,345
Zigzag	197	185	174	162	150	453	756	1,058	1,361
MCBTK (Drum Chimney)	794	646	497	349	200	156	112	68	24
Hoffman – gas	26	24	22	20	20	16	12	8	4
HHK – coal			1	4	10	18	26	34	42
Tunnel Kiln					0		1	3	4
Others						-	-	-	
Total	4140	4322	4505	4690	4880	5104	5329	5555	5780

Source: [3]

Table 3.4: Total Coal Consumption Data 2006-2012 (in tons)

Type of kiln	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012
FCK	2,623,320	2,912,490	3,201,660	3,490,830	3,780,000	3,747,450	3,714,900
Zigzag	173,360	163,020	152,680	142,340	132,000	398,420	664,840
MCBTK (Drum Chimney)	619,320	503,490	387,660	271,830	156,000	121,680	87,360
Hoffman – gas	-	-	-	-	-	-	-
HHK – coal	-	-	1,260	5,040	12,600	22,680	32,760
Tunnel Kiln	-	-	-	-	-	-	2,340
Others	-	-	-	-	-	-	-
Total	**3,416,000**	**3,579,000**	**3,743,260**	**3,910,040**	**4,080,600**	4,290,230	4,502,200

Source: Typical Calorific value of Bituminous type Coal: 6135 Kcal/Kg[4]

Biomass: Consumption was compiled from published data of the Bangladesh Bureau of Statistics (BBS). In the BBS, biomass fuel is called traditional fuel, and seven categories are listed. By lumping similar biomass, the seven categories were reduced to the following four categories: i) cow dung; ii) agricultural waste which includes jute sticks, rice straw, rice hulls, and bagasse; iii) firewood; and iv) other waste which includes twigs, leaves, branches and off-cuts etc. The calorific values used in this reporting were the IPCC default values.

3 2016 data by Department of environment, corrected by Bangladesh Auto Bricks Owners Association for HHK and Tunnel Kiln number
2015 data from DoE
2011 data from World Bank report 2011
2009 data from CDM 5125 and 6085

4 Barapukuria Coal Mine Company Ltd. & CDM-PDD: 6085

3.4.1.5 Non-Energy Use

Some petroleum products from refining of crude oil are not used as fuel. Therefore, these are considered as storing carbon, and do not contribute to emissions. These are:

Lubricants: Raw material for lubricants is imported by BPC and processed in the blending plants of Eastern Lubricants Blenders Ltd., and Standard Asiatic Oil Co. Ltd. Besides BPC, lubricants and base oil for lubricants are also imported by the private sector. It was not possible to get data on private sector imports.

Naphtha: It is obtained from refining crude oil. In the absence of local demand, it is exported from Bangladesh to other countries, and thus does not contribute to emissions.

Bitumen: Bitumen is used mostly for paving roads. A small amount of bitumen is burned in road construction work. Since no data or estimates were available on the amounts being burned, the total sales were considered as store carbon.

Natural Gas (NG): The quantity of natural gas used as a raw material for producing urea was subtracted while estimating emissions from NG, and was estimated from the total quantity of urea produced in the given year. First, the amount of carbon in urea was calculated, and then the amount of NG corresponding to the carbon was determined.

3.5 CO_2 Inventory

3.5.1 Summary of energy sector CO_2 inventory

Table 3.5 and Figure 3.2 show the total CO_2 emissions from reference and sectoral approaches being attempted for the base inventory year starting from 2006 to 2012. CO_2 emissions have been estimated for the years from 2006 to 2012 and it has been found that the difference between these two approaches are within the acceptable limit, varying only between ± 1~10%.

Table 3.5. Summary of Energy Sector CO_2 Emission (Gigagrams)

Year (2006-2012)	2006	2007	2008	2009	2010	2011	2012
Sectoral	45,411	48,224	51,915	57,547	64,476	65,510	69,867
Reference	50,061	52,371	55,608	58,612	63,853	68,242	74,249
Difference	4,650	4,147	3,693	1,065	(623)	2,732	4,381
% difference	10.24%	8.60%	5.96%	1.85%	-0.97%	4.17%	6.27%

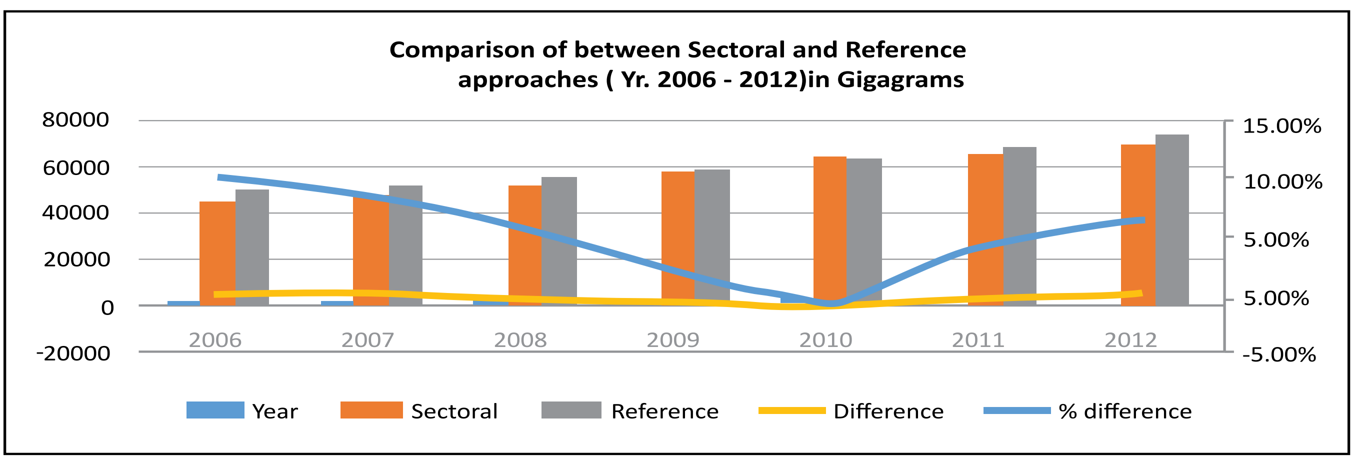
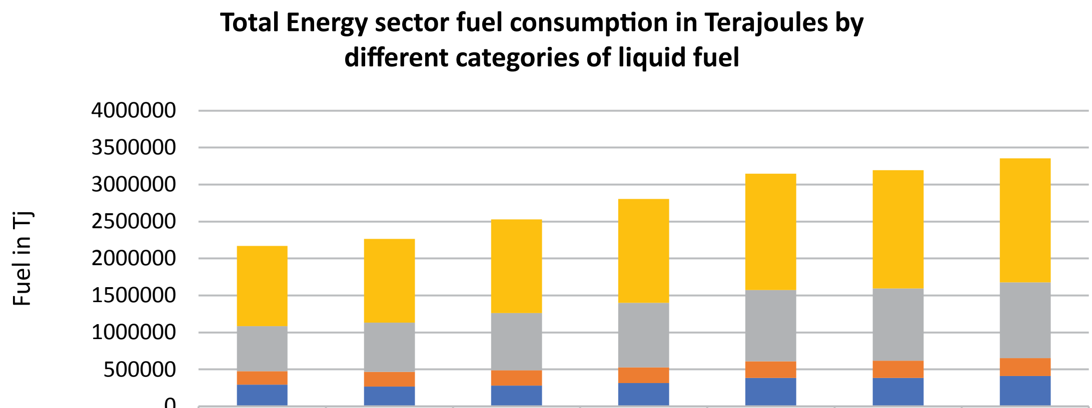


Figure 3.2: Comparison of Energy Sector CO_2 Emission by Reference & Sectoral Approaches

Figure 3.3 shows the total energy consumption in terajoules by different categories of fuel used in the energy sector. This also shows an annual incremental consumption increase from 2006.

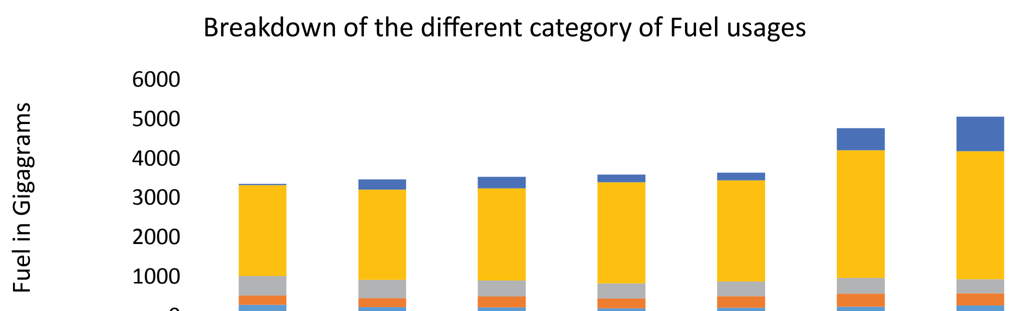


	2006	2007	2008	2009	2010	2011	2012
Total	1085309	1132355	1263858	1402179	1573468	1596425	1677283
Natural Gas	608491	667429.248	777529	873844	965754	979615	1024480
Solid Fuel, Coal	181142	197839.225	204858	213901	222916	231943	243878
Liquid Fuel	295676	267087.015	281471	314434	384798	384867	408925

Year

Figure 3.3: Total Energy Consumption (TJ) by the Energy Sector

Figures 3.4 & 3.5 further show the breakdown of different liquid fuel consumption and corresponding emissions, as per IPCC fuel types mentioned in the guidelines.



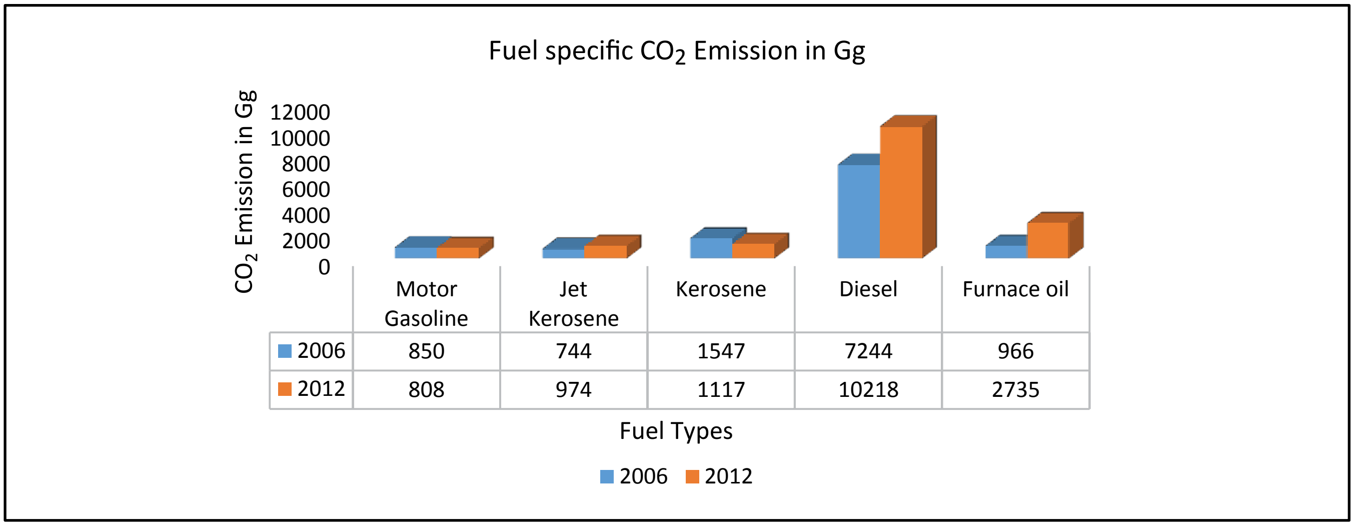
	2006	2007	2008	2009	2010	2011	2012
Furnace oil	33	256	290	194	194	565	884
Diesel	2300	2294	2340	2568	2568	3239	3240
Kerosene	499	462	405	377	377	397	358
Jet Kerosene	238	226	277	254	287	336	312
Motor Gasoline	280	225	214	194	213	231	266

Year

Motor Gasoline Jet Kerosene Kerosene Diesel Furnace oil

Figure 3.4: Breakdown of different liquid fuel consumption and corresponding emissions

The above graph shows a continual increase in liquid fuel consumption in the inventory period in terms of all categories of fuel, except motor gasoline, which saw a gradual decline from the year 2007 to 2009 because of CNG conversion of most cars and three wheelers.



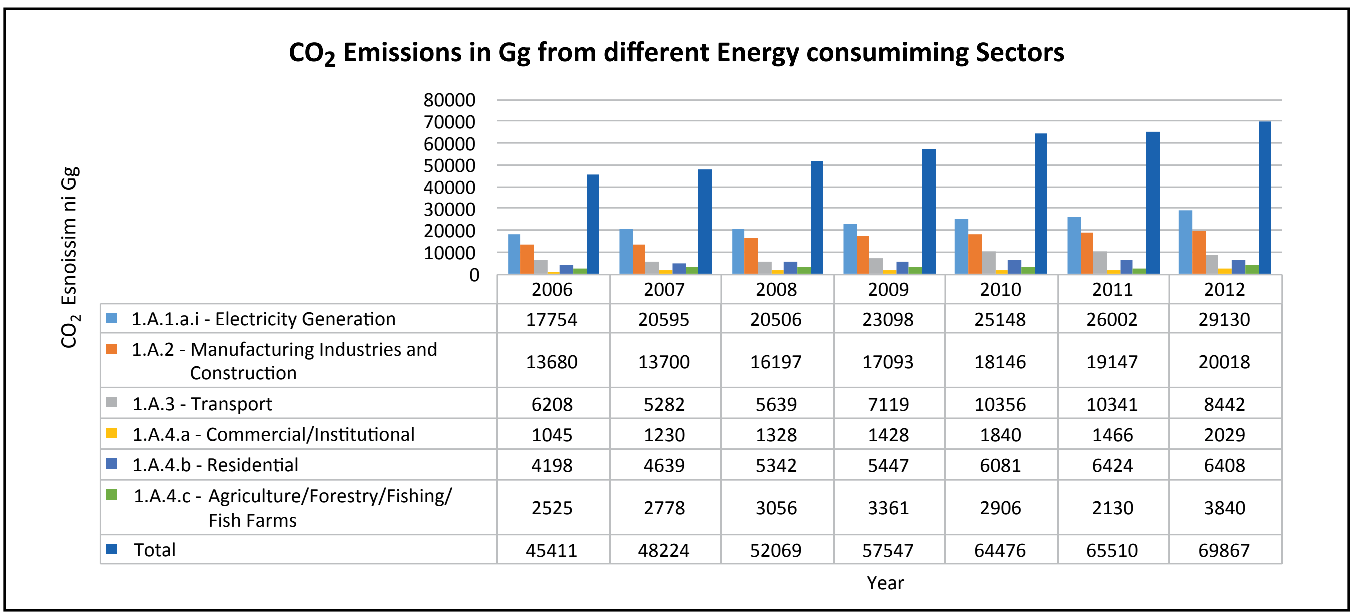
	Motor Gasoline	Jet Kerosene	Kerosene	Diesel	Furnace oil
2006	850	744	1547	7244	966
2012	808	974	1117	10218	2735

Figure 3.5: Liquid Fuel Specific CO_2 emissions in Gg

The above graph shows a steady growth in the liquid fuel categories and a remarkable increase in furnace oil consumption. The main reason for this is that rental power generators are fueled by furnace oil and since 2008, a large number of rental power generator facilities have been supplying electricity to the national grid.

CO_2 emissions and energy consumed (in TJ) by combustion activities by the entire energy sector show a steady linear growth.

Figure 3.6 shows the aggregated CO_2 emission of all the applicable activities under the energy sector. Among the different fuel consuming sectors, that of the Energy Industries is the highest contributor to GHG emissions, followed by Manufacturing & Construction.



	2006	2007	2008	2009	2010	2011	2012
1.A.1.a.i - Electricity Generation	17754	20595	20506	23098	25148	26002	29130
1.A.2 - Manufacturing Industries and Construction	13680	13700	16197	17093	18146	19147	20018
1.A.3 - Transport	6208	5282	5639	7119	10356	10341	8442
1.A.4.a - Commercial/Institutional	1045	1230	1328	1428	1840	1466	2029
1.A.4.b - Residential	4198	4639	5342	5447	6081	6424	6408
1.A.4.c - Agriculture/Forestry/Fishing/ Fish Farms	2525	2778	3056	3361	2906	2130	3840
Total	45411	48224	52069	57547	64476	65510	69867

Figure 3.6: CO_2 Emissions in Gg from different energy consuming sectors

3.5.2 Analysis of Sub-Sectors

Energy Industries: From Table 3.6 and in the context of Bangladesh, it is observed that electricity generation is the only CO_2 emission source in the IPCC Energy Industries category. Some furnace oil is consumed for petroleum refining but since there is one petroleum refinery in the country of modest capacity, the emission from petroleum refining is negligible, and even if another refinery is constructed the emission will remain small. The emission trend started its upward direction from 2008, the main reason being the liquid fuel based rental power generators that emerged at that time, and the trend has increased considerably since 2012.

Table 3.6: CO_2 Emission from Energy Industries

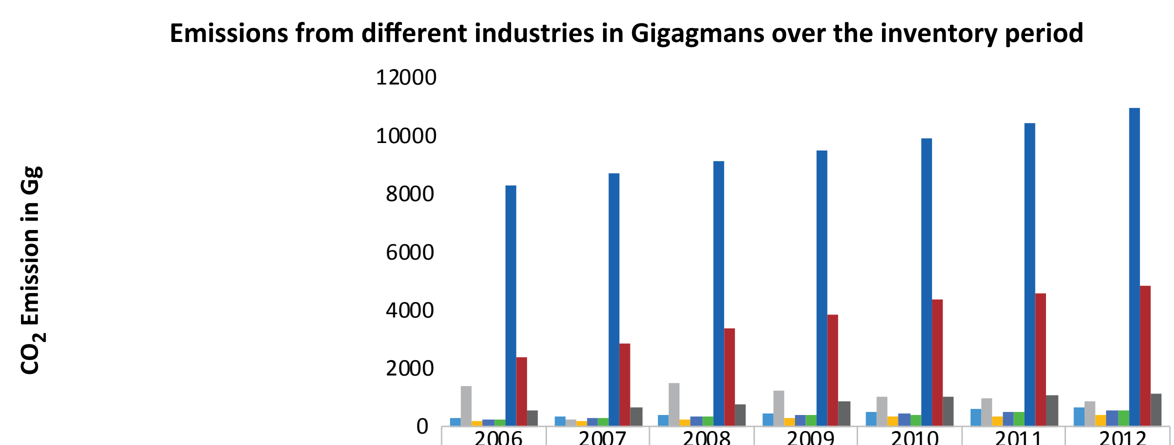
Energy Industries	2006	2007	2008	2009	2010	2011	2012
Electricity Generation	17754	20595	20506	23098	25148	26002	29130

Manufacturing & Construction: Figure 3.7 shows CO_2 emissions from the manufacturing and construction sector, disaggregated to some key industry categories. In Bangladesh, fertilizer is treated as a separate sector because historically it was the second largest gas consuming sector – second only to the power sector. It was so big that the combined consumption of all industries in the country was smaller than that of the fertilizer sector. Just a few years ago the fertilizer industry was the clear number one emission source in the industries sector.

It is interesting to note that the brick industry has emerged as the number one emission source, surpassing the fertilizer industry. There are three reasons why the brick industry has overtaken the fertilizer industry, grouped under the IPCC head chemicals, even though the fertilizer industry is a consumer of nearly 10% of the total gas. First, the fertilizer industry has experienced no growth since 1995, while the brick industry has seen a steady growth of 6~7% in the last decade. Secondly, nearly 30% of the gas supplied to fertilizer industries is for non-energy use, i.e., carbon stored in urea. Thirdly, brick uses coal, which is much more carbon intensive than natural gas.

Another interesting phenomenon is that the textile and leather group has already surpassed the chemical group in the few years since 2005. More than 80% of our export earnings come from the textile and leather industries.

Figure 3.7 shows the annual summary of CO_2 emissions by the different industrial sub-sectors under the energy sector. Construction is by far the highest contributor of CO_2 emissions followed by non-specified industry (bricks manufacturing), textiles and leather and chemicals.



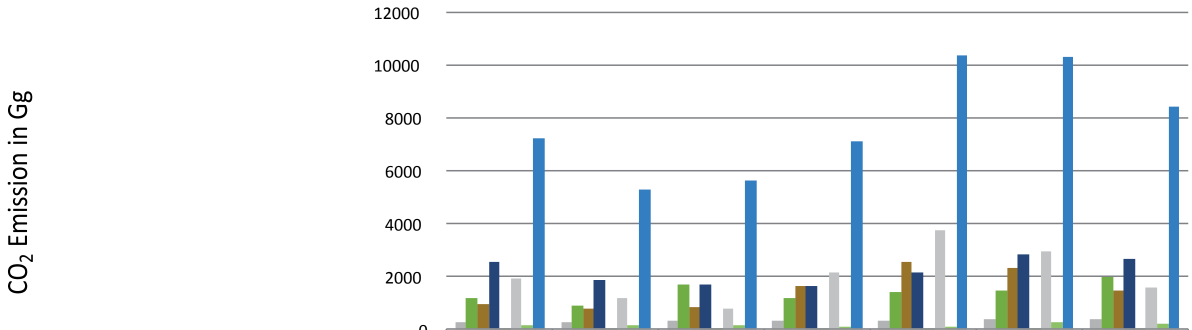
	2006	2007	2008	2009	2010	2011	2012
Iron and Steel	289	342	398	451	527	613	654
Chemicals	1402	251	1501	1232	1030	993	888
Pulp, Paper and Print	182	217	253	286	333	377	402
Food Processing, Beverages and Tobacco	257	307	360	408	471	519	551
Non-Metallic Minerals	257	307	360	408	415	505	551
Construction	8337	8735	9136	9543	9959	10471	10988
Textile and Leather	2396	2870	3401	3868	4389	4584	4836
Non-specified Industry	558	670	789	896	1022	1086	1148

Year

Figure 3.7: Relative contributions to CO_2 emission in gigagrams by different industrial sub-sectors in the years 2006, 2007, 2008, 2009, 2010, 2011 and 2012

Transport: Figure 3.8 below furnishes a breakdown of emissions from the transportation sector, and it shows the relative contributions of the different transportation modes. It is observed that approximately one-third of emissions come from trucks and buses. This is only likely to increase under the current practices in Bangladesh. It is a strong indication that land transportation, both passenger and freight, must be addressed, and other modes of transportation must be promoted to keep this increasing emission trend in check.

CO_2 emission in Gg from transportation sub- sector from 2006 to 2012



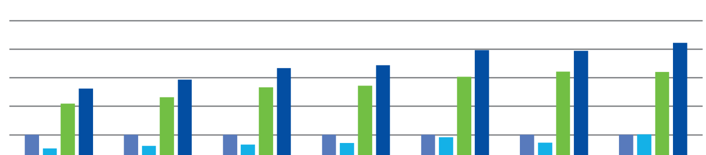
	2006	2007	2008	2009	2010	2011	2012
1.A.3.a.ii - Domestic Aviation	294	279	313	313	354	415	385
1.A.3.b.i.1 - Passenger cars with 3-way catalysts	1218	893	1736	1176	1396	1456	2015
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts	971	823	858	1671	2576	2308	1478
1.A.3.b.iii - Heavy-duty trucks and buses	2589	1899	1692	1625	2136	2854	2672
1.A.3.b.iv - Motorcycles	43	35	33	30	35	37	41
1.A.3.c - Railways	1942	1173	816	2184	3761	2986	1612
1.A.3.d.ii - Domestic Water- borne Navigation	161	180	191	120	97	286	240
Total	7217	5282	5639	7119	10356	10341	8442

Year

Figure 3.8: CO_2 Emission by different Transportation Modes (2006-2012)

Residential and Commercial: As can be seen from Figure 3.9, the commercial sector consumes mainly natural gas and diesel from the stand-by generators in the case of a power outage, while the residential sector consumes LPG, natural gas and kerosene. While natural gas and LPG are used mainly for cooking, kerosene is mainly used by rural households for lighting. It is worth pointing out that residential households, especially in the rural areas of Bangladesh, also use a significant quantity of biomass as cooking fuel. Since CO_2 emission of biomass is not counted, it is reported separately as a memo item.

CO_2 emission from commercial and residential energy usages, 2006-2012



	1	2	3	4	5	6	7
Year	2006	2007	2008	2009	2010	2011	2012
1.A.4.a - Commercial/Institutional	1045	1230	1328	1428	1840	1466	2029
1.A.4.b - Residential	4198	4639	5342	5447	6081	6424	6408
Total	5243	5869	6670	6875	7922	7890	8437

Figure 3.9: CO_2 Emission from Residential and Commercial Sectors (gigagrams)

Agriculture: The main fuel consuming activity is water pumping using diesel pumps for irrigation. The quantity of diesel consumed in the agriculture sector is a lumped figure reported by BPC as per their supply to outlets and depots designated for agricultural diesel pumps. In the absence of data, it was assumed that 33% of the diesel consumed in the agriculture sector was used for irrigation, and the rest in operating other farm equipment such as power tillers, tractors and rice/wheat threshers and for running fishing boats.

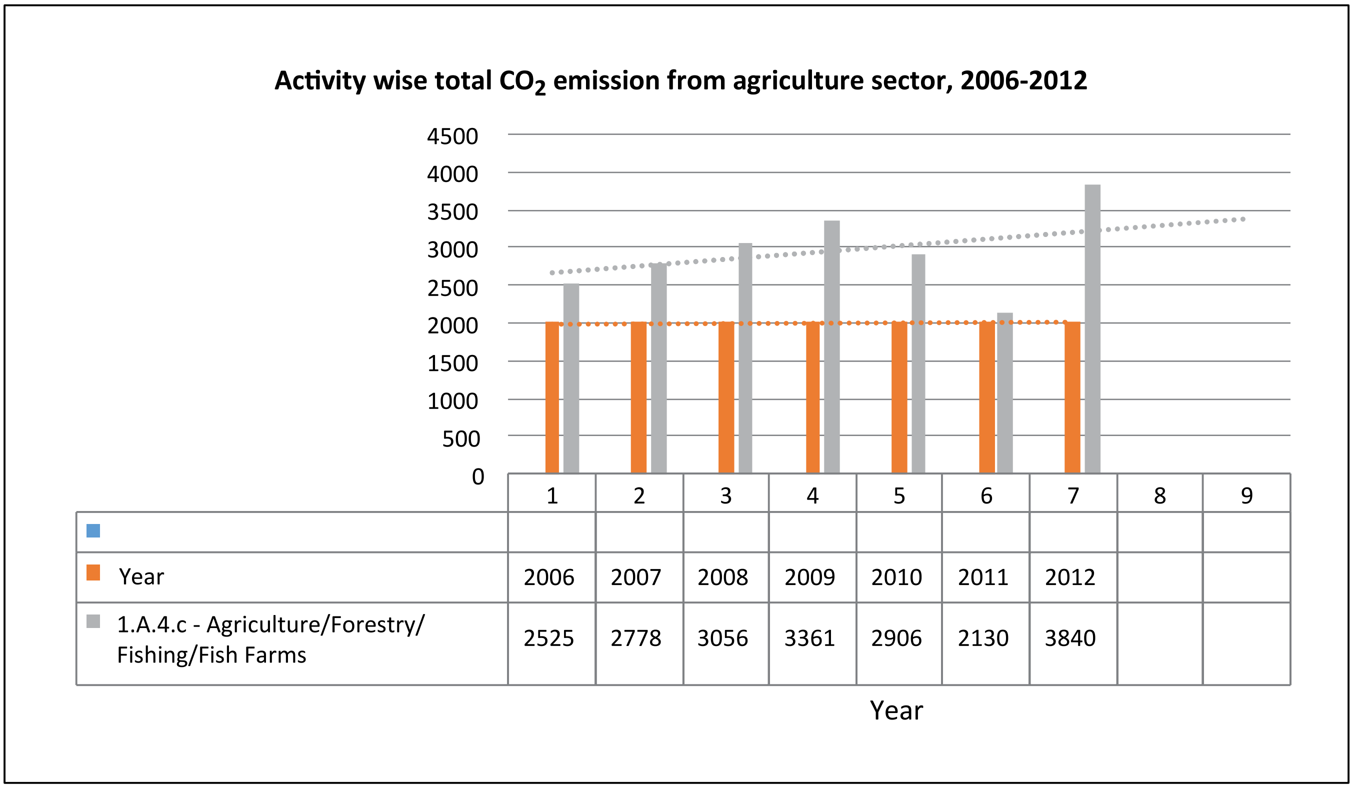


Figure 3.10: CO_2 Emission from Agriculture Sector Energy Use

3.5.3 Analysis by Fuel

Solid, Liquid and Gas: Figure 3 shows the CO_2 emissions from the three fuels. Since natural gas is the predominant fuel in Bangladesh, it is not surprising that the highest CO_2 emissions are also from natural gas. Interestingly, even though coal use is very small in terms of tonnes of oil equivalent, the percentage of CO_2 emissions in the total is not. This is due to the fact that coal is twice as carbon intensive as natural gas.

Energy in TJ derived from fuel combustion activities is shown in Figure 3 and it can be seen that the overwhelming portion of energy is obtained from natural gas. It follows then, that natural gas will be the number one source of CO_2 emissions in Bangladesh.

Figure 3.4 shows CO_2 emissions from both primary and secondary fuels. The second highest CO_2 emitting fuel is now diesel. Kerosene is also a significant emitter. The drop in the use of kerosene is probably related to the expansion of rural electrification and the dissemination of Solar Home Systems (SHS).

Figure 3.4 also shows the consumption of jet kerosene (JP-1), furnace oil (FO) and diesel as international aviation and marine bunkers. These amounts were subtracted from the total fuel consumed for correctly accounting for emissions occurring within the borders of Bangladesh as per the IPCC guidelines.

Biomass: Table 3.7 shows the quantity of different types of solid primary biomass consumed in million tonnes (MT) and their respective CO_2 emissions in kilo tonnes (KT). As required by IPCC guidelines, these are reported for information but not added to the total national GHG inventory. IPCC default conversion and emission factors were used to calculate emissions from biomass burning.

Table 3.7: CO_2 Emissions from burning of biomass

Year	Total (Gg)	Energy in TJ	CO_2, Gg
2006	41,800	484,880	48,488
2007	42,665	494,914	49,491
2008	43,214	501,282	41,935
2009	44,424	515,318	51,532
2010	44,997	521,965	52,196
2011	45,694	530,050	53,005
2012	46,412	538,379	53,838

3.5.4 Fugitive and Non-CO_2 Emissions

Figure 3.11 below shows the CH_4 and N_2O emission from fugitive sources such as leakage for four years - 2006, 2007, 2008 and 2009; for methane, only natural gas leakage was considered, which occurs along the supply chain, especially in the distribution system. The emissions at the user end for example in cooking stoves, CNG filling stations and in industrial burners could not be accounted for. It was assumed that 0.1% of natural gas sales volume leaks out from the system as per default IPCC values. For N_2O emissions, the default procedure of the IPCC methodology was employed.

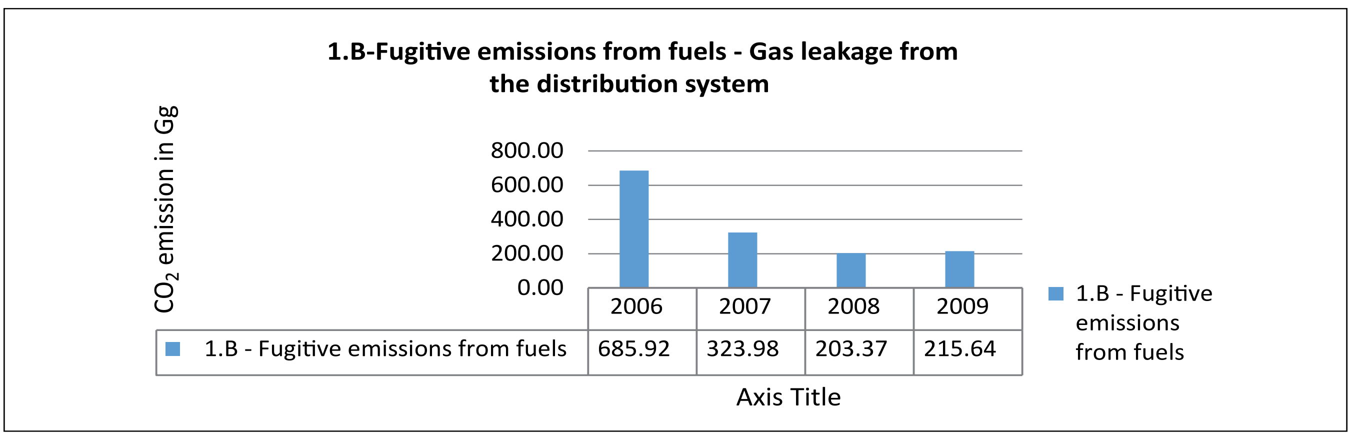


Figure 3.11: Fugitive Emission from Fuels - Gas Leakage from the Distribution System

The total CH_4 and N_2O emissions from the Energy Sector for the period of 2006 to 2012 and the total fugitive CH_4 and CO_2 emissions from the Energy Sector for the period of 2006 and 2012 are shown in Tables 3.8 and 3.9.

Table 3.8: CO_2 and N_2O Emissions from the Energy Sector for 2006 and 2012 (Gg)

Categories	2006			2012		
	CH_4	N_2O	Eq. CO_2	CH_4	N_2O	Eq. CO_2
1 Energy Sector Total	19.88	0.41	548	26.04	0.48	699
1.A Fuel Combustion Activities	2.10	0.41	174	2.76	0.48	210
1.B Fugitive Emissions from fuels	17.8	-	373	23.27	-	489

Table 3.9: Fugitive CH_4 and CO_2 Emissions from the Energy Sector for 2006 and 2012 (Gg)

Categories	2006			2012		
	CO_2	CH_4	Eq. CO_2	CO_2	CH_4	Eq. CO_2
1.B.2.b.ii Flaring	22.67		23	29.64		30
1.B.2.b.iii.5 Distribution		17.8	373		23.27	489
1.B Fugitive Emissions from fuels	22.67	17.8	396	29.64	23.27	518

3.5.5 Summary of GHG Emissions from the Energy Sector

Table 3.10 gives the summarized results in CO_2 equivalent units of the emissions of the three GHGs that were estimated in this report and their relative contributions for the year 2006. As can be clearly seen, the non-CO_2 gases account for less than 2% and contribute a negligible amount to the overall emissions. However, it is important to point out that uncertainties in the estimation of the non-CO_2 gases are very high.

Table 3.10: Summary of GHG (2006)

GAS	Emission (Gg)	GWP	CO_2 Equivalent (Gg)	% of Total Emission
CO_2	45,410.96	1	45,410.96	**97.24**
CH_4	4.89	25	122.5	**.262**
N_2O	0.55	298	163.9	**0.35**
Total			**46,697.36**	

The detailed sector and sub-sector specific CO_2 estimation along with the reasonable explanations on the data choice and key assumptions were developed for the inventory years 2006 and 2012 and are shown in Tables 3.14 and 3.15 respectively.

3.6. Uncertainties

Uncertainties of the CO_2 emissions from fuel combustion were estimated in accordance with IPCC guidelines and in the IPCC software platform. Expert judgments were used for the estimation of the uncertainties associated with activity data. In most cases the total fuel supplied to a given sector was known with very little uncertainly. The problem arose when that had to be disaggregated into user categories or end-uses. Expert elicitation was not possible due to resources and time constraints. Table 3.11 shows the estimates of uncertainties of activity data and emission factors for the eight energy sub-sectors.

Table 3.11: Uncertainty Estimates

Energy Sub-Sectors	Activity Data	Emission Factor
1. Energy Industries	10%	**5%**
2. Manufacturing & Construction	20%	**5%**
3. Transport	25%	**5%**
4. Residential	15%	**5%**
5. Fertilizer	5%	**5%**
6. Agriculture	15%	**5%**
7. Non-Specified Sector	30%	**10%**
8. Commercial	**20%**	**10%**

The gross uncertainties for each sub-sector are provided in Table 3.15. However, for the following cases more elaboration is needed:

Activity data of coal

Calorific value of coal

Breakdown of diesel into different uses

System loss of natural gas

Activity data of biomass

CH_4 and N_2O emissions estimation

The difficulty with coal activity data has been mentioned several times. According to government figures, less than one million tonnes of coal is imported, but it is widely known that much more is consumed in the country. The unaccounted for coal is entering the country through the porous border, which is more than 1,000 kilometers long. Without an accurate survey of all brick kilns using coal, it is impossible to ascertain this quantity. An uncertainty of between -10% and +30% can be expected.

The calorific value of coal posed a particular challenge because coal is imported from several different fields and is of varying quality. Measurements at BUET indicate that CV varies from 5000 kcal/kg to 7000 kcal/kg. Therefore, the IPCC default value was used.

Figures for the total quantity of diesel supplied are reliable, but its use in different sectors and end uses is not known. Diesel is used in a variety of applications. Even though sale points for different sectors are designated, diesel is sold for various uses other than in the designated sector. For example, stations for vehicles sell diesel to standby generators, and oil depots for agricultural applications sell diesel to country boats. The most uncertainty in the use of diesel is in small generators.

The system loss of natural gas, which is a euphemism for the unpaid or unmetered use of natural gas from the grid, poses a special accounting challenge. This is shown as a separate quantity every year. A small portion of this quantity is probably actual loss from the transmission and distribution lines, but most of it is consumed. Since the gas is combusted it was allocated into the Non-Specified Sector and appears in the inventory as a CO_2 emission.

Data on biomass has been taken from the government published Statistical Yearbook of Bangladesh but the data is not a result of any survey or actual data. It comes from a model developed in the mid-eighties under a project called the Bangladesh Energy Planning Project (BEPP). However, crosschecking with other sources and indirect calculations based on the number of rural households and industries leads to the conclusion that the uncertainty is not more than +20%.

Uncertainties in the estimation of CH_4 and N_2O are not possible to estimate because there is absolutely no data or indications of these emissions. Default IPCC values had to be used. Natural gas distribution lines can be a source of significant CH_4 fugitive emissions. In this reporting, 0.1% of sales volume has been assumed, which is a negligible quantity; this value can easily exceed 0.25%. In that case the uncertainty will be more than 200%. The total combined uncertainty results from IPCC software platform on Energy, IPPU and LULUCF sector is shown in Table 3.14.

3.7 Quality Control and Quality Assurance of inventory works

- **Quality Assurance (QA)** – a planned system of review procedures conducted by personnel not involved in the inventory development process.
- **Quality Control (QC)** – a system of routine technical activities implemented by the inventory development team to measure and control the quality of the inventory as it is prepared.

An effective QA/QC plan contains the following elements:

- Personnel responsible for coordinating QA/QC activities.
- General (Tier 1) QC procedures.

- QA review procedures.
- Reporting, documentation, and archiving procedures.

Each of these elements is described in more detail below.

QA/QC Personnel

The QA/QC coordinator is the main person responsible for implementing the QA/QC plan. In this role, the QA/QC coordinator (Director, CC & IC):

- Clarifies and communicates QA/QC responsibilities to inventory members;
- Develops and maintains QA/QC checklists appropriate to various inventory team members' roles, with support from consultants;
- Ensures the timely and accurate completion of QA/QC checklists and related activities;
- Works with consultants to develop an overall QA/QC timeline and when external reviews will occur;
- Works with consultants to manage and deliver documentation of QA/QC activities to the inventory lead and archive coordinator; and
- Coordinates external reviews of the inventory document and ensures that comments are incorporated into the inventory.

In this role, the QA/QC coordinator communicates with several other inventory members. Table 3.12 summarises the key personnel and their overall responsibilities in the QA/QC related activities in the GHG estimation.

Table 3.12: Summarizes the key personnel responsible for QA/QC activities.

Title	QA/QC Responsibility	Name	Designation / Organization	Contact Information
Inventory Lead	All aspects of the inventory program cross, cutting QA/QC	Md. Ziaul Haque	Director, AQM, DoE	zhaque27@gmail.com
QA/QC Lead/Coordinator	Implementing the overall QA/QC plan	Mirza Shawkat Ali	Director, CC & IC, DoE	mirzasa1@yahoo.com
Category Lead(s)	Implementing category specific QA/QC procedures (Tier 1 and Tier 2 procedures listed in Table)	DoE Sector Leads (6) DoE (mentioned in the office order)	DoE	
Outside Expert(s)	Expert review of the inventory	Core Expert Working Group-2		

General (Tier 1) QC Procedures for Source/Sink Category Leads

STEP 3: Each item in Table 3.13 was completed by entering the name or initials of the person completing the item and the date the item was completed.

Table 3.13: General (Tier 1) QC Activities (to be completed by the QA/QC Coordinator with the help of sector leads)

QC Activity	Procedures	Task Completed		Corrective Measure Taken	
		Name / Initials	Date	Supporting Documents (List Document Name)	Date
Date Gathering, Input, and Handing Checks					
Check that assumptions and criteria for the selection of activity data and emission factors are documented	• Cross-check descriptions of activity data and emission factors with information on categories and ensure that these are properly recorded and archived.				
Check for transcription errors in data input and reference	• Confirm that bibliographical data references are properly cited in the internal documentation (MDD template report) • Cross-check a sample of input data from each category (either measurements or parameters used in calculations) for transcription errors. • Utilize electronic data where possible to minimize transcription errors • Check that spreadsheet features are used to minimize user/entry error: ○ Avoid hardwiring factors into formulas ○ Create automatic look-up tables for common values used throughout calculations. ○ Use cell protection so fixed data cannot accidentally be changed ○ Build in automated checks, such as computational checks for calculations, or range checks for input data.				
Check that emissions/removals are calculated correctly	• Reproduce a representative sample of emissions/removals calculations. • If models are used, selectively mimic complex model calculations with abbreviated calculations to judge relative accuracy				
Check that parameter and emission/removal units are correctly recorded and that appropriate conversion factors are used	• Check that units are properly labeled in calculation sheets (and MDD template report) • Check that units are correctly carried through from beginning to end of calculations. • Check that conversion factors are *correct.* • Check that temporal and spatial adjustment factors are used correctly.				

These standards generally focus on the processing, handling, documenting, archiving, and reporting procedures common to all categories.

Supply data on oil and gas in Bangladesh is very reliable, but coal and biomass are best estimates based on expert judgment and indicators. With respect to gas and oil, no special quality control and quality assurance is required because the data is available from very reliable government sources. However, when it comes to sectoral split, the data is far from reliable. For quality control purposes the indirect methods were employed:

1. The quantity of diesel consumed by irrigation pumps was crosschecked against the number of irrigation pumps, which is known from agricultural surveys to be within ±5%.;
2. The quantity of gasoline and diesel consumed was crosschecked against the number of vehicles multiplied by the average annual passenger-kilometer rate in the case of cars and buses and freight-kilometer in the case of trucks;
3. The quantity of biomass consumed in the rural residential sector was estimated by multiplying the number of households by the quantity required by one household, which has been reported by many studies;
4. The energy sector inventory was checked against published figures from the UN and the World Bank, and the level of consistency was found to be excellent. The fact that the sectoral approach matched the reference approach to within ±2% supports the quality of the inventory.

3.8 Completeness

Data by activity and fuel types for different sectors are found at different states of completeness. The data on natural gas is relatively complete. Other liquid fuels are available as aggregate amounts, but detailed breakdowns are not available in many cases. However, the relative accuracy is less important than may be assumed because natural gas is by far the largest fuel source in Bangladesh. Table 3.18 presents a summary of the fuel combustion activities in different sectors, data source, fuels used in those sectors, and comments on the state of completeness or availability of data. Table 3.19 also presents the summary CO_2 emissions for the year 2012.

With respect to completeness of the GHG inventory of Bangladesh, the following comments can be made:

1. The fugitive emissions from gas related activities could not be accounted for. As discussed in the uncertainty section, there are no estimates in the country of how much leakage occurs in the transmission and distribution lines. The problem is aggravated by the fact that the reported system loss includes both leakage and unaccounted for gas (UFG). Leakage has to be accounted as methane emission, while UFG is carbon dioxide emission. As a result, the IPCC default procedure had to be followed.
2. Even though the total supplied diesel is shown as consumed in various sectors, it is common knowledge that between 100,000 and 300,000 tonnes of diesel are smuggled into neighbouring countries because of the favourable price differential. This being an unknown quantity, the inventory could not account for it.
3. For many fuel items, the actual consumption at the consumer or device level could not be ascertained. These all had to be estimated either from the supply side or by using expert judgment. For example, diesel use in farm equipment, country boats and generators is not known; gasoline use in small household generators is not known; coal use in brick kilns is not known; and kerosene use for cooking is not known.
4. The fraction oxidized for coal is not known because the combustion process takes place in a crude kiln, and often the unburned coal is sold to rural commercial establishments such as restaurants.
5. The quantity of furnace oil (FO) in different sectors is not known. However, from expert judgment, it is known that the predominant use is in the industry sector. All FO was, therefore, allocated to that sector.
6. A certain quantity of FO enters the country as bunker fuel of end-of-life ships, imported to be broken down for steel scraps.
7. Lack of good data at the device level posed a big challenge in preparing the sectoral approach inventory. Even though this did not affect the CO_2 emissions estimation, the estimation of the other gases is greatly affected.
8. Only the three main GHGs were reported. The inventory did not deal with other gases such as CO, NOX, SO_2 and NMVOC.

Table 3.14. Summary of CO_2 emissions from the energy sector in accordance with data source and fuel type

Inventory Year: 2006						
	Emissions (Gg)			Data Source	Fuel	Remarks
Categories	CO_2	CH_4	N_2O			
1 - Energy	45410.96	4.89	0.55			
1.A - Fuel Combustion Activities	45410.87	3.17	0.55			
1.A.1 - Energy Industries	17754.10	0.34	0.04			
1.A.1.a.i - Electricity Generation	17754.10	0.34	0.04	System Planning, BPDB, BPC	NG, FO, Diesel, SKO	Data on each fuel based generation taken from BPDB, System Planning Department
1.A.2 - Manufacturing Industries and Construction	13680.32	0.98	0.14	Petrobangla, BPC, BBS, World Bank & ADB report on coal consumption in brick manufacturing etc	NG, FO, Diesel	No industry specific data available at the utility level, expert judgement and previous publication were taken as reference to segregate total energy consumed by the industrial sector into different industry types
1.A.2.a - Iron and Steel	289.11	0.01	0.00			
1.A.2.c - Chemicals	1402.00	0.03	0.00			
1.A.2.d - Pulp, Paper and Print	182.19	0.00	0.00			
1.A.2.e - Food Processing, Beverages and Tobacco	257.44	0.01	0.00			
1.A.2.f - Non-Metallic Minerals	257.44	0.01	0.00			
1.A.2.k - Construction	8337.36	0.88	0.13			
1.A.2.l - Textile and Leather	2396.31	0.04	0.00			
1.A.2.m - Non-specified Industry	558.47	0.01	0.00			
1.A.3 - Transport	6207.78	0.96	0.32			
1.A.3.a - Civil Aviation	294.47	0.00	0.01	BPC	Jet Kerosene	
1.A.3.a.i - International Aviation (International Bunkers)						Not added to total emissions, for information only
1.A.3.a.ii - Domestic Aviation	294.47	0.00	0.01	BPC	Jet Kerosene	Expert judgement taken to segregate fuel consumption between international and domestic aviation
1.A.3.b - Road Transportation	3811.26	0.84	0.20			
1.A.3.b.i - Cars	1218.09	0.71	0.07			
1.A.3.b.i.1 - Passenger cars with 3-way catalysts	1218.09	0.71	0.07	BPC, Petrobangla	NG, Motor Gasoline	No split on NG consumption data available on the Transport sector, expert judgement used to consider a rational split among different categories of vehicle Similary, expert judgement taken while arriving at a rational split for other type of fuel usages by the road and railways Agricultural off road vehicles
1.A.3.b.ii - Light-duty trucks	970.77	0.05	0.05			
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts	970.77	0.05	0.05	BPC	NG, Disesel	
1.A.3.b.iii - Heavy-duty trucks and buses	1579.48	0.08	0.08	BPC	NG, Disesel	
1.A.3.b.iv - Motorcycles	42.92	0.00	0.00	BPC	Motor asoline	

	Emissions (Gg)			Data Source	Fuel	Remarks
Categories	**CO_2**	**CH_4**	**N_2O**			
1.A.3.c - Railways	1941.51	0.10	0.10	BPC	FO, Diesel	
1.A.3.d - Water-borne Navigation	160.54	0.01	0.00			
1.A.3.d.i - International water-borne navigation (International bunkers)				BPC	FO, Diesel	Rational spilt between international and domestic considered based on expert judgement
1.A.3.d.ii - Domestic Water-borne Navigation	160.54	0.01	0.00	BPC		
1.A.4 - Other Sectors	7768.67	0.89	0.04			
1.A.4.a - Commercial/Institutional	1045.36	0.13	0.01	Petrobangla,BPC	Diesel	
1.A.4.b - Residential	4197.82	0.41	0.01	Petrobangla,BPC	Diesel	
1.A.4.c - Agriculture/Forestry/ Fishing/Fish Farms	**2525.48**	**0.34**	**0.02**		**Diesel**	
1.A.4.c.i - Stationary	841.83	0.11	0.01	BPC	Diesel	Expert judgement taken to segregate fuel consumption among different categories of agricultural fuel usages
1.A.4.c.ii - Off-road Vehicles and Other Machinery	841.83	0.11	0.01			
1.A.4.c.iii - Fishing (mobile combustion)	841.83	0.11	0.01			
1.B - Fugitive emissions from fuels	0.09	1.72	0.00			
1.B.2 - Oil and Natural Gas	0.09	1.72	0.00			
1.B.2.b - Natural Gas	0.09	1.72	0.00			
1.B.2.b.iii.5 - Distribution	0.09	1.72		Petrobangla	Natural Gas	Difference between actual production and supply considered as distribution loss
Total Emissions in Gg	**45,410.96**	**4.89**	**0.55**			
Total CO_2e Emissins in Gg			**45,696.41**			
	Emissions (Gg)					
Categories	CO_2	CH_4	N_2O			
Memo Items (3)						
International Bunkers	447.68	0.004	0.01	BPC		
1.A.3.a.i - International Aviation (International Bunkers) (1)	441.72	0.003	0.01	BPC	Jet Kerosene	
1.A.3.d.i - International water-borne navigation (International bunkers) (1)	5.96	0.001	0.00	BPC	Furnace oil + Diesel	
1.A.5.c - Multilateral Operations (1)(2)						
Information Items						

Categories	CO_2	CH_4	N_2O	Data Source	Fuel	Remarks
CO_2 from Biomass Combustion for Energy Production	48488			BUET Bio-mass survey report	Indigenous renewable bio-mass consumed for cooking	
Total Emission in Gg	**48,935.68**	**0.00**	**0.01**			
Total CO_2e Emissins in Gg		**48,939.58**				

Table-3.15: Inventory Year: 2012

	Emissions (Gg)			Data Source	Fuel	Remarks
Categories	**CO_2**	**CH_4**	**N_2O**			
1 - Energy	69867.27	93.18	3.69			
1.A - Fuel Combustion Activities	69867.27	93.18	3.69			
1.A.1 - Energy Industries	29130.01	0.57	0.08			
1.A.1.a - Main Activity Electricity and Heat Production	29130.01	0.57	0.08			
1.A.1.a.i - Electricity Generation	29130.01	0.57	0.08	System Planning, BPDB, BPC	NG, FO, Diesel, SKO	Data on each fuel based generation taken from BPDB, System Planning department
1.A.2 - Manufacturing Industries and Construction	20018.41	1.35	0.20	Petrobangla, BPC, BBS, World Bank & ADB report on coal consumption in Brick manufacturing etc	NG, FO, Diesel	No industry specific data available at the utility level, expert judgement and previous publication were taken as reference to segregate total energy consumed by the industrial sector into different industry types
1.A.2.a - Iron and Steel	654.15	0.02	0.00			
1.A.2.b - Non-Ferrous Metals						
1.A.2.c - Chemicals	888.30	0.02	0.00			
1.A.2.d - Pulp, Paper and Print	401.73	0.01	0.00			
1.A.2.e - Food Processing, Beverages and Tobacco	551.07	0.01	0.00			
1.A.2.f - Non-Metallic Minerals	551.07	0.01	0.00			
1.A.2.k - Construction	10987.94	1.16	0.17			
1.A.2.l - Textile and Leather	4835.72	0.09	0.01			
1.A.2.m - Non-specified Industry	1148.43	0.02	0.00			
1.A.3 - Transport	8441.99	89.87	3.35			

	Emissions (Gg)			Data Source	Fuel	Remarks
1.A.3.a - Civil Aviation	385.12	0.00	0.01	BPC	Jet Kerosene	
1.A.3.a.i - International Aviation (International Bunkers) (1)						Not added to total emission, for information only
1.A.3.a.ii - Domestic Aviation	385.12	0.00	0.01	BPC	Jet Kerosene	Expert judgement taken to segregate fuel consumption between international and domestic aviation
1.A.3.b - Road Transportation	6205.15	89.78	3.31			
1.A.3.b.i - Cars	2014.51	1.64	0.10			
1.A.3.b.i.1 - Passenger cars with 3-way catalysts	2014.51	1.64	0.10	BPC, Petrobangla	NG, Motor Gasoline	No split on NG consumption data available on the Transport sector, expert judgement used to consider a rational split among different categories of vehicle Similary, expert judgement taken to arrive at a rational split for other types of fuel usages by the road, railways, and agricultural off road vehicles
1.A.3.b.i.2 - Passenger cars without 3-way catalysts						
1.A.3.b.ii - Light-duty trucks	1477.94	6.82	0.68			
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts						
1.A.3.b.ii.2 - Light-duty trucks without 3- way catalysts	1477.94	6.82	0.68	BPC	NG, Disesel	
1.A.3.b.iii - Heavy-duty trucks and buses	2671.91	81.30	2.53	BPC	NG, Disesel	
1.A.3.b.iv - Motorcycles	40.80	0.02	0.00	BPC	Motor Gasoline	
1.A.3.c - Railways	1611.96	0.07	0.01	BPC	FO, Diesel	
1.A.3.d - Water-borne Navigation	**239.75**	**0.02**	**0.01**			
1.A.3.d.i - International water-borne navigation (International bunkers) (1)				BPC	FO, Diesel	Rational spilt between international and domestic considered based on expert judgement
1.A.3.d.ii - Domestic Water-borne Navigation	239.75	0.02	0.01	BPC		
1.A.4 - Other Sectors	12276.85	1.40	0.06			
1.A.4.a - Commercial/Institutional	2028.54	0.25	0.01	Petrobangla,BPC	Diesel	
1.A.4.b - Residential	6408.43	0.63	0.02	Petrobangla,BPC	Diesel	
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	3839.88	0.52	0.03		Diesel	

	Emissions (Gg)			Data Source	Fuel	Remarks
1.A.4.c.i - Stationary	1279.96	0.17	0.01	BPC	Diesel	Expert judgement taken to segregate fuel consumption among different categories of agricultural fuel usages
1.A.4.c.ii - Off-road Vehicles and Other Machinery	1279.96	0.17	0.01			
1.A.4.c.iii - Fishing (mobile combustion)	1279.96	0.17	0.01			
Total Emission in Gg	**69867**	**93**	**4**			
Total CO_2e Emissins in Gg			**73,296.23**			
	Emissions (Gg)					
Categories	CO_2	CH_4	N_2O			
Memo Items (3)						
International Bunkers	601.05	0.01	0.02	BPC		
1.A.3.a.i - International Aviation (International Bunkers) (1)	577.68	0.00	0.02	BPC	Jet Kerosene	
1.A.3.d.i - International water-borne navigation (International bunkers) (1)	23.37	0.00	0.00	BPC	Furnace oil + Diesel	
Information Items						
CO_2 from Biomass Combustion for Energy Production	53838			BUET Bio-mass survey report	Indigenous renewable bio-mass consumed for cooking	
Total Emission in Gg	**54438.97**	**0.01**	**0.03**			
Total CO_2e Emissins in Gg			**54,449.15**			

3.9 Emissions from Industrial Processes and Product Use (IPPI)

This covers GHG emissions from industrial processes, where the emissions are created from chemical processes as opposed to combustion (CO_2 emissions from the combustion of fuels in industry is covered under the industry sector). There are two main sectors that emit process emissions in Bangladesh, the ammonia/urea sector and the cement sector.

To prepare the GHG Inventory from the industry sector, the following steps were completed:

1. Study of the Industry sector – the major industry types emitting greenhouse gases (GHGs) in the country that are mentioned in the IPCC 2006 Guidelines;
2. Identifying the institutions from which authentic data can be obtained and establishing communication with them in order to take assistance from them in the preparation of Third National Communication (TNC) project;
3. Collection of data from relevant institutions about the production of cement and fertilizer production linked with GHG emission; and
4. For calculation and reporting, the 'Industry' module of the IPCC 2006 Guidelines 1996 was thoroughly studied.

3.9.1 Introduction

The Industrial Processes category accounts for emissions generated in the production and use of minerals, the production of metals, the chemical industry, some processes such as paper production, foods and drinks, and finally, in the production and consumption of halocarbons and sulphur hexafluoride (Table 3.20). CO_2, CH_4, NO_2, HFC, PFC, and SF_6 are the GHGs emitted from industrial processes. In addition, other secondary gases such as carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NOx), and non-methane volatile organic compounds (NMVOCs) are also included in the IPCC Guidelines. In general terms, the main gas emitted in this category is CO_2.

Although Bangladesh is not an industrialized country, the country has made great efforts in preparing an inventory of greenhouse gas emissions along with efforts to reduce its own emissions of greenhouse gases.

3.9.2 Sub-sectors of industrial sector

Emissions are often produced as a by-product of various non-energy-related activities. For example, in the industrial sector, raw materials are often chemically transformed from one state to another. This transformation often releases such greenhouse gases as CO_2. The production processes that emit CO_2 include cement production, lime production, soda ash production and use and limestone consumption.

The following table illustrates the categorization of industrial plants according to IPCC 2006 Guidelines:

Table 3.16: Subcategories of industrial processes

2A Mineral Products	2A1 Cement Production
	2A2 Calcium Oxide and Calcium Hydroxide Production
	2A3 Limestone and Dolomite Use
	2A4 Soda Ash Production and Use
	2A5 Asphalt Roofing Production
	2A6 Road Paving with Asphalt
	2A7 Glass Production

2B Chemical Industry	2B1 Ammonia Production
	2B2 Nitric Acid Production
	2B3 Adipic Acid Production
	2B4 Carbide Production
	2B5 Others
2C Metal Production	2C1 Iron and Steel Production
	2C2 Ferroalloys Production
	2C3 Aluminum Production
	2C4 Sulphur hexafluoride Used in Aluminum and Magnesium Foundries
2D Other Industrial Processes	2D1 Pulp and Paper Industries
	2D2 Food and Drink
2E Production of Halocarbons and Sulphur hexafluoride	2E1 Emissions as waste or byproducts
	2E2 Fugitive emissions
2F Consumption of Halocarbons and Sulphur hexafluoride	2F1 Refrigeration and Air Conditioning Equipment
	2F2 Foam Blowing
	2F3 Fire Extinguishers
	2F4 Aerosols
	2F5 Solvents
	2F6 Electrical Equipment and Automatic Switches

3.9.3 Major IPPU related GHG emitting industries in general

a. Mineral industry: Clinker production (for cement production), lime production, soda ash production and use, asphalt roofing production and use and glass industry
b. Chemical industry: Ammonia and urea fertilizer
c. Metal production: Steel and ferroalloy production
d. Food products : Soft drinks, alcoholic beverages, sugar and bread

In the context of applicability, only cement and urea fertilizer contribute to the process related CO_2 emissions in Bangladesh.

3.9.3.1 Cement Industry

Carbon dioxide is produced during the production of clinker, an intermediate product from which cement is made. High temperatures in cement kilns chemically change raw materials (limestone) into cement clinker. In a process called calcination or calcining, calcium carbonate is heated, forming lime and carbon dioxide. CO_2 is emitted during clinker production rather than cement production itself. Emission estimates should be based on the lime content and production of clinker. In Bangladesh, most cement manufacturing plants use imported clinker; only three industries produce clinker for themselves: one government owned cement factory named Chatak Cement Co. two others - Lafarge Surma Cement Ltd., and Prime Cement Ltd.
Cement Production Process

There are three production steps involved in the production of cement:

- Preparing raw materials: Mixing/homogenising, grinding and preheating (drying) to produce the raw meal;
- Burning of raw meal to form cement - clinker in the kiln: The components of the raw meal react at high

temperatures (900-1500°C) in the precalciner and in the rotary kiln, to give cement clinker; and

- Finish grinding of clinker and mixing with additives: After cooling the clinker is ground together with additives.

Carbon Dioxide Emissions from the Cement Production Process

Carbon dioxide emissions in cement manufacturing come directly from the combustion of fossil fuels and from calcining the limestone in the raw mix. An indirect and significantly smaller source of CO_2 is from the consumption of electricity assuming that the electricity is generated from fossil fuels. Roughly half of the emitted CO_2 originates from the fuel and half originates from the conversion of the raw material. This report is concerned with the conversion of raw material. Emissions from burning fossil fuels are reported in the Energy Sector.

Carbon Dioxide Emission from Calcination (Process Emissions)

Process CO_2 is formed by calcining which can be expressed by the following equation:

$CaCO_3 \rightarrow CaO + CO_2$

1 kg of $CaCO_3$ gives 0.56 kg of CaO and 0.44 kg of CO_2

The share of CaO in clinker actually amounts to 64-67%. The remaining part consists of iron oxides and aluminum oxides. CO_2 emissions from clinker production amounts therefore to about 0.5 kg/kg clinker.

The specific process CO_2 emission for cement production depends on the ratio of clinker to cement. This ratio varies normally from 0.5 to 0.975.

Cement sector

Data is available on annual clinker production (in millions of tonnes) at the two cement plants in Bangladesh (Lafarge Suma and Chatak). The IPCC default emissions factor of 0.507 is applied to this to give GHG emissions. A growth rate of 5~6% is assumed meaning that the process-related GHG emissions from cement production in 2030 will be 0.71 $MtCO_2e$ a year. Table 3.21 shows the total clinker production of Chatak cement and Lafarge Surma Cement Company Ltd. in the period of the inventory.

<u>Chhatak Cement Co. Ltd.</u>

Fraction of lime (CaO) in clinker (%) = 66 – 67

Average fraction of lime (CaO) in clinker (%) = 66.5

Emission Factor (t CO_2/t clinker) = 0.5071 x 0.665/0.646

(according to IPCC Guideline, 2006) = 0.5071 x 1.029

= 0.5218

<u>Lafarge Surma Cement Ltd</u>

Production Start – 2006

Capacity – 1200000 t / year

Fraction of lime (CaO) in clinker (%) = 64.6

Emission Factor (t CO_2/t clinker) = 0.5071 x 0.646/0.646

= 0.5071 x 1

= 0.5071

Table 3.17: Production of clinker at Chhatak and Lafarge Cement Co. Ltd

Clinker Production at Lafarge and Chatak Total (Metric Tons)	
2006	1345744
2007	1310610
2008	1343610
2009	1343610
2010	1307703
2011	1337446
2012	1297332

The total CO_2 emissions from cement sector is shown in Table 3.20

3.9.3.2 Ammonia Fertilizer Industry

In most instances, anhydrous ammonia is produced by catalytic steam reforming of natural gas (mostly CH_4). Natural gas is used as the feedstock. Hydrogen is separated from the fuel and combined with nitrogen to produce ammonia (NH_3). The remaining carbon is eventually emitted as CO_2. Emissions of NOX, NMVOC, CO and SO_2 may also occur during ammonia production.

In Bangladesh, ammonia is produced for manufacturing ammonium and urea fertilizer. Currently, there are six ammonia producing plants in the country, all of which are state owned. They appear in Table 3.18.

Table 3.18: Ammonia Fertilizer Industries

Enterprise Name	Product	Installed capacity	Year of establishment
1. Chittagong Urea Fertilizer Factory Ltd.	Urea	5,61,000 M.T./ Year	1987
2. Jamuna Fertilizer Company Ltd.	Urea	5,61,000 M.T./ Year	1989
3. Zia Fertilizer Company Ltd.	Urea	5,28,000 M.T./ Year	1981
4. Urea Fertilizer Factory Ltd.	Urea	4,70,000 M. T./ Year	1970
5. Polash Urea Fertilizer Factory Ltd.	Urea	95,000 M.T./ Year	1985
6. Natural Gas Fertilizer Factory Ltd.	Urea, ASP	1,06,000 M.T. / Year (Urea)	1961

Emissions estimation from ammonia production

Emissions of CO_2 depend on the amount and composition of gas used in the process. It is assumed that all carbon will be emitted into the atmosphere. The most accurate method of estimation is based on the consumption of gas. (The carbon content of natural gas may vary; *The 2006 IPCC Guidelines for National Greenhouse Gas Inventories Reference Manual for* sources provides the values 812 m^3 gas/ton NH3 and 0.525 kg carbon/m^3 gas).

If the gas consumption is not available, an alternative is to calculate the emissions from the ammonia production. (The *2006 IPCC Guidelines for National Greenhouse Gas Inventories Reference Manual* for sources recommends emission factor as 1.5 tonnes CO_2 per tonne NH_3 produced which excludes gas used as a fuel). Gas used as a fuel must be excluded. This is included in the Energy Sector to avoid double counting as stated in the IPCC Guidelines.

Based on Ammonia Production

STEP 2: Estimating CO_2 emitted

The amount of ammonia produced in tonnes estimated.

- The default emission factor is 1.5 t CO_2/t NH_3 used.
- Amount of NH3 multiplied the emission factor to obtain CO_2 and transformed into Gg.

Table 3.19: Emission estimation from ammonia production

Amount of Ammonia Produced	Kg CO_2 Generated	Amount of Urea Produced in Kg	CO_2 recovered from Urea Production	CO_2 Emission (kg CO_2)	CO_2 Emission (Gg CO_2)	Year
1402795	2104192850	1730261000	1268858067	835334783	835	2006
1555901	2333850950	1817193000	1332608200	1001242750	1001	2007
1316869	1975303100	1476606000	1082844400	892458700	892	2008
1167328	1750991500	1280294000	938882267	812109233	812	2009
887407	1331111050	1056102000	774474800	556636250	557	2010
907296	1360943500	908837000	666480467	694463033	694	2011
754145	1131217400	933686000	684703067	446514333	447	2012

Ammonia/urea

GHG emissions from this sector have been calculated following IPCC Tier 1 methods. Data is available on gas consumption (in thousand standard cubic feet, MSCF) in 2012 for the seven ammonia-urea complexes in Bangladesh[5] as well as total ammonia and urea installed capacity (in tonnes). Assuming a utilisation rate of the installed capacity of 100% (based on the fact that demand exceeds production, and assuming that local capacity will always be exhausted before imports are bought in), the total installed capacity for urea production was used to calculate the CO_2 emissions used in the production of urea (2.12 $MtCO_2$ a year).

Estimating CO_2 emissions

Table 3.20: CO_2 emissions from Cement and Fertilizer Factories

Year	2006	2007	2008	2009	2010	2011	2012
Cement	700	682	699	699	680	695	675
Fertilizer	835	1001	892	812	557	694	447
Total	1535	1683	1591	1511	1237	1390	1121

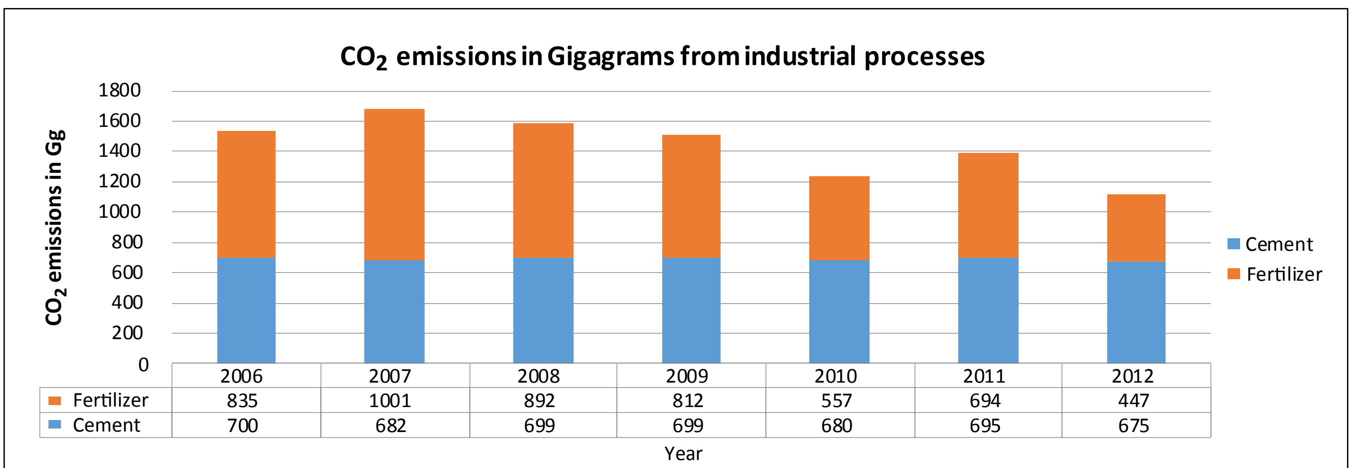


Figure 3.12: CO_2 emissions in gigagrams from industrial processes

5 Natural Gas Fertilizer Factory (NGFF) at Fenchugonj, Urea Fertilizer Factory Ltd. (UFFL) at Ghorasal, Zia Fertilizer Co. Ltd. (ZFCL) at Ashugonj, Polash Urea Fertilizer Factory (PUFF) at Polash adjacent to UFFL, Chittagong Urea Fertilizer Ltd. (CUFL) at Rangadia, Jamuna Fertilizer Co. Ltd. (JFCL) at Tarakandi and KAFCO at Rangadia by the side of CUFL. All but the last of these are operated by Bangladesh Chemical Industries Corporation (BCIC).

3.10 Greenhouse Gas Emission from Agriculture Sector

A significant amount of greenhouse gases (GHGs), such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are released into the atmosphere through agricultural activities (Smith et al., 2007). Carbon dioxide is emitted mostly from microbial decomposition or burning of plant residues and soil organic matter (Janzen, 2004; Smith, 2004). Methane is produced when organic materials decompose under reduced or oxygen-deprived conditions, notably from enteric fermentation by ruminant livestock, stored manures and paddy rice cultivation under flooded conditions (Mosier et al. 1998). Nitrous oxide is produced by transformation of nitrogen in soils and manures by microbial activities and is often enhanced where available N exceeds plant requirements, especially under water saturated conditions (Smith & Conen, 2004; Oenema et al., 2005). The agricultural sector is one of the major contributors, emitting about 60% of total anthropogenic N_2O (Smith et al., 2007). Emissions of N_2O and NO are mainly associated with N fertilizer use (or soil N content) and water regime. Agricultural greenhouse gas fluxes are complex and heterogeneous, but the amount of emission depends on the management of agricultural systems.

Four major sources of GHG emissions from the agriculture sector have been identified in Bangladesh for reporting purposes in the Third National Communication. These are: (i) CH_4 emissions from cultivated rice fields; (ii) N_2O and CO_2 emissions from N-based fertilizer; (iii) Enteric fermentation; and (iv) CH_4 and N_2O emissions from manure management. The dominant sources of emissions are CH4 from rice field and enteric fermentation from the livestock subsector. The next important sources are N_2O emission from fertilizer applications and direct N_2O emissions from manure systems. A summary of GHG emissions is presented in Table 3.21. In the case of total emissions, the overall trend for the period from 2006 to 2012 is one of gradual increase with a small dip in 2011. During this seven-year period, the total emissions increased from 42874 to 45877 (Gg CO_2eq) at an average annual growth rate of 1.14%.

Table 3.21: Summary of Emission of Agriculture Sector (Gg CO_2eq)

Source of Emission	2006	2007	2008	2009	2010	2011	2012
CH_4 emission from rice fields	13583	13814	14357	14702	14686	14924	15089
Direct Nitrous Oxide (N_2O) from Fertilizer applications	5375	5567	5631	5465	5563	4966	5251
Indirect Nitrous Oxide (N_2O) emissions from N based fertilizer	1746	1809	1831	1776	1808	1614	1707
Total Enteric CH_4 Emissions	12389	12562	12717	12888	13064	13233	13421
Total Manure CH_4 Emissions	2938	2963	2981	3005	3029	3051	3076
Total Direct N_2O Emissions from Manure System	4794	4847	4892	4945	5000	5050	5109
Total Indirect N_2O Emissions – Volatilization	1599	1623	1640	1662	1683	1703	1726
Total Indirect N_2O Emissions - Leaching/Runoff	450	349	465	473	481	489	498
Total	42874	43534	44514	44916	45314	45030	45877

As consumption of food items is a major driver of agricultural growth, it is very likely that emissions from all source categories in this sector will also increase. At the national level, the per capita per day intake of food items has increased by about 4.3 percent, i.e.; from 947.8 g in 2005 to 990.0 g in 2010. On the one hand, the average quantity of rice intake decreased by about 5.4 percent to 416.01 g in 2010 from 439.64 g in 2005. Although the per capita rice intake decreased, the gross consumption has increased because of population growth. On the other hand, consumption of wheat increased to 26.09 g in 2010 from 12.08 g in 2005 registering a 115.98% increase. Per capita per day intake of potato increased to 70.52 g in 2010 from 63.30 g in 2005. Consumption of meat also increased from 8.4 to 19.07 g per capita per day during the period from 2005 to 2010. During the same period, per capita per day intake of milk and milk products did not change much, it increased from 32.4g to 33.72g (HIES 2010, BBS, 2011).

Biomass burning in crop fields is not common in Bangladesh. Some biomass burning takes place in the hills where 'slash and burn' is practiced by some minority ethnic groups. However, biomass burning is declining rapidly as horticultural crops are planted in areas where 'slash and burn' may have been the norm. With the exception of some Gangetic alluvial soils, soils in Bangladesh are generally acidic to neutral in nature. The pH range for these soils varies from around 4 to 7. Only when free acids are present, the pH value may go below 4. The most common liming agents are calcitic limestone (calcium carbonate) and dolomite (FRG, 2005). Although liming is recommended for highly acidic soils and for some crops, it is not common in Bangladesh. As biomass burning and liming are sporadically practiced in the country, only the dominant sources of GHG emissions have been considered.

3.10.1 Sub-sector: Methane Emission from Cultivated Rice Fields

3.10.1.1 Introduction

Anaerobic decomposition of organic material in flooded rice fields produces CH_4 which escapes into the atmosphere. Upland fields, which are not flooded, produce insignificant amounts of CH_4. Other cultivated areas consisting of irrigated, rain-fed and deep-water lands produce CH_4. The parameters that influence CH_4 emissions vary widely both spatially and temporally. Moreover, CH_4 flux from a paddy field is critically dependent on several factors including climate, characteristics of soil and paddy and agricultural practices, particularly water regime.

The Interregional Research Programme on Methane Emissions from Rice Fields established a network of eight measuring stations in five Asian countries. These stations covered different environments and encompassed varying practices in crop management. All stations were equipped with a closed chamber system designed for frequent sampling and long-term measurements of emission rates. Even under identical treatment, e.g., continuous flooding and no organic fertilizers, average emission rates varied from 15 to 200 kg CH_4 ha^{-1} season.$^{-1}$ Low temperatures limited CH_4 emissions in temperate and subtropical stations such as northern China and northern India. Differences observed under given climates, (e,g. in the tropics) indicated the importance of soil properties in regulating the CH_4 emission potential. However, local variations in crop management superseded the impact of soil- and climate-related factors that resulted in uniformly high emission rates of about 300 kg CH_4 ha-1 season-1 for the irrigated rice stations in the Philippines (Maligaya) and China (Beijing and Hangzhou).

In the 1998 Asia Least Cost Greenhouse Gas Abatement (ALGAS) Study, the total harvested area of 8.03 million hectares (Mha) was considered for the fiscal year 1989–90 and the total CH_4 emission from the rice fields were estimated at 767 Gg. In the Initial National Communication (INC), (MoEF, 2002) with a total harvested area of 10.07 Mha, the total CH_4 was estimated at 662.23 Gg for the year 1994. In the Second National Communication (SNC), (MoEF, 2012) the reported total CH_4 emission was 374.93 Gg for the year 2004-05 from a total harvested area of 10.37 Mha.

For the Third National Communication, the total CH_4 emission from rice fields has been estimated and the values are 543.31 and 603.55 Gg for the year 2006 and 2012 respectively. The total methane emission from rice fields has increased due to the increase in the crop area, particularly the irrigated boro (dry season rice) rice area.

3.10.1.2 Methodology

Software Used

The Agriculture and Land Use (ALU): National Greenhouse Gas Inventory Software version 5.0.1 was used for the estimation of methane emission from rice fields. This software was developed at Colorado State University. The programme can be used to estimate emissions and removals associated with biomass carbon stocks, soil carbon stocks, soil nitrous oxide emissions, rice methane emission, enteric methane emission, manure methane and nitrous oxide emissions, as well as non-CO_2 GHG emissions from biomass burning. Methods are based on 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories. The software has several innovative features. It:

Accommodates Tier 1 and 2 methods as defined by the IPCC;

Allows compilers to integrate GIS spatial data along with national statistics on agriculture and forestry;

Is designed to produce a consistent and complete representation of land use for inventory assessment;

Can develop an enhanced characterization for livestock;

Has explicit quality control and quality assurance steps;

Provides a long-term archive of data and results in digital format; and

Generates emission reports that can be included in communications with interested parties.

The following equations and factors were used for estimating CH_4 emissions from rice cultivation. The values of different factors have been considered for different climates, ecological zones, cropping patterns and water regimes before and during cultivation etc. and are presented in Annex-5.

CH_4rice = A * t * EFrice * 0.000001
EFrice = EFc * SFw * SFp * SFo * SFs * SFr
SFo = (1 + SUM(ROA * CFOA))^0.59

Where,

Abbreviation	Description	Units	Type (Factor Value)
CH_4 rice	Methane Emissions from Rice Cultivation	(Gg CH_4 yr^{-1})	Equation Result
A	Annual Harvested Area for Rice	(ha)	Quantity Value (Table 1.1)
T	Cultivation Period for Rice	(days)	Quantity Value (Table 1.1)
EFrice	Adjusted Daily CH_4 Emission Factor for Rice Cultivation	(kg CH_4 ha^{-1} day^{-1})	Calculated Factor (Annexure)
EFc	Default CH_4 Baseline Emission Factor	(kg CH_4 ha^{-1} day^{-1})	Factor Value (Annexure)
SFw	Scaling Factor for Cultivation Period Water Regime	(unitless)	Factor Value (Annexure)
SFp	Scaling Factor for Pre-Season Water Regime	(unitless)	Factor Value (Annexure)
SFs	Scaling Factor for Soil Type	(unitless)	Factor Value (Annexure)
SFr	Scaling Factor for Rice Cultivar	(unitless)	Factor Value (Annexure)
SFo	Methane Scaling Factor for Organic Amendment	(unitless)	Equation Result (Annexure)
ROA	Application Rate of Organic Amendment	(tonnes ha^{-1})	Quantity Value (Annexure)
CFOA	Conversion Factor for Organic Amendment	(fraction)	Factor Value (Annexure)

Methane estimation

In the year 2006 (2005-06) a total area of 10.529 Mha of land was under paddy cultivation of which 9.8%, 4.8%, 46.8% and 38.6% *were aus, broadcast (B) aman,* transplanted (T) aman and boro respectively (Table 3.22). The paddy area increased gradually from 2006 to 2012. The coverage of B aman rice decreased slightly in the same period. However, also during the same period, the area under boro cultivation increased significantly. The aus area remained almost unchanged in the seven year period. The total paddy area increased by about 9.5% in between 2006 and 2012.

Table 3.22: Cultivated Area and Cultivation Period of Different Rice Crops

Crop Name	Cultivated Area (million hectares)							Cultivation Period (days)
	2006	2007	2008	2009	2010	2011	2012	
Aus	**1.03**	**0.91**	**0.92**	**1.07**	**0.98**	**1.11**	**1.14**	**90**
B Aman	**0.51**	**0.48**	**0.31**	**0.40**	**0.48**	**0.43**	**0.38**	**180**
T Aman	**4.92**	**4.93**	**4.74**	**5.09**	**5.19**	**5.22**	**5.20**	**110**
Boro	**4.07**	**4.26**	**4.61**	**4.72**	**4.71**	**4.77**	**4.81**	**120**
Total Rice	*10.53*	*10.58*	*10.58*	*11.28*	*11.36*	*11.53*	*11.53*	

Source: Yearbook of Agricultural Statistics of Bangladesh (BBS 2008 and 2013)

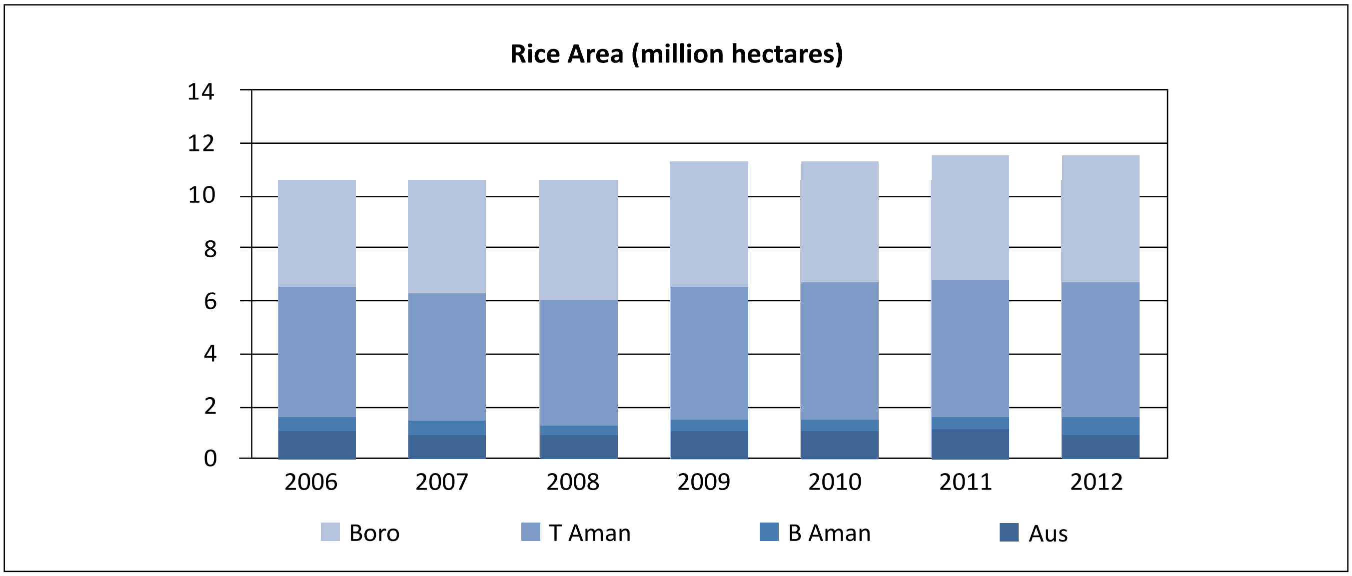


Figure 3.13: Different Rice Cultivated Areas from 2006 to 2012

In 2006, the total methane emission from rice cultivation was estimated at about 543.31 Gg. Methane emission from rice cultivation gradually increased and the amount in 2012 stands at 603.55 Gg. The increase is attributed to increasing the rice cultivation area, especially that of the *boro*. However, in 2010 emissions decreased slightly compared to the previous year which may be attributed to a slightly decreased *boro* area. Year-wise total methane emission from rice cultivation by year are presented in Table 3.23.

Table 3.23: Total Methane Emissions from Rice Cultivation

Year	Gg CH_4	(Gg CO_2eq)
2006	543.31	13583
2007	552.58	13814
2008	574.28	14357
2009	588.07	14702
2010	587.46	14686
2011	596.97	14924
2012	603.55	15089

3.11 Sub-sector: Nitrous Oxide and Carbon Dioxide Emission from N-based Fertilizer

3.11.1 Introduction

Nitrogen-based fertilizer and other N-containing amendments, when applied to agricultural soils, are sources of direct and indirect N_2O emissions. In Bangladesh, urea (CH_4N_2O) and diammonium phosphate (DAP, $(NH_4)_2HPO_4$)) are the most commonly used N-based fertilizers. The N-based fertilizers produce N_2O. which is produced naturally in soils through the processes of nitrification, the aerobic microbial oxidation of ammonium to nitrate, and denitrification, the anaerobic microbial reduction of nitrate to nitrogen gas (N_2). Nitrous oxide is a gaseous intermediate in the reaction sequence of denitrification and a by-product of nitrification that leaks from microbial cells into the soil and ultimately into the atmosphere. One of the main controlling factors in this reaction is the availability of inorganic N in the soil.

According to Van der Gon and Bleeker (2005) the emissions of N_2O that result from anthropogenic N inputs occur through both a direct pathway (i.e. directly from the soils to which the N is added), and through two indirect pathways (i.e. through volatilization as NH_3 and NOx and subsequent redeposition, and through leaching and runoff).

In the Second National Communication (MoEF, 2012), direct nitrous oxide emissions were estimated at 19.17 and 22.80 Gg N_2O from N-based fertilizers for the year 2001 and 2005 respectively. The indirect nitrous oxide emission from N-based fertilizer was not considered in the Second National Communication.

The direct nitrous oxide emission from N-base fertilizers estimated for this report is 18.04 and 17.62 Gg N_2O for the years 2006 and 2012 respectively. Indirect nitrous oxide emissions from N-based fertilizer (atmospheric N deposition and leaching/runoff) are 5.87 and 5.76 Gg N_2O for the years 2006 and 2012 respectively. The emissions decreased slightly due to increased use of diammonium phosphate instead of urea.

3.11.2 Methodology

For an estimation of direct and indirect N_2O emissions from N-based fertilizers, the ALU software version 5.0.1 was used (described in subsection below).

3.11.3 Direct N_2O Emissions from N Fertilizers

The following equations and factors were used for estimating direct nitrous oxide emission from N-based fertilizers.

$N_2O(D)sn$ = Sum(N_2Osn)

N_2Osn = Fsn * EFsn * (44/28)

Where,

Abbreviation	Description	Units	Type (Factor Value)
$N_2O(D)sn$	Total Direct N_2O Emissions from N Fertilizers	(kg N_2O yr^{-1})	Equation Result
N_2Osn	Direct N_2O Emissions from N Fertilizers	(kg N_2O yr^{-1})	Equation Result
Fsn	Annual Amount of Synthetic Fertilizer N Applied to Soils	(kg N yr^{-1})	Quantity Value (Annexure)
EFsn	Direct N_2O Emission Factor	[(kg N_2O -N (kg N Input) $^{-1}$]	Factor Value (0.01)

3.11.4 Total Urea CO_2 Emissions

Adding urea to soils during fertilization leads to a loss of CO_2 that was fixed in the industrial production process. Urea is converted to ammonium (NH_4+), hydroxyl ion (OH-), and bicarbonate (HCO_3-), in the presence of water and urease enzymes. The formulas used for estimating CO_2 emissions from urea fertilizers are given in the next page.

$Ctotal = Sum(CO_2urea)$
$CO_2urea = Murea * EFurea * (44/12)$
$Murea = (Domestic + Imports - Exports) * pUrea$

Where:

Abbreviation	Description	Units	Type (Factor Value)
CO_2total	Total Urea CO_2 Emissions	(tonnes CO_2 yr^{-1})	Equation Result
CO_2urea	Urea CO_2 Emissions	(tonnes CO_2 yr^{-1})	Equation Result
Murea	Annual Urea Fertilizer Applied to Soils	(tonnes urea yr^{-1})	Equation Result
EFurea	Urea Carbon Emission Factor	[tonnes C (tonnes $urea^{-1}$)]	Factor Value (0.2)
Domestic	Annual Urea Fertilizer from Domestic Production	(tonnes urea fertilizer yr^{-1})	Quantity Value (Annexure)
Imports	Annual Urea Fertilizer Imported	(tonnes urea fertilizer yr^{-1})	Quantity Value (Annexure)
Exports	Annual Urea Fertilizer Exported	(tonnes urea fertilizer yr^{-1})	Quantity Value (Annexure)
pUrea	Percent of Fertilizer that is Urea	(tonnes urea fertilizer yr^{-1})	Quantity Value

3.11.5 Total Indirect N_2O Emissions - Atmospheric N Deposition

The following equations and factors were used for estimating indirect N_2O emission from N-based fertilizers.

$N_2O(ATDtot)sn = Sum(N_2O(ATD)sn)$
$N_2O(ATD)sn = Fsn * FracGASF * EFv * (44/28)$

Where,

Abbreviation	Description	Units	Type (Factor Value)
N_2O(ATDtot)sn	Total Indirect N_2O Emissions - Atmospheric N Deposition	(kg N_2O yr^{-1})	Equation Result
N_2O(ATD)sn	Indirect N_2O from N Fertilizer - Atmospheric N Deposition	(kg N_2O yr^{-1})	Equation Result
Fsn	Annual Amount of Synthetic Fertilizer N Applied to Soils	(kg N yr^{-1})	Quantity Value (Annexure)
FracGASF	Fraction of N Fertilizer that Volatilizes	(fraction)	Factor Value (0.1)
EFv	Indirect N_2O Emission Factor – Volatilization	[kg N_2O-N (kg N volatilized) $^{-1}$]	Factor Value (0.01)

3.11.6 Total Indirect N2O Emissions - Leaching/Runoff

For estimating indirect nitrous oxide emission from N based fertilizer, the following equations and factors were used.

$N_2O(Ltot)sn = Sum(N_2O(L)sn)$
$N_2O(L)sn = Fsn * FracLEACH * EFlr * (44/28)$

Where,

Abbreviation	Description	Units	Type (Factor Value)
N_2O(Ltot)sn	Total Indirect N_2O Emissions - Leaching/Runoff	(kg N_2O yr^{-1})	Equation Result
N_2O(L)sn	Indirect N_2O from N Fertilizer - Leaching/Runoff	(kg N_2O yr^{-1})	Equation Result
Fsn	Annual Amount of Synthetic Fertilizer N Applied to Soils	(kg N yr^{-1})	Quantity Value (Annexure)
FracLEACH	Fraction of N Fertilizer lost - Leaching/Runoff	(fraction)	Factor Value (0.3)
EFlr	Indirect N_2O Emission Factor - Leaching/Runoff	[(kg N_2O-N (kg N leached) $^{-1}$]	Factor Value (0.0075)

3.11.7 Direct Nitrous Oxide (N_2O) and Carbon Dioxide (CO_2) estimation

In 2006 the amount of direct N_2O emissions from N-based fertilizer and CO_2 emissions from urea fertilizer were estimated to be 18.04 Gg and 183374 Gg respectively. The direct N_2O emissions from N-based fertilizers and CO_2 from urea decreased to 17.62 Gg and 162507 Gg respectively in 2012 (Table 3.24). The reduction in emissions may be attributed to increased use of DAP fertilizer instead of urea.

Table 3.24: Direct Nitrous Oxide emissions from N based fertilizer and Carbon Dioxide emissions from urea fertilizer

Year	Urea (Gg)	DAP (Gg)	N_2O Emissions (Gg N_2O)	N_2O Emissions (Gg CO_2eq)	CO_2 Emissions (Gg CO_2eq)
2006	2501	125	18.04	5375	183374
2007	2592	125	18.68	5567	190070
2008	2636	90	18.90	5631	193324
2009	2575	46	18.34	5465	188833
2010	2565	187	18.67	5563	188100
2011	2208	371	16.66	4966	161920
2012	2216	690	17.62	5251	162507

Source: Urea & DAP consumption figures are from BBS: Yearbook of Agricultural Statistics 2015 and Fertilizer Association of Bangladesh (URL:http://brri.portal.gov.bd/sites/default/files/files/brri.portal .gov.bd/page/b6531346_66a5_45e7_ 9cb0 d00c7c7009dc/Fertilizer_bfa.pdf)

In Table 3.25 the indirect N_2O emissions from N-based fertilizer is presented. From the table, it is evident that the indirect emissions as Atmospheric N Deposition and from Leaching/Runoff showed a decreasing trend as the amount decreased from 5.86 Gg in 2006 to 5.73 Gg in 2012.

Table 3.25: Indirect Nitrous Oxide (N_2O) emissions from N based fertilizer

Year	Gg N_2O			(Gg CO_2eq)
	Atmospheric N Deposition	Leaching/Runoff	Total	Total
2006	1.80	4.06	5.86	1747
2007	1.87	4.20	6.07	1809
2008	1.89	4.25	6.14	1830
2009	1.83	4.13	5.96	1776
2010	1.87	4.20	6.07	1808
2011	1.67	3.75	5.42	1614
2012	1.76	3.97	5.73	1707

3.12 Sub-sector: Enteric Fermentation

3.12.1 Introduction

During animal digestion, methane is produced through enteric fermentation, a process in which methane is produced as a by-product in the rumen by microbes that reside in animal digestive systems that break down the feed consumed by the animal. Ruminants, which include cattle, buffalo, sheep, and goats, have the highest methane emission among all animal types because they have a rumen, or large forestomach, in which a significant amount of methane-producing fermentation occurs. The amount of methane produced and excreted by an individual animal also depends upon the amount and type of feed it consumes (EPA, 1995). Non-ruminant domestic animals, such as pigs and horses, have much lower methane emissions than ruminants because much less methane-producing fermentation takes place in their digestive systems. The number of pigs and horses in Bangladesh is insignificant so these were not considered for the reporting.

In the Second National Communication (MoEF, 2012), the total methane from enteric fermentation was estimated at 467.77 and 493.16 Gg CH_4 for the years 2001 and 2005 respectively. The total methane emission from enteric fermentation for the years 2006 and 2012 has been estimated and the values are 495.57 and 536.86 Gg CH_4 respectively. Out of the total CH_4 emissions from enteric fermentation in the year 2012, about 43%, 25%, 10%, 21% and 2% was produced by dairy cows, non-dairy cows, buffalo, goat, and sheep respectively.

3.12.2 Methodology

Methane emission from enteric fermentation was estimated using the ALU software version 5.0.1. The following factors and equations were used for estimating enteric methane emission.

CH4ent = Sum(CH4ent(b))
CH4ent(b) = (Nt * EFt(b)) / 1000000

Where:

Abbreviation	Description	Units	Type (Factor Value)
CH_4ent	Total Enteric CH_4 Emissions	(Gg CH_4 yr^{-1})	Equation Result
CH_4ent(b)	Enteric CH_4 Emissions: Basic Characterization	(Gg CH_4 yr^{-1})	Equation Result
Nt	Number of Livestock (Average Annual Population)	(head)	Quantity Value (Table 30)
EFt(b)	Enteric CH_4 Emission Factor: Basic Characterization	(kg CH_4 $head^{-1}$ yr^{-1})	Factor Value (Annexure)

3.12.3 Methane estimation

Data on livestock population was collected from the Department of Livestock Services (DLS). The total number of livestock population by different year is presented in Table 3.26. In 2006, livestock population was estimated to comprise 14.14 million dairy cows, 8.66 million non-dairy cows, 1.16 million buffaloes, 19.94 million goats, 2.57 million sheep and 232.99 million poultry birds. The livestock population increased gradually due to an increase in domestic demand for meat, eggs, milk and milk products.

Table 3.26 Total Livestock Population (in millions)

Livestock Category	Year						
	2006	2007	2008	2009	2010	2011	2012
Dairy Cows[6]	14.14	14.18	14.20	14.25	14.29	14.34	14.38
Non Dairy Cows	8.66	8.69	8.70	8.73	8.76	8.79	8.81
Buffalo	1.16	1.21	1.26	1.30	1.35	1.39	1.44
Goat	19.94	20.75	21.56	22.40	23.28	24.15	25.12
Sheep	2.57	2.68	2.78	2.88	2.98	3.00	3.08
Poultry	232.99	245.97	252.31	262.63	270.71	278.81	288.57

Source: Department of Livestock Services (DLS)

6 Dairy cows are 62% of the total cattle. This factor is derived in FAO – BLRI Joint workshop on data validation held during 23-24 January 2016 in Dhaka.

Where:

Abbreviation	Description	Units	Type (Factor Value)
CH_4man	Total Manure CH_4 Emissions	($Gg\ CH_4\ yr^{-1}$)	Equation Result
CH_4man(b)	Manure CH_4 Emissions: Basic Characterization	($Gg\ CH_4\ yr^{-1}$)	Equation Result
Nt	Number Head of Livestock (Average Annual Population)	(head)	Quantity Value (Table 3.1)
EFt(b)	Manure CH_4 Emission Factor: Basic Characterization	($kg\ CH_4\ head^{-1}/yr^{-1}$)	Factor Value (Appendix D)

Total enteric methane emission was estimated at 495.6 Gg for the year 2006 using enteric CH_4 emission factors (EFt) based on the SNC report. While using the Indian Subcontinent EFt factors, the estimated enteric CH_4 emission was 1230.2 Gg for the same year which is found to be much higher than that estimated with the SNC based factors. Methane emission increased at an average annual growth rate of 1.34% from 2006 to 2012 due to the increase in livestock population for both cases. The total enteric CH_4 emission by different livestock categories is presented in Table 3.27 and Table 3.28.

Table 3.27: Total Enteric CH_4 Emissions [based on SNC- CH_4 head-1 Year-1 (kg)]

Year	Gg CH_4						($Gg\ CO_2eq$)
	Dairy Cows	Non Dairy Cows	Buffalo	Goat	Sheep	Total	Total
2006	226.18	129.96	42.92	89.73	6.79	495.57	12389
2007	226.87	130.36	44.77	93.38	7.08	502.45	12562
2008	227.17	130.53	46.62	97.02	7.34	508.68	12717
2009	227.92	130.96	48.25	100.80	7.60	515.53	12888
2010	228.67	131.39	49.91	104.74	7.86	522.57	13064
2011	229.36	131.79	51.58	108.67	7.93	529.32	13233
2012	230.09	132.21	53.39	113.02	8.14	536.86	13421

Table 3.28: Total Enteric CH_4 Emissions [based on Indian Subcontinent- CH_4 head-1 Year-1 (kg)

Year	Gg CH_4						($Gg\ CO_2eq$)
	Dairy Cows	Non Dairy Cows	Buffalo	Goat	Sheep	Total	Total
2006	819.89	233.93	63.80	99.70	12.85	1230.17	30754
2007	822.41	234.65	66.55	103.75	13.40	1240.75	31019
2008	823.48	234.95	69.30	107.80	13.90	1249.44	31236
2009	826.22	235.73	71.72	112.01	14.39	1260.06	31502
2010	828.91	236.50	74.20	116.38	14.89	1270.87	31771
2011	831.43	237.22	76.67	120.75	15.01	1281.08	32027
2012	834.09	237.98	79.37	125.58	15.41	1292.43	32311

3.13 Sub-sector: Methane (CH_4) and Nitrous Oxide (N_2O) Emission from Manure Management

3.13.1 Introduction

Manure management is a major source of methane and nitrous oxide emissions from the agriculture sector. The main factors affecting CH_4 emissions are the amount of manure produced and the portion of the manure that decomposes anaerobically. The former depends on the rate of waste production per animal and the number of animals, while the latter on how the manure is managed. When manure is stored or treated as a liquid (e.g., in lagoons, ponds, tanks, or pits), it decomposes anaerobically and can produce a significant quantity of CH_4. The temperature and the retention time of the storage unit greatly affect the amount of methane produced. When manure is handled as a solid (i.e., in stacks or piles) or when it is deposited under aerobic conditions, it tends to produce more CO_2 and less CH_4.

Direct N_4O emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. The production and emission of N_2O from managed manures requires the presence of either nitrites or nitrates in an anaerobic environment preceded by aerobic conditions necessary for the formation of these oxidized forms of nitrogen.

In the Second National Communication (MoEF, 2012), the total methane and nitrous oxide emissions from manure management were estimated at 251.90 Gg CH_4 and 28.88 Gg N_2O respectively for the year 2001. The total methane and nitrous oxide emissions were estimated at 258.54 Gg CH4 and 33.83 Gg N_2O respectively for the year 2005. Notably, the CH_4 emissions from manure management in this national communication are almost half of those reported in the Second National Communication. The lower values are attributed to the use of different estimation methodologies.

The total CH4 emissions from manure management for the years 2006 and 2012 were estimated and the values are 117.51 and 123.04 Gg CH_4 respectively. The total direct N_2O emissions from manure management are estimated at 16.09 and 17.14 Gg N_2O for the years 2006 and 2012 respectively. The total indirect N_2O emissions from manure management are estimated at 5.37and 5.79 Gg N_2O for the year 2006 and 2012 respectively. The total emission from this source was estimated at 9781 Gg CO_2eq in 2006 and increased to 10409 Gg CO_2eq in 2012 (Table 3.29).

Table 3.29: Total Manure CH_4 and N_2O Emissions by Year from Manure Management

Year	CH_4 (GgCH_4)	N_2O (GgN_2O)	Total (Gg CO_2eq)
2006	117.51	23.16	9781
2007	118.53	23.25	9782
2008	119.24	23.48	9978
2009	120.21	23.76	10085
2010	121.14	24.04	10193
2011	122.04	24.30	10293

3.13.2 Methodology

The ALU (Agriculture and Land Use) software version 5.0.1 was used for estimation of methane emission from manure management.

3.13.3 Direct Methane (CH_4) estimation

The following equations and factors were used for estimating total CH_4 emissions from manure.

$CH_4man = Sum(CH_4man(b))$
$CH_4man(b) = (Nt * EFt(b)) / 1000000$

Where,

Abbreviation	Description	Units	Type (Factor Value)
CH_4man	Total Manure CH_4 Emissions	($Gg\ CH_4\ yr^{-1}$)	Equation Result
CH_4man(b)	Manure CH_4 Emissions: Basic Characterization	($Gg\ CH_4\ yr^{-1}$)	Equation Result
Nt	Number Head of Livestock (Average Annual Population)	(head)	Quantity Value (Table 3.1)
EFt(b)	Manure CH_4 Emission Factor: Basic Characterization	($kg\ CH_4\ head^{-1}/yr^{-1}$)	Factor Value (Annexure)

3.13.4 Direct Nitrous Oxide (N_2O) estimation

The following equations and factors were used for estimating direct nitrous oxide emissions from manure systems.
$N_2ODmm = Sum(N_2ODmm(b))$

$N_2ODmm(b) = Nt * Nex(b) * MS * EF3 * (44/28)$
$Nex(b) = Nrate * (TAM / 1000) * 365$

Abbreviation	Description	Units	Type (Factor Value)
N_2ODmm	Total Direct N_2O Emissions from Manure System	($kg\ N_2O\ yr^{-1}$)	Equation Result
N_2ODmm(b)	Direct N_2O from Manure System: Basic Characterization	($kg\ N_2O\ yr^{-1}$)	Equation Result
Nt	Number Head of Livestock (Average Annual Population)	(head)	Quantity Value (Table 3.1)
MS	Fraction Livestock Manure in Manure System	(fraction)	Quantity Value (Annexure)
EF3	Direct N_2O Emission Factor for Manure System	($kg\ N_2O\text{-}N\ kg^{-1}\ N$)	Factor Value (Annexure D)
Nex(b)	Annual N Excretion Rate: Basic Characterization	($kg\ N\ animal^{-1}\ yr^{-1}$)	Equation Result
Nrate	Daily N Excretion Rate: Basic Characterization	[$kg\ N\ (1000\ kg\ animal)^{-1}\ day^{-1}$]	Factor Value (Annexure)
TAM	Typical Animal Mass: Basic Characterization	($kg\ animal^{-1}$)	Factor Value (Annexure)

3.13.5 Indirect Nitrous Oxide (N_2O) estimation from volatilization

The following equations and factors were used for estimating indirect nitrous oxide emissions from volatilization.
$N_2OGmm = Sum(N_2OGmm(b))$

$Nvol(b) = Nt * Nex(b) * MS * FracGASM$
$N_2OGmm(b) = Nvol(b) * EFv * (44/28)$
$Nex(b) = Nrate * (TAM / 1000) * 365$

Where,

Abbreviation	Description	Units	Type (Factor Value)
N_2OGmm	Total Indirect N_2O Emissions – Volatilization	(kg N_2O yr^{-1})	Equation Result
Nvol(b)	N Volatilization from Manure System: Basic Characterization	(kg N yr^{-1})	Equation Result
Nt	Number Head of Livestock (Average Annual Population)	(head)	Quantity Value (Table 3.1)
MS	Fraction Livestock Manure in Manure System	(fraction)	Quantity Value (Annexure D)
FracGASM	Fraction of Manure N Volitization	(fraction)	Factor Value (Annexure D)
$N_2OGmm(b)$	Indirect N_2O Emissions - Volatilization: Basic Characterization	(kg N_2O yr^{-1})	Equation Result
EFv	Indirect N_2O Emission Factor - Atmospheric N Deposition	(kg N_2O-N kg^{-1} N volatilized)	Factor Value (Annexure D)
Nex(b)	Annual N Excretion Rate: Basic Characterization	(kg N $animal^{-1}yr^{-1}$)	Equation Result
Nrate	Daily N Excretion Rate: Basic Characterization	[kg N (1000 kg animal) $^{-1}$ day^{-1}]	Factor Value (Annexure D)
TAM	Typical Animal Mass: Basic Characterization	(kg $animal^{-1}$)	Factor Value (Annexure D)

3.13.6 Indirect Nitrous Oxide (N_2O) estimation from leaching/runoff

The following equations and factors were used for estimating indirect nitrous oxide emissions from leaching/ runoff.

$N_2OLmm = Sum(N_2OLmm(b))$
$Nleach(b) = Nt * Nex(b) * MS * FracLEACH$
$N_2OLmm(b) = Nleach(b) * EFlr * (44/28)$
$Nex(b) = Nrate * (TAM / 1000) * 365$

Where,

Abbreviation	Description	Units	Type (Factor Value)
N_2OLmm	Total Indirect N_2O Emissions - Leaching/Runoff	(kg N_2O yr^{-1})	Equation Result
Nleach(b)	N Leached from Manure System: Basic Characterization	(kg N yr^{-1})	Equation Result
Nt	Number Head of Livestock (Average Annual Population)	(head)	Quantity Value (Table 3.1)
MS	Fraction Livestock Manure in Manure System	(fraction)	Quantity Value (Annexure D)
FracLEACH	Fraction of N Lost from Manure System by Leaching/Runoff	(fraction)	Factor Value (0.1)
$N_2OLmm(b)$	Indirect N_2O Emissions - Leaching: Basic Characterization	(kg N_2O yr^{-1})	Equation Result
EFlr	Indirect N_2O Emission Factor - Leaching/Runoff	(kg N_2O-N kg^{-1} N leached)	Factor Value (0.0075)
Nex(b)	Annual N Excretion Rate: Basic Characterization	(kg N animal yr^{-1})	Equation Result
Nrate	Daily N Excretion Rate: Basic Characterization	[kg N (1000 kg animal)$^{-1}$ day^{-1}]	Factor Value (Annexure)
TAM	Typical Animal Mass: Basic Characterization	(kg $animal^{-1}$)	Factor Value (Annexure)

3.13.7 Direct Methane (CH_4) and Nitrous Oxide (N_2O) estimation

Total manure CH_4 emissions was estimated at 117.51 and 123.04 Gg for the years 2006 and 2012 respectively (Table 3.30). During this seven-year period, the total emissions gradually increased at an average annual growth rate of 0.77%. Emissions increased steadily with the increase in the population of different livestock categories. Similarly, N_2O emissions were estimated at 16.09 and 17.14 Gg for the years 2006 and 2012 respectively (Table 3.31). During this period, the total N_2O emission of the livestock subsector gradually increased at an average annual growth rate of 1.06%.

Table 3.30: Total Manure CH_4 Emissions by Year by Different Livestock Categories

Year	Gg CH_4							(Gg CO_2eq)
	Dairy Cows	Non Dairy Cows	Buffalo	Goat	Sheep	Poultry	Total	Total
2006	84.82	17.33	5.80	4.39	0.51	4.66	117.51	2938
2007	85.08	17.38	6.05	4.57	0.54	4.92	118.53	2963
2008	85.19	17.40	6.30	4.74	0.56	5.05	119.24	2981
2009	85.47	17.46	6.52	4.93	0.58	5.25	120.21	3005
2010	85.75	17.52	6.75	5.12	0.60	5.41	121.14	3029
2011	86.01	17.57	6.97	5.31	0.60	5.58	122.04	3051
2012	86.29	17.63	7.22	5.53	0.62	5.77	123.04	3076

Table 3.31: Total Direct N_2O Emissions from Manure System by Year by Different Livestock Categories

Year	Gg N_2O							(Gg CO_2eq)
	Dairy Cows	Non Dairy Cows	Buffalo	Goat	Sheep	Poultry	Total	Total
2006	10.85	1.93	0.72	2.35	0.24	0.00	16.09	4794
2007	10.89	1.93	0.75	2.45	0.25	0.00	16.26	4847
2008	10.90	1.93	0.78	2.54	0.26	0.00	16.42	4892
2009	10.94	1.94	0.81	2.64	0.27	0.00	16.59	4945
2010	10.97	1.95	0.84	2.74	0.28	0.00	16.78	5000
2011	11.00	1.95	0.86	2.85	0.28	0.00	16.95	5050
2012	11.04	1.96	0.90	2.96	0.29	0.00	17.14	5109

3.13.8 Indirect Nitrous Oxide (N_2O) estimation

It is observed from Table 3.32 that emissions through volatilization from livestock subsector were estimated at 5.37 and 5.79 Gg for the years 2006 and 2012 respectively. For the same period, the contributions to the total indirect N_2O emission from leaching or runoff was estimated at 1.70 and 1.67 Gg respectively (Table 3.33).

Table 3.32: Total Indirect N_2O Emissions - Volatilization

Year	Gg N_2O							(Gg CO_2eq)
	Dairy Cows	Non Dairy Cows	Buffalo	Goat	Sheep	Poultry	Total	Total
2006	3.19	0.72	0.24	0.56	0.06	0.59	5.37	1599
2007	3.20	0.72	0.25	0.59	0.06	0.63	5.45	1623
2008	3.20	0.73	0.26	0.61	0.06	0.64	5.50	1640
2009	3.21	0.73	0.27	0.63	0.07	0.67	5.58	1662
2010	3.22	0.73	0.28	0.66	0.07	0.69	5.65	1683
2011	3.23	0.73	0.29	0.68	0.07	0.71	5.71	1703
2012	3.24	0.73	0.30	0.71	0.07	0.73	5.79	1726

Table 3.33: Total Indirect N_2O Emissions - Leaching/Runoff

Year	Gg N_2O							($Gg\ CO_2eq$)
	Dairy Cows	Non Dairy Cows	Buffalo	Goat	Sheep	Poultry	Total	Total
2006	0.79	0.14	0.24	0.35	0.04	0.15	1.70	450
2007	0.79	0.14	0.05	0.37	0.04	0.16	1.54	349
2008	0.79	0.14	0.05	0.38	0.04	0.16	1.56	465
2009	0.79	0.14	0.05	0.40	0.04	0.17	1.59	473
2010	0.80	0.14	0.06	0.41	0.04	0.17	1.62	481
2011	0.80	0.14	0.06	0.43	0.04	0.18	1.64	489
2012	0.80	0.14	0.06	0.44	0.04	0.18	1.67	498

3.14 Uncertainties

Although the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000) recognizes that the uncertainty of estimates cannot be totally removed, and that the main objective should be to produce accurate estimates, i.e., estimates that are neither underestimated nor overestimated, while at the same time, whenever possible to look for ways to improve the precision of estimates, the estimates of emissions of greenhouse gases from agriculture sources presented in this inventory are subject to uncertainty due to several reasons. The key uncertainties in these estimates arise from the emission factors and the activity data or lack of precision of basic data, and lack of comprehensive knowledge of the processes that cause emissions of greenhouse gases. In addition, due to the absence of country-specific emission factors for different sources, the emission is either underestimated or overestimated. Lack of continuous or regular monitoring of all agricultural sources of GHG emissions is not being carried out in the country. Therefore, due to a lack of adequate data, the uncertainty in emissions quantities could not be statistically analysed. However, based on expert judgment and data quality, an effort was made at least to present qualitative estimates of uncertainty for CH_4 and N_2O emissions from different agricultural sources and these are presented in Table 3.34.

Specifically, the following sources of uncertainty may be highlighted:

As per requirement of the software used (ALU ver 5.0.1) data was not readily available. The land use data is not available by ecological and climatic zones. In this regard, percentage data has been used for preparing land use data by ecological and climatic zones.

Methane emission from rice cultivation depends largely on how long the fields are kept under inundated conditions. Methane emission factors are the largest source of uncertainty in estimates for rice cultivation. Since rice is grown both under irrigated and rain-fed conditions and also in three different seasons, seasonal emissions may vary considerably.

Data for the area or percentage of water regime before/during cultivation is not readily available. Therefore, expert judgment was used for preparing the data considering crops and land types.

The data on imports and domestic production of N-based fertilizers (Urea and DAP) was used for estimating nitrous oxide emissions. In some cases, the actual yearly consumption amount may not correspond to the total imports and domestic production, as urea is also used for non-agricultural purposes.

Emissions of nitrous oxide through other agricultural soil management practices, such as irrigation, tillage practices, or the fallowing of land, can also be affected as these activities can affect the nitrous oxide fluxes to and from the soil. There is much uncertainty about the direction and magnitude of the effects of these other practices.

The biggest uncertainty in estimates of methane emission from livestock digestion results from the large diversity of animal management/feeding practices found in the country, none of which can be precisely characterized and evaluated. The livestock population and production statistics by types have temporal variations. The data on average body weight of different livestock populations is not available. All these factors make emissions estimates uncertain. In estimating emissions from the livestock sector, IPCC default factors were used.

Table 3.34: The qualitative estimates of uncertainty for CH_4 and N_2O emission

Source of Emission	Uncertainty
CH_4 emission from rice field	Low
Direct Nitrous Oxide (N_2O) from Fertilizer application	High
Indirect Nitrous Oxide (N_2O) emissions from N based fertilizer	High
Total Enteric CH_4 Emissions	Moderate
Total Manure CH_4 Emissions	Moderate
Total Direct N_2O Emissions from Manure Systems	High
Total Indirect N_2O Emissions – Volatilization	High
Total Indirect N_2O Emissions - Leaching/Runoff	High

3.15 Conclusion

The availability and quality of emission-related data and country-specific coefficients for the calculation of emissions from different components of agriculture is always a limitation in a country like Bangladesh. Despite efforts to gather quality data and information, the data sets used for the analysis may suffer from various limitations. Lack of metadata makes it difficult to use and it is in some cases unreliable.

Moving forward, a more systematic effort should be made in collecting activity data from various agricultural sources on emissions and factors, either on a national or on a regional basis and involving respective departments of the government and responsible organizations. Data should be collected in such a way that it matches with the reporting as well as with any specific software requirements used in the estimation of emissions. For example, if ALU is used in future for emission estimation, then the following data/factors should either be collected or generated in the specified format:

The values for different factors (CH_4 Emission Factor for rice cultivation and livestock enteric fermentation and manure management, N_2O emission factor for fertilizer and livestock manure management etc.) should be developed for Bangladesh;

Data on organic amendments for crop cultivation;

Data on livestock population by age and body weight, manure management system by livestock categories etc.;
As the availability of good quality data is a prerequisite for producing a better report, for future communications, concerted efforts need to be strengthened in order to have an extensive dataset with increased spatial and temporal coverage. Once such a data collection system is developed, even Tier II GHG inventory reporting would be possible for the country.

3.16 Land Use, Land Use Change and Forestry (LULUCF) Sector

3.16.1 Emission from Changes in Land Use and Forest

3.16.1.1 Overview of Bangladesh Forests

Bangladesh covers an area of 1,47,570 sq. km and shares a border with India to the west. Myanmar and India to the east and the Bay of Bengal to the south. As per the decision of the International Arbitral Tribunal (2012-2014), Bangladesh currently has 118,813 sq km of marine area (DoE 2015). About 80% of total land surface of Bangladesh is considered as floodplain (BBS 2011). Hilly terrain covers only some 12% of total land area in the north-east and south-east, with average elevations of 244m and 610m, respectively (UN-REDD 2012). Overall, 17.49% of total land surface area of Bangladesh is now considered as state owned land to support tree cover. However, the Perspective Plan of Bangladesh (2010-2021) entitled 'Making Vision 2021 a Reality' (GED 2012a), reported that the recorded state-owned forest land (not necessarily supporting tree cover), and potential forest/tree growing areas, has been identified as 7 million acres (2.82 mha), which is 20% of the land area.

Category of Forest Land

The forest land of Bangladesh is broadly categorized as state forest land (2.26 million hectares) and private forest land (0.27 million hectares). Of the state forest land, 1.53 million hectares (Table 3.35) are under the jurisdiction of the Forest Department (FD) within the Ministry of Environment and Forests (MoEF). It includes reserved, protected, acquired and mangrove forest lands and newly accreted char lands in the estuaries of major rivers. The remaining 0.73 million hectares of land designated as Unclassed State Forest (USF) are under the control of the Ministry of Land. Village forests (homestead land) form the most productive tree resource base in the country and account for 0.27 million hectares.

Table 3.35: Category of Forest Land

Category of forest land	Area (million ha)	% of total land
Forest land managed by Forest Department	1.53	10.54
Unclassed state forest	0.73	5.07
Village forest	0.27	1.88
Total	2.53	17.49

Classification of Forest

Based on the classification of forest types of the Indo-Pakistan Sub-continent, ecologically speaking there are four types of forests in Bangladesh (Table 3.36).

Type 1. Hill Forests

The hill forests are mainly situated in the district of Chittagong, Cox's Bazar, Rangamati, Khagrachari, Bandarban and Sylhet. The total area of the hill forests is 670,000 hectares which accounts for 44% of the total area managed by the Forest Department and 4.65% of the total land surface area of Bangladesh. Both tropical wet evergreen and semi-evergreen forests are present in the form of hilly forests in Bangladesh. The difference between evergreen and semi-evergreen forests are minor and primarily distinguishable by the presence of some deciduous species in the top canopy layer. The National Forest Resources Assessment 2005-2007 reported that the hill forests areas of Bangladesh is now 551,000 hectares (Altrell et al. 2007).

Table 3.36: Different types of Forest managed by Forest Department

Sl. no	Forest Type	Area (million ha)	% of total land
1	Hill Forests	0.67	4.65
2	Natural Mangrove Forests	0.60	4.07
3	Mangrove Plantation Forests	0.14	0.97
4	Plain Land Sal Forest	0.12	0.83
	Total	1.53	10.54

Type 2. Natural Mangrove Forests

The Sundarbans, the world's largest continuous natural mangrove forest in Bangladesh, covers an area of 6,01,700 hectares which accounts for 4.07% of the total area of Bangladesh and 40% of the total area managed by the Forest Department. Of the total area, approximately 70% is land, 30% is water, 62% falls within the territory of

Bangladesh and the remaining area belongs to India. Based on the level of salinity, Sundarbans has been divided into three ecological zones, namely least, moderate and strongly saline zones, and the degree of salinity greatly influences the floristic composition, growth and distribution of species.

The Sundarbans was recognized as wetlands of international importance (Ramsar Site) under the Ramsar Convention in 1992. About 1,400 square kilometers of the forest was declared a World Heritage Site by UNESCO in 1997, and of this, 490 square kilometers is water.

Type 3. Mangrove Plantation Forests

The coastal areas of Bangladesh are broadly divided into three distinct regions: the eastern, central and western regions. The ecology of coastal land and water provides opportunities for man-made mangrove plantations in the newly accreted char land. The Bangladesh Forest Department has been actively engaged in establishing mangrove plantation along 710 km of exposed coast line facing the Bay of Bengal since 1960 and the most noteworthy achievement of the Forest Department is that it has created a vegetative belt in more than 150,000 hectares with mangrove plantation, fulfilling the primary objective of saving lives and properties of coastal and sea dwellers. Another creditable achievement is associated with the stabilization of the newly accreted lands and the enhancement process of accretions (Islam and Nandy 2001).

Type 4. Plain Land Sal Forests

The plain land 'Sal' forest is situated mainly in the districst of Gazipur, Tangail, Mymensingh, Sherpur, Jamalpur, Netrokona, Naoga, Rangpur, Dinajpur and Panchagar. The Sal forests originally comprise an area of 120,255 hectares of notified forests under the control of the Bangladesh Forest Department, of which 104,616 hectares (87%) are located in the central region and 15,639 hectares (13%) in the northern region (DoE 2015). Most of the Sal forests are now severely degraded and poorly stocked. The National Forest Resources Assessment 2005-2007 reported that the Sal forests areas of Bangladesh is now only 34,000 hectares (Altrell, et al. 2007).

3.16.2 Land Use Change

There has been much debate concerning land use change, particularly the change with forest cover in Bangladesh. Apart from the Forest Department, the Soil Resource Development Institute (SRDI) and Bangladesh Bureau of Statistics (BBS) serve as the main providers of national data. Data on changes in forest cover are also available from the Global Forest Resource Assessment (GFRA) as well as from other international websites. Recent data on forest cover in Bangladesh collected from all these sources partially or significantly differs from each other. For example, the extent of forest area reported by SRDI 2013 is 1909330 ha or 12.94%; by BBS 2012, 2328650 ha or 15.78%; and by GFRA 2015, 1440,000 ha or 9.76% (Fig. 3.14). The main reason for the discrepancies is associated with the different types of visual interpretation of land satellite images as well as the varying use of landscape indicators. One report may include all types of forest area including nurseries, gardens, etc. while another includes or excludes rivers, lakes, ponds, etc. It is therefore, logical that there should be ground level inventory and assessment of forest resources which will serve as the foundation of annual and long-term monitoring of natural resources.

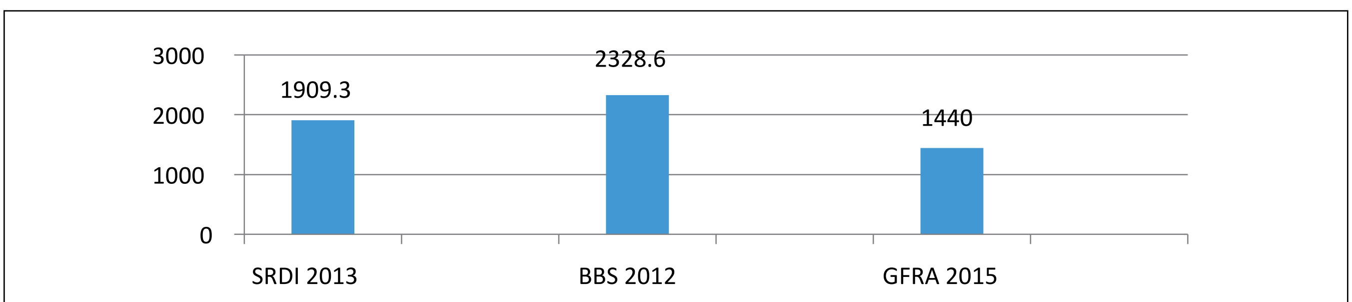


Figure 3.14 Area under Forest Cover (in 000 ha) in Bangladesh

A National Forest Resources Assessment (NFA) was conducted with the technical assistance of FAO and in association with the Forest Department in the period 2005-2006, the first exercise of its kind in Bangladesh (Altrell et al. 2007). NFA is an ongoing process and annual monitoring, re-measurement and re-assessment were supposed to add to the value of the initial assessment, but the work remained uncompleted. Accordingly, it was decided to use the NFA 2005-2006 data as baseline information to conduct the analysis on land use changes and establish the changes in forest cover for the period 2006-2012.

3.16.2.1 Land Use Change through Afforestation

NFA 2005-2006 divided the total area of Bangladesh into five major land use classes (LUC); 56% of the area was classified as cultivated land, 20% as villages, 14% as inland water, 10% as forest and less than 1% as built-up areas. Of the total forest area, 84% or 1204,000 hectares were classified as natural forest and 16% or 238,000 hectares as plantation forest. The assessment reported that both natural hill forests and mangrove forests (551,000 ha and 436,000 ha respectively) cover more than two-thirds of the total forest area of the country. Of this area, only 45,000 ha has been recorded as mangrove plantation forest throughout Bangladesh.

The Forest Department has established 148,025 ha of mangrove plantation forest since 1969 (Ryan 2001, Nandy et al. 2001). It has been proven that mangrove plantations are vulnerable to a variety of anthropogenic threats from livestock, mainly buffalo, grazing, extraction of timber and outright conversion of plantations to other land uses such as agriculture, aquaculture and salt production (UNDP-Bangladesh 2015) and more than 33% of these plantations have been eroded and encroached upon (Ahmad 2012). Some 600 ha of plantation have been lost due to encroachment in the Noakhali Coastal Afforestation Division in recent years. Locally, powerful elites often play a great role in the appropriation of newly accreted lands and degradation and loss of plantation (Ahmad 2011). These are the main reasons why the NFA 2005-2006 findings on the area covered by mangrove plantation forests (45,000 ha – as recorded in the inventory report) do not correspond to the local institution's expectations.

From 2006 to 2012, the Bangladesh Forest Department was engaged in land use change (LUC) with the establishment of 88,336.4 ha afforestation and by 2012, it had enhanced the forest cover up to 992,336.4 ha. In this regard, the FD established 35,758.0 ha of mangrove plantations and 52,578.4 ha of non-mangrove plantations including strip plantations throughout Bangladesh (Table 3.37).

Table 3.37 Land Use Change (LUC) through Afforestation

Sl. No	Year of Plantation	Total Plantation, ha	Mangrove-Non including strip) Plantation, ha	Plantation Mangrove, ha
1	2007 - 2006	10956.0	7029.0	3927.0
2	2008 - 2007	13231.2	9677.2	3554.0
3	2009 - 2008	11484.0	4449.0	7035.0
4	2010 - 2009	11992.6	7213.6	4779.0
5	2011 - 2010	18750.6	13261.6	5489.0
6	**2012 - 2011**	**21922.0**	**10948.0**	**10974.0**

Annual land use changes and changes by different types of afforestation are shown in Figures 3.15 and 3.16 respectively.

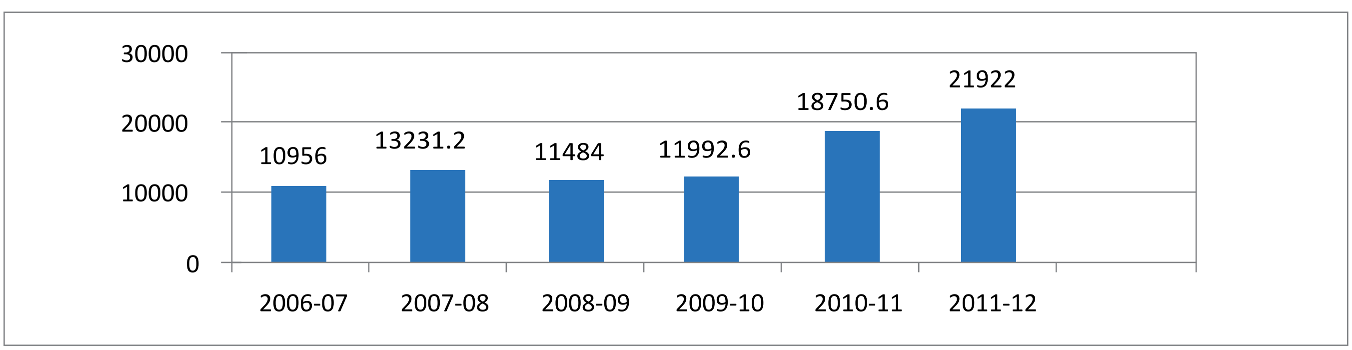


Figure 3.15: Annual Land Use Change (in ha) 2006 – 2012

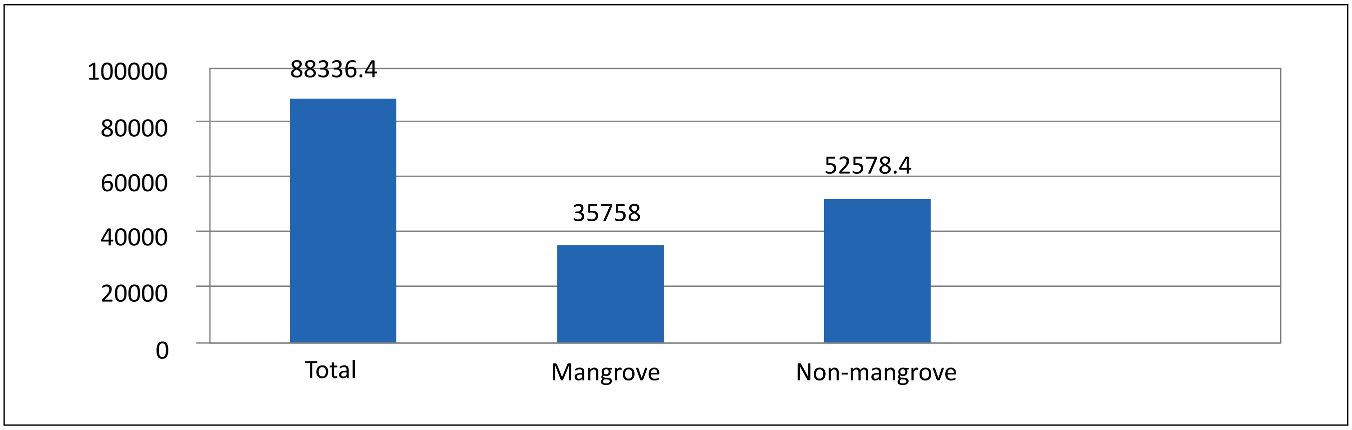


Figure 3.16 Types of Afforestation 2006 -2012 and Total Land Use Changes (in ha)

The National Forest Resources Assessment (NFA 2005-2006) divided the total territory of Bangladesh into five national land use classes (NLUC) as follows: Forest NLUC, Cultivated NLUC, Village NLUC, Built-up (Urban) Area NLUC and Inland Water NLUC (Table 3.38). Based on the ground level inventory, NFA 2005-2006 also sub-divided each NLUC into six groups as follows: no tree cover (Group-1), less than 5% tree cover (Group 2), 5 to 10% tree cover (Group-3), 10 to 30% tree cover (Group 4), 30 to 70% tree cover (Group-5) and more than 70% tree cover (Group 6).

Table 3.38: Tree Cover Area in all National Land Use Classes

Sl No	National LUC	Area under Tree Cover, 000ha						
		Gr.1	Gr.2	Gr.3	Gr.4	Gr.5	Gr.6	Total
		No Tree Cover (TC)	TC <5%	TC 5-10%	TC 10-30%	TC 30-70%	TC 70%	
1	Forest	-	68	30	440	574	330	1442
2	Cultivated Land	5553	1866	460	197	227	25	8328
3	Village	40	752	873	675	491	31	2862
4	Built-up Area	12	72	19	-	-	-	103
5	Inland Water	1910	100	12	-	-	-	2022
Total		**7515**	**2858**	**1394**	**1312**	**1292**	**386**	**14757**

Source: NFA 2005-2006

Of a total land area of 14.76 m ha, almost 7.52 m ha has no tree cover. This means that almost 50% of the total area of Bangladesh has some kind of tree cover (Altrell, et al. 2007). Of this area, 29.3% has low tree cover (Gr.2,3). NFA 2005-2006 defined forest as land spanning more than 0.5 ha with trees reaching more than 5m in height covering more than 10% of the land. Hence, Groups 4, 5 and 6 of Forest NLUC correspond to area under forest cover. Trees on crop land and those growing in agricultural production systems of Cultivated NLUC and not covering over 0.5 ha are not considered forest cover due to the temporary nature of isolated plantation. Village NLUC in Bangladesh serves as the major source and supply of forest production. While most of the homesteads are small, varying in size from 0.002 to 0.435 ha, and do not meet the criteria of forest covered area i.e more than 0.5 ha, larger homesteads with more than 30% tree cover do. Accordingly, groups 5 and 6 of Village NLUC have been considered as forest cover. Both Built-up Area (Urban) NLUC and Inland Water NLUC, with less than 10% tree cover, are not considered forest cover. A ground level inventory on forest area under tree cover, conducted by NFA 2005-2006, established that the total forest area under tree cover in Bangladesh was 1866,000 ha and of this, more than 10% tree cover was recorded in National Forest LUCs and more than 30% in Village NLUCs (Table 3.39).

Table 3.39 Total Area under Forest Cover National Land Use Classes

Land Use Classes and Area as per NFA 2005-2006 (in 000 ha)		Area under Forest Cover as per NFA 2005-2006, ha	Land Use Changes during 2006-2012, ha	Total Area under Forest Cover, ha	Forest Cover per NLUC, %
International LUC	**National LUC**				
Forest 1442	Forest 1442	1344,000	88336.4	1432,336.4	99.33
Other Wooded Land 289	Cultivated Land 8327	-	-	-	-
Other Land 11004	Village Land 2862	522,000	-	522,000	18.24
	Built Up Areas 104	-	-	-	-
Inland Water 2022	Inland Water 2022	-	-	-	-
Total	**14757**	**1866,000**	**88336.4**	**1954,336.4**	**13.24**

*Forest cover with trees attaining over 10% in Forest NLUC and over 30% in Village NLUC

Table 3.40 Loss and Gain Forest Cover

Year	Forest Cover Loss, ha		Forest Cover (FC) Status in 2012, ha		
	Total	Annual	Total FC	FC loss	Existing FC
2005-2010	3400	680	47663.8	2720	44943.8
2010-2012	1320	660	40672.6	1320	39352.6
Total Loss and Gain, in ha			88336.4	4040	84296.4*

* Remaining Total Forest Cover: 1866000+84296.4= 1950,296.4 ha or 13.22%

Based on annual forest cover (FC) loss in Bangladesh, as established by FAO (680 ha/yr 2005-2010 and 660 ha/yr 2010-2012), it was found that a total of 4040 ha of forest cover was lost in the period 2006 to 2012 (Table 3.40). As a result, the remaining total forest cover in Bangladesh in 2012 was 1950,296.4 ha or 13.22% of the total area of Bangladesh (Fig.3.17).

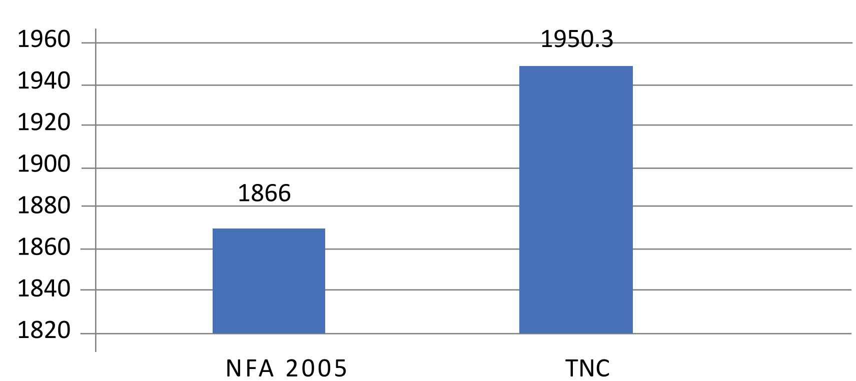


Figure 3.17 : Total Area under Forest Cover (in 000 ha) identified by NFA 2005 and TNC for 2012

3.16.2.2 Total Tree Volume of Total Forest Cover in Bangladesh

As per NFA 2005-2006, the average gross volume of total forest cover in Bangladesh is 14 m3/ ha and the average commercial volume is 10 m3/ha (Altrell, et al. 2007). These figures were used as a basis for the identification of total gross and commercial volume and documented in this report. In this regard, all areas under tree cover from groups 2 -7, as shown in Table 3.38 were incorporated except the areas with no tree cover (Table 3.41 and 3.42).

Table 3.41: Total Tree Volume in Major NLUC

Sl No.	National Land Use Type with area under tree cover, ha	Av. Gross Volume /ha as per NFA 2005-2006, (m3)	Total Gross Volume by 2012 (million m3)	Remarks
1	Forest Land 1526,296.4	48.3	73.72	Other areas having tree cover have been included (excluding areas with no tree cover)
2	Cultivated Land 2775,000	4.3	11.93	
3	Village Land, 2822,000 ha	36.1	101.87	
4	Built-up Area, 91,000	23.3	2.12	
5	Inland Water, 112,000	0.5	0.06	
Total		-	**189.7**	

Table 3.42: Total Commercial Tree Volume in Major NLUC

Sl No.	National Land Use Type with area under tree cover, ha	Av. Commercial Volume /ha as per NFA 2005 -2006, (m3)	Total Commercial Volume by 2012 (million m3)	Remarks
1	Forest Land 1526,296.4	29.7	45.33	Other areas having tree cover have been included (excluding area with no tree cover)
2	Cultivated Land 2775,000	2.9	8.05	
3	Village Land, 2822,000 ha	28.2	79.58	
4	Built-up Area, 91,000	17.2	1.57	
5	Inland Water, 112,000	0.3	0.03	
Total		-	**134.6**	

Thus, the total gross tree volume is 189.7 million m3 and the total commercial tree volume is 134.6 million m3 in 2012.

3.16.2.3 Total Aboveground and Underground Biomass of Total Forest Cover in Bangladesh

The average aboveground biomass density per ha, established by NFA 2005-2006 for major LUC and the total above ground biomass are shown in Table 3.43.

Table 3.43: Aboveground Biomass Density in Major LUC

Sl No.	National Land Use Type with area under tree cover, ha	Av. Biomass Density as per NFA 2005-2006, (ton/ha)	Total Aboveground Biomass by 2012 (million ton)	Remarks
1	Forest Land 1526,296.4	193	294.58	Other areas having tree cover have been included (excluding area with no tree cover)
2	Cultivated Land 2775,000	17	47.18	
3	Village Land, 2822,000 ha	144	406.37	
4	Built-up Area, 91,000	93	8.46	
5	Inland Water, 112,000	2	0.22	
Total		-	**756.81**	

Thus, the total aboveground biomass was 756.81 million tons in Bangladesh in 2012.

It is globally recognized that the aboveground biomass is five to six times heavier than the underground biomass. For most of the plants growing under normal conditions, the ratio is 1:5 to 1:6 (Harris 1992, Perry 1982). Any increase in ratio indicates that the plants are growing in stressed or unfavourable conditions. Considering the favourable growing conditions for all plants in Bangladesh, a ratio of 1:5 was used in calculating the total underground biomass which appears as (756.81/5) or 151.36 million tons.

Thus, the total underground biomass was151.36 million tons and corresponding underground carbon is 75.80 million tons in Bangladesh in 2012.

3.16.2.4 Total Aboveground Carbon Stocks in Bangladesh

The average aboveground carbon per ha, established by NFA 2005-2006 for major LUC and the total aboveground carbon stock are shown in Table 3.44.

Table 3.44: Total Aboveground Biomass Carbon Stock in Major NLUC

Sl No.	National Land Use Type with area under tree cover, ha	Av. Carbon Stock as per NFA 2005-2006, (ton/ha)	Total Aboveground Carbon Stock by 2012 (million tons)	Remarks
1	Forest Land 1526,296.4	96	146.52	Other areas having tree cover have been included (excluding area with no tree cover)
2	Cultivated Land 2775,000	9	24.98	
3	Village Land, 2822,000 ha	72	203.18	
4	Built-up Area, 91,000	46	4.19	
5	Inland Water, 112,000	1	0.11	
Total		-	**378.98**	

Thus, the total aboveground biomass carbon stock was 378.98 million tons in Bangladesh in 2012 and total underground biomass carbon stock in major NLUC was (378.98/5) or 75.80 million tons in 2012.

3.17 Total Underground Carbon Stocks in Bangladesh

For the first time, inventory on underground carbon (C) stocks in soils of Bangladesh was initiated and coordinated by the Bangladesh Agricultural Research Council (BARC) in April 2010. Sub-Projects on Carbon Sequestration in Soils of Bangladesh (CSSB) were conducted by the Soil Science Divisions of Bangladesh Rice Research Institute (BRRI), the Bangladesh Institute of Nuclear Agriculture (BINA) and the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) between 2010 and 2013. To obtain up to date information on the dynamics of underground carbon stock, assessment was made in all Agro Ecological Zones (AEZ) of Bangladesh (Hossain, et al. 2014). In order to accelerate the assessment process, all 30 AEZs were proportionately distributed to these three institutions namely BRRI (AEZ nos. 1 to 10), BINA (AEZ nos. 11 to 20) and BSMRAU (AEZ nos. 21 to 30). Soil samples were collected from all 30 AEZs to quantify existing carbon stock in soils for which GPS readings were taken in each and every location of sample collection. Two upazilas from each AEZ, three mouzas from each upazila, ten sampling spots from each mouza and four samples from each spot considering four soil depths (viz. 0-5, 5-10, 10-15, 20 cm) were used for sample collection. The C stock in soils was calculated by using the following equation (Komatsuzaki and Syuaib, 2009):

C stock (t/ha) = C concentration (%) x bulk density (g /cm3) x soil depth (cm).

3.17.1 Underground Carbon Stock in different Types of Land

Assessment of soil carbon stock was made in all 30 AEZs, each of which comprises four to five types of land viz. High Land (HL), Medium High Land (MHL), Medium Low Land (MLL), Low Land (LL), and Very Low Land (VLL). Distribution of Soil Classes and Land Types is shown in Table 52 (Reza et al. 1992). The Agro Ecological Zones are AEZ 1: Old Himalayan Piedmont Plain; AEZ 2: Active Tista Floodplain; AEZ 3: Tista Meander Floodplain; AEZ 4: Karatoya Bengali Floodplain; AEZ 5: Lower Atrai Basin; AEZ 6: Lower Purnabhaba Floodplain; AEZ 7: Active Brammaputra & Jamuna Floodplain; AEZ 8: Young Brammaputra & Jamuna Floodplain; AEZ 9: Old Brammaputra Floodplain; AEZ 10: Active Ganges Floodplain; AEZ 11: High Ganges River Floodplain; AEZ 12: Low Ganges River Floodplain; AEZ 13: Ganges Tidal Floodplain; AEZ 14: Gopalganj-Khulna Bils; AEZ 15: Arial Bil; AEZ 16: middle Meghna River Floodplain; AEZ 17: Lower Meghna River Floodplain; AEZ 18: Young Meghna Estuarine Floodplain;

AEZ 19: Old Meghna Estuarine Floodplain; AEZ 20: Eastern Surma-Kusiyara Floodplain; AEZ 21: Sylhet basin; AEZ 22: Northern Eastern Piedmond Plains; AEZ 23: Chittagong Coastal Plains; AEZ 24: Saint Martin's Coral Island; AEZ 25: Level Barind Tract; AEZ 26: High Barind Tract; AEZ 27: North-Eastern Barind Tract; AEZ 28: Madhupur Tract; AEZ 29: Northern and Eastern Hills and AEZ 30: Akhaura Terrace.

Table 3.45: Area of Bangladesh Soil Classes and Land Types under 30 AEZs

Sl. no	Soil Class	Area under Land Type (00,ha)						Total Area (00,ha)	
		HL*	MHL	MLL	LL	VLL	H+W	ha	%
1	Loamy Sandy	2261	3164	918	255	-	1463	8061	5.56
2	Loamy Clayey	14472	31575	10233	4459	628	9475	70842	48.89
3	Clayey	5785	4582	1717	2802	1052	1731	17669	12.19
4	Loamy	1594	8014	2657	666	-	6505	19436	13.41
5	Sandy	2.6	5.0	0.2	-	-	0.2	8	0.01
6	Clayey Loamy Organic	68	292	921	629	247	90	2247	1.55
7	Clayey Loamy	293	1168	935.5	1681	3.6	653	4735	3.27
8	Loamy Clayey Sandy	632	1600	484	-	-	1004	3720	2.57
9	Loamy, Loamy Skeletal-Sandy	16899	363	-	-	-	909	18171	12.54
Total (ha)		**42007**	**50763**	**17866**	**10492**	**1931**	**21830**	**144,889**	**-**
Total (%)		**28.99**	**35.04**	**12.33**	**7.25**	**1.33**	**15.07**	**-**	**-**

High Land (HL), Medium High Land (MHL), Medium Low Land (MLL), Low Land (LL), Very Low Land (VLL), Homestead and Water (H+W). Source: BFRI 1992

The Soil Science Division of BRRI, after a thorough assessment in AEZ numbers 1 to 10, concluded that the highest carbon stock was recorded in AEZ 1 irrespective of land types and it was higher in LL than in other types of land. The Soil Science Division of BINA recorded maximum carbon stock in AEZ 14 after analyzing AEZ nos. 11 to 20 and also found that LL & VLL contained a higher amount of organic carbon than other types of land (Hossain et al. 2014). The Soil Science Division of BSMRAU concluded that the overall carbon stock is low in AEZ nos. 21 to 30 and the underground carbon stock was found to be higher in LL and MLL (Rahman et al. 2014). It was established for all types of land that the underground carbon stock decreases with the increase of soil depth irrespective of soil types. Analysis on underground carbon stock in different types of land after compilation of all data generated by BRRI, BINA & BSMRAU showed maximum carbon stock with an average capacity of 29.7 t/ha in VLL followed by LL and MLL (Table 3.46). The corresponding AEZs are Gopalganj-Khulna Bils (AEZ no. 14) followed by Low Ganges River Floodplain (AEZ no. 12), Arial Bill (AEZ no. 15) and Old Meghna Estuarine Floodplain (AEZ no. 19).

Table 3.46: Average Underground Carbon Stock in different Types of Land

AEZ No	Soil carbon stock (t/ha)					C stock per AEZ (ton/ha)
	HL	MHL	MLL	LL	VLL	
AEZ 1	6.46	8.25	14.19	-	-	28.90
AEZ 2	5.51	3.98	-	-	-	9.49
AEZ 3	3.39	6.09	-	6.45	-	15.93
AEZ 4	4.58	4.58	-	4.67	-	13.83
AEZ 5	2.64	3.55	3.60	5.22	-	15.01
AEZ 6	-	-	5.39	5.31	-	10.70

AEZ No	Soil carbon stock (t/ha)					C stock per AEZ (ton/ha)
	HL	MHL	MLL	LL	VLL	
AEZ 7	5.32	5.70	-	7.36	-	18.38
AEZ 8	4.43	5.77	-	8.11	-	18.31
AEZ 9	5.65	6.81	-	11.71	-	24.17
AEZ 10	-	5.03	-	6.41	-	11.44
AEZ 11	6.57	8.59	9.15	11.06	-	35.37
AEZ 12	9.31	12.86	19.66	18.01	33.49	93.33
AEZ 13	8.29	8.76	9.37	-	-	26.42
AEZ 14	17.68	36.26	48.34	64.29	69.61	236.18
AEZ 15	-	-	22.23	34.87	-	57.10
AEZ 16	-	3.55	1.60	5.03	8.30	18.48
AEZ 17	3.93	4.67	5.23	-	-	13.83
AEZ 18	-	5.10	6.63	-	-	11.73
AEZ 19	9.23	11.84	9.28	10.14	7.39	47.88
AEZ 20	5.08	5.22	6.87	8.52	-	25.69
AEZ 21	-	5.80	5.53	5.71	-	17.04
AEZ 22	-	5.79	4.96	7.12	-	17.87
AEZ 23	1.74	2.65	-	-	-	4.39
AEZ 24	2.41	-	-	-	-	2.41
AEZ 25	4.23	4.37	-	-	-	8.60
AEZ 26	2.81	3.14	-	-	-	5.95
AEZ 27	4.13	4.22	5.39	-	-	13.74
AEZ 28	4.11	4.85	6.61	6.56	-	22.13
AEZ 29	4.52	5.61	-	-	-	10.13
AEZ 30	4.11	4.83	-	-	-	8.94
Total (t/ha)	**126.13**	**187.87**	**184.03**	**226.55**	**118.79**	**843.37**
Average (%)	**5.48**	**6.96**	**10.83**	**12.59**	**29.70**	**28.11**

Source: Hussain, et al. BARC 2014

It is also apparent from the analysis that almost 50% of the country is dominated by the Loamy and Clayey Class among all nine soil classes available in Bangladesh. On the other hand, HL and MHL are the most dominating land types in Bangladesh (Table 3.45).

Carbon stock per unit area ranges from 5.48 to 6.96% in these dominating land types while it is five times higher in VLL (29.7 t/ha) and more than double in LL and MLL than that of HL and MHL (Table 3.46).

3.17.2 Underground Carbon Stock in all AEZs

Underground soil carbon is the major determinant for increasing aboveground biomass productivity and a sequester of an enormous amount of atmospheric carbon. It is globally recognized that soils contain three times the amount of carbon that is stored in aboveground vegetation and twice the amount stored in the atmosphere (Batjes 1996). Globally, underground soil organic carbons are estimated to be around 1500 giga tons in one-metre depth (Smith 2007, Ronnie 2016). In spite of the fact that much research has been carried out on the ability of soil to sequester carbon which serves as a powerful driver in reversing climate change, Bangladesh has only just initiated its field level activities. In 2010, BRRI, BINA and BSMRAU initiated comprehensive grassroot level carbon inventory in AEZ 1-10, AEZ 11-20 and AEZ 21-30 respectively and submitted project completion reports to the PMU of BARC. These reports were compiled in a specific format and did not provide a summary of all data from all groups in estimating underground carbon reserves of all ecological zones.

Table 3.47: Total Underground Carbon Stock in all AEZs

AEZ No	Total Area per AEZ (ha)	Av. C Stock per AEZ (ton/ha)	Total C Stock per AEZ (million ton)
AEZ 1	400800	28.90	11.58
AEZ 2	86300	9.49	0.82
AEZ 3	946800	15.93	15.08
AEZ 4	257200	13.83	3.56
AEZ 5	85100	15.01	1.28
AEZ 6	12900	10.70	0.14
AEZ 7	319000	18.38	5.86
AEZ 8	592400	18.31	10.85
AEZ 9	723000	24.17	17.47
AEZ 10	333400	11.44	3.81
AEZ 11	1320500	35.37	46.71
AEZ 12	796800	93.33	74.37
AEZ 13	1706600	26.42	45.09
AEZ 14	224700	236.18	53.07
AEZ 15	14400	57.10	0.82
AEZ 16	155500	18.48	2.87
AEZ 17	90900	13.83	1.26
AEZ 18	926900	11.73	10.87
AEZ 19	774000	47.88	37.06
AEZ 20	462200	25.69	11.87
AEZ 21	457300	17.04	7.79
AEZ 22	403800	17.87	7.22
AEZ 23	372000	4.39	1.63
AEZ 24	800	2.41	0.002
AEZ 25	504900	8.60	4.34
AEZ 26	160000	5.95	0.95
AEZ 27	107900	13.74	1.48
AEZ 28	424400	22.13	9.39
AEZ 29	1817100	10.13	18.41
AEZ 30	11300	8.94	0.10
Total	**144,88,900**	**-**	**407.28**

As has been discussed, the capacity of underground carbon storage differs from one type of land to other. In analysing total underground carbon stock, 30 AEZs were divided into four groups depending on their carbon storage capacity per unit area. AEZs containing > 20 t/ha belong to Group 1, those containing 15 to 20 belong to Group 2, 10 to 15 to Group 3 and less than 10 t/ha to Group 4 (Table 3.48).

Table 3.48: Underground Soil Carbon Stock in all AEZs by group

Group No. (Carbon Storage Capacity, t/ha)	Area under AEZ Group		Underground Carbon Stock per Group,	Remarks
	Total Area, ha	%		
			million ton	
Gr. 1 (>20)	6847,400	46.26	192.48	Total Area (144,88,900) is equivalent to 98.18% of total territory of Bangladesh
Gr.2 (15-20)	2959,900	20.43	83.20	
Gr.3 (10-15)	3546,300	24.48	99.69	
Gr. 4 (<10)	1135,300	7.83	31.91	
Total	**144,88,900**	**100.00**	**407.28**	

It is apparent from table 3.47 and 3.48 that Group 1 comprises 10 AEZs (AEZ nos. 1,9,11,12, 13,14,15,19,20,28) which cover 6847,400 ha or 46.26% of the total area of all AEZs that contribute to the reserve of 192.48 million ton of underground carbon. Similarly, Group 2 comprises 7 AEZs (AEZ nos. 3,5,7,8,16, 21,22) which cover 2959,900 ha or 20.43% of the total area that contribute to the reserve of 83.20 million ton of underground carbon. In Group 3, there are also 7 AEZs (AEZ nos. 4,6,10,17,18,27,29) covering 3546,300 ha or 24.48% of the area contributing to the reserve of 99.69 million ton of underground carbon. The remaining 6 AEZs of Group 4 cover 1135,300 ha or 7.83% of the total area and contribute to the reserve of 31.91million ton of underground carbon. The overall underground carbon stock in soil is 407.28 million tons from 144,88,900 ha of AEZ areas (Table 3.48) which is 98.18% of the total area of Bangladesh.

Thus, the total carbon stock in underground soil and in underground biomass was (407.28+75.80) or 483.08 million tons in 2012.

3.18 Land use Change through Other Programmes

It is also necessary to examine forest cover under other categories of land - Village Forest Land or Homestead Land, Reserved Forest Land, Unclassed State Forest Land, Tea Garden Land.

Homestead or Village Forest Land

There are about 15.4 million homesteads extending over an area of 0.27 million hectares in Bangladesh. Homestead size varies largely from 0.043 to 0.435 hectares (Alam 2008). Though fruit trees are dominant in larger homesteads, forest species are also planted. A study on the diversity of species showed that the number of plant species in the coastal areas was higher (70 species) than that found in the homesteads of Tangail (52 species), Ishurdi (34 species), Jessore (28 species), Patuakhali (20 species), Rajshahi (28 species) and Rangpur (21 species) districts (Islam et al. 2013). Around 76% of farmers preferred to plant fruit tree species for future plantation while 62% preferred timber species in their homesteads (Alam and Masum 2005). Village Forest serves as the major source of a remarkable portion of the national demand of forest produce. There is no complete and detailed current village forest information for the entire country for any particular year or period. First Village Forest Inventory (VFI) was conducted by Hamermaster E.T. in 1981 and divided the whole territory of Bangladesh into six strata not including the Chittagong Hill Tracts. This inventory was based on a sample survey and mainly focused on timber volumes in the strata village areas of Bangladesh.

The last comparative Village Forest Inventory (VFI 1981) was made by the NFA 2005-2006 by using the village map and same stratum of the 1981 VFI and calculated the area and current gross volume for each stratum. Comparison of the gross volume per hectare identified by VFI 1981 with NFA 2005 – 2006 clearly showed that the gross volume had sharply increased in each stratum and ranged from 54 to 333%.

The country observed a gradual shift in its approach to forest management from the traditional custodian role of the Forest Department to that same department taking more of a participatory management approach.

The implementation of the Community Forestry Project with the villagers of seven northern districts of Bangladesh from 1981 to 1987 was a unique example of a paradigm shift in the social forestry programme of Bangladesh. Since the beginning of the Social Forestry Programme in 1981 by the Bangladesh Forest Department, a large number of Social Forestry Nurseries and Training Centres and Social Forestry Plantation Centres has been established. In addition, agroforestry plantation, block plantation and seedling distribution, strip plantation, rehabilitation of jhumias, village afforestation, institutional planting, annual tree fairs and sales of millions of seedlings were carried out throughout the country. Unfortunately, no published database is available due to the lack of a comprehensive national assessment of village forestry programmes in Bangladesh.

There are three main categories of homestead or village forest land:

Reserved Forests (RF): These are lands under the direct control of the FD. The Forest Act is applicable for their protection. According to FD records the total area of Reserved Forests in Bangladesh is 1.2 million hectares (Mha). Though these lands are declared as 'Reserved Forest' they do not always have good tree cover that can be designated as forests. About 0.6 Mha has been classified under section 4 or 6 of the Forest Act and has been under the process of preservation for a long time. For the purpose of field forestry, these lands are treated as reserved forests even if they do not all enjoy complete tree cover.

Un-classed State Forest Land: These are the lands that are under the control of the Ministry of Land, Government of Bangladesh. They are designated as Un-classed State Forests (USF) and/or Khash lands such as newly accreted mud flats, fresh water wetlands such as haor, baor, beel, etc. According to the Year Book of Statistics, the total area of USF in 2001-02 was 0.7 Mha. Almost all of these lands are located in the Chittagong Hill Tracts (CHT) and are thought to be used by the tribal people for 'slash and burn' agriculture. The tree cover on USF is very poor. No reliable estimate of USF tree cover is available.

Tea Garden Land: An area of about 48,300 hectares is under 158 tea gardens in Bangladesh. Roughly about 30,000 hectares of tea garden land were under tree cover in 1971. At present there are 13,330 hectares of degraded natural forest, 2,132 hectares of forest plantation and 7,098 hectares of rubber plantation. Together they provide tree cover of about 22,561 hectares. This data indicates that over three times the area of forest plantations has been put under rubber plantations. Economics is the basic driving force for causing such a shift in favour of rubber plantations.

3.19 Change in forest and other woody biomass stocks in the inventory period

Human interaction with existing forests and planted areas occurs due to the commercial extraction of natural resources like logs and fuel wood and the production and use of wood commodities.

Photo: Forest in Bangladesh

Methodology

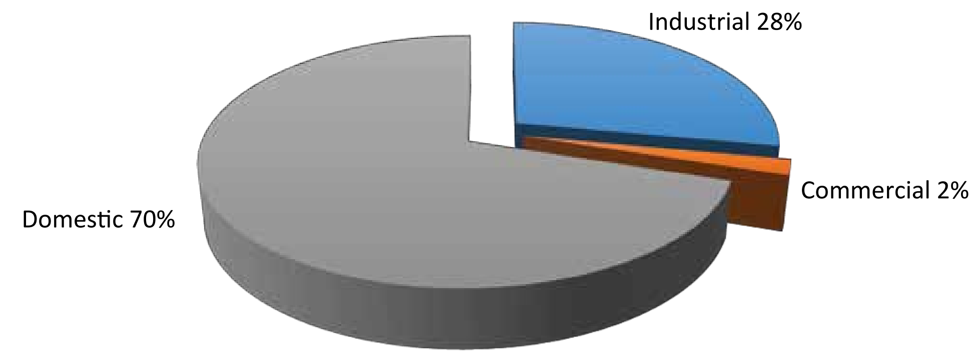
Data collection:
Baseline data for calculating land-use was collected from the Soil Resource Development Institute (SRDI) and the Forest Department.

Data Analysis:
Data was analysed by calculating areas by different land use type. Data was then compared with national data and other secondary resources and available publications such as the National Forest Resource Assessment (NFA, 2005-2007).

Following IPCC 2006 Guidelines, carbon uptake in the afforested/planted areas was calculated and is shown in Table 3.49.

Table 3.49: Annual increase of bio-mass stocks

	Initial Land use	Landuse during reporting year	Area of land converted to forest land (A) (ha)	Average annual above ground bio-mass growth (tonnes dm/(ha*yr)	Ratio of below ground biomass to above ground biomass (ton bg dm/ton ag dm)	Average annual above and below ground biomass growth (G_{total}=Gw*(1+R)	Carbon fraction of dry matter (tonnes carbon /ton ne dm)	Annual increase in biomass stocks due to biomass growth (Removal tonnes CO_2/yr)
Year-2007	Total Plantation	Forestland /settlement forest	10,956	8	0.24	10.96	0.49	2,15,740
Year-2008	Total Plantation		13,231	8	0.24	10.96	0.49	2,60,538
Year-2009	Total Plantation		11,484	8	0.24	10.96	0.49	2,26,137
Year-2010	Total Plantation		11,992	8	0.24	10.96	0.49	2,36,140
Year-2011	Total Plantation		18,750	8	0.24	10.96	0.49	3,69,220
Year-2012	Total Plantation		21,922	8	0.24	10.96	0.49	4,31,676
Total Increase of bio-mass stocks during the period of 2006-2012: **1,739,451 tonnes CO_2**								



3.20 Calculation of CO_2 from LULUCF

Per IPCC 2006 Guidelines and based on the availability of country specific data, the priority areas for GHG emission calculations from LULUCF involves the following activities, which are:

- CO_2 emission due to fuel wood removal
- Forest land conversion to other land-use
- Change in soil carbon

3.20.1 CO_2 emissions from fuel wood removal

Fuel wood extraction from the managed or natural forest and other planted areas contributes to loss of biomass carbon stocks and hence needs to be accounted for in the inventory year. Per IPCC 2006 guidelines, the biomass carbon loss due to fuel wood removal was estimated using FAO statistics and local information with the rational projection up to the year 2012 using IPCC default factors.

Fuel wood is the main forest product (61% of total round wood) in Bangladesh. Annually the country requires about 9.4 million M3 of fuel wood of a supply of about 6.18 million M3. Figure 3.18 shows the proportion of domestic (for example, cooking), industrial (for example, brick burning), and commercial (for example, bakeries and restaurants) use of the total fuel wood consumption in the country.

Figure 3.18. Share in use of fuel wood

The consumption was expected to rise (Figure. 3.19) to 11.9 million M3 by 2015. The fuel wood consumption in Bangladesh has an income and a regional pattern.

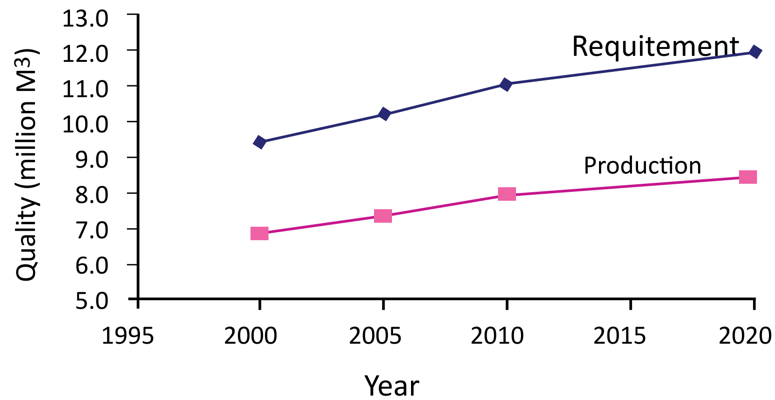


Figure 3.19. Requirement and production of fuel wood

The total fuel wood production was estimated as 6.8 million M3 in 2000 and was expected to have risen to 8.5 million M3 by 2015. This availability has significant regional variations, as a large portion of public forests is located in the eastern region. Other areas, which are densely populated, have to depend, to a great deal, on whatever is locally available, for example agricultural residues and homestead vegetation. Different studies (FMP, 1992) indicate that due to short supply, the use of fuel wood is declining and that of agricultural residues is increasing. The majority of the fuel wood supply comes from the village groves. There exists some ambiguity as to the actual contribution of village groves in fuel wood production. CO_2 emissions due to fuel wood removal are estimated in Table 3.50.

Table 3.50: Annual carbon loss and CO_2 emission due to fuel wood removal

Annual volume of fuelwood removal(m3/ year)	Bio-mass conversion and expansion factor (BCEFr)	Ratio of below ground biomass to above ground biomass (ton bg dm/ton ag dm)	Annual volume of fuelwood removals as tree parts (m3/yr)	Carbon fraction of dry matter (tonnes carbon/tonne dm)	Basic wood density (tonnes/m3)	Annual carbon loss due to fuel wood removal tonnes C/year $Lfw=[FG_{trees}*BCEF_r*(1+R)*FG_{part}*D]*CF$
In 2006 6800000	1.05	0.24	136,0000	0.49	0.40	4604,824
					In Eq. Giga-grams	4605
					In Eq. Giga-grams CO_2 emission	4244
In 2012 7000000	1.05	0.24	160,0000	0.49	0.40	4740,260
					In Eq. Giga-grams	4740
					In Eq. Giga-grams CO_2 emission	4368

Source: [7]

7 For calorific value of fuel wood, FAO Wood Fuels handbook For emission, http://www.volker-quaschning.de/datserv/CO2-spez/index_e.php

3.20.2 Forest and grassland conversion to other land use

Due to strict forest regulation to protect natural resources and improve forest management practice, forest land conversion to other type of land usages like croplands or settlements has been reduced significantly in the last ten years. This helps forests to gain a significant amount of biomass resources rather than losing forest coverage and experiencing degradation. During the inventory period and according to forest department information, only a small chunk of forest land was transferred to some institutions. Table 3.51 shows the total amount of forest land already transferred and using this information, CO_2 emission from such loss of forest land is estimated in Table 3.52.

Table 3.51. Major land transfers since 1971

Year	Area in hectares	Remarks
Since 1971 to 2007	17448	Most of these were used for establishing rubber plantations.
1978	7	
1982	741	
1986	65	
1988	2	
2007	1587	Under the process of transfer

Source: FD, Government of Bangladesh

Table 3.52: CO_2 emission due to Land use change

Initial Landuse	Land use during reporting year	Area of land converted to settlements (ΔA) (ha)	Bio-mass stocks before the conversion (tonnes dm/ha) (Bb)	Carbon fraction of dry matter (tonnes carbon/tonne dm) (CF)	Annual biomass carbon growth (tonnes carbon/year) ΔCG	Annual change in carbon stocks in biomass (tonnes carbon/yr ΔCb= ΔCg+(0-Bb)*ΔA*CF
Forestland/ Settlement	Settlement/ New settlement	1587	193	0.49	10.96	(153146)
					In Eq. Giga-grams	153.146
					In Eq. CO_2 emission in Gg	561.53

3.20.3 Soil Carbon

Soils are the largest carbon reservoirs of the terrestrial carbon cycle. About three times more carbon is contained in soils than in the world's vegetation. Soils are able to hold double the amount of carbon than vegetation.

Methodology:

Data collection:

Due to the unavailability of data in the absence of any recent survey to assess the present level of carbon stock in the soil, the base data for calculating soil carbon was collected from two sources. One source was the Reconnaissance Soil Survey under the Soil Survey Project of Pakistan which was carried out from 1965 to 1975. Another was the Soil Series of Thana surveyed by SRDI from 1990-2000. The carbon stock change was assessed from the level of carbon stock assessed in SNC and based on rational approximations in the period from 2006 to 2012.

Data Analysis:

In Reconnaissance Soil Survey, percentages of soil carbon are given in different locations of the districts. In the soil series, a percentage of organic matter is given for different series. It is known that soil C = SOM/1.72. For the calculation, the mean value of carbon is taken for each district. One hectare of forest land contains 4200 tons of soils considering 30 cm depth (soil bulk density is 1.4 gm). The quantity of carbon is measured by using the value of the area and percentage of carbon for each district.

Calculation:

Carbon uptake/release is calculated following IPCC 2006 Guidelines. (Table 3.53) Soil carbon change is based on the assessment from the carbon stock level assessed in the previous inventory.

Table 3.53. Soil carbon calculation

District name	Area(ha)	Percentage of Carbon in 1970 (%)	Total weight of carbon in 1970 (ton) C % x 4200)	Percentage of Carbon in 2000 (%)	Total weight of carbon in 1970 (ton) C % x 4200)	Net changes in siol c per 30 yrs	Net changes in soil c per year (ton)
Cox's Bazar	249186	0.873	9135585.94	0.400	4185185.52	-4950400.42	-165013.35
barisal-patuakhali-bhola-Jhalokathi-barguna	1121431	0.947	44589485.38	0.909	42819245.52	-1770239.86	-59008.00
Sumanganj & Habiganj	263658	2.709	29998439.13	2.647	29312661.87	-685777.25	-22859.24
Jamalpur & Sherpur	339,574.00	0.808	11516652.21	1.080	15403328.73	3886676.52	129555.88
Kushtia maherpur chuadanga	349465	0.812	11919933.45	0.890	13056267.37	1136333.91	37877.80
Rongpur Nilphamari	394,869.00	0.720	11943277.46	0.613	10172547.9	-1770729.56	-59024.32
Brahmonbaria	192711	1.798	14556127.56	1.013	8195833.094	-6360294.46	-212009.82
Thakurgaon	180952	2.051	15587372.31	0.495	3758524.527	-11828847.79	-394294.93
Bogra	291990	0.739	9065851.52	0.882	10817202.79	1751351.27	58378.38
Chittagong	528298	0.903	20045175.06	1.371	30411908.57	10366733.51	345557.78
Sylhet- Moulvibazar	628979	1.858	49071882.25	1.470	38835000.56	-10236881.68	-341229.39
Jessore	257,820	3.886	42080521.00	1.566	16954213.45	-25126307.55	-837543.58
Khulna- bagerhat	835357	2.499	87680589.55	1.503	52732745.98	-34947843.57	-1164928.12
Tangail	342439	0.874	12572647.89	0.572	8227188.985	-4345458.90	-144848.63
CHT	904135	0.794	30141888.24	1.578	59924473.61	**29782585.37**	**992752.85**
Rajshahi	240701	0.830	8389743.95	0.837	8460490.876	**70746.93**	**2358.23**
Gopalganj, Madaripur	263392	4.192	46376975.44	2.659	29413538.98	-16963436.45	-565447.88
Total	**7384957**						**2399726.33**

The total measured soil carbon emissions in 32 districts in each year (1970-2000) was 239.7 Gg. The total area of these 32 districts is 7384957 ha. Assuming that carbon emissions are approximately proportional to the area because of the more or less similar conditions of the soils, the total carbon emissions of the country in 2000 were 2399.7 x 14757000 /7384957 = 4795.2 Gg. Given 30 years of aggregated emissions due to stock changes in the soil carbon as was reported in the 2005 inventory and if we approximate it in the period 2006 to 2012, the net changes are: 3795.2*(7/30)=885.54 Gg

Total CO_2 emissions from soil carbon at 2012 = 885.54 x 44/12 = 3247 Gg.

Total CO_2 emissions in 2006-2012 from LULUCF sector is given below:

Table 3.54. Total CO_2 emissions from LULUCF sector 2006-2012

Type	Uptake Giga grams CO_2	Emission in Giga grams CO_2
Annual increase in biomass stocks due to biomass growth in Forest (Restoration)	(1740)	
**Emission due to deforestation		562
CO_2 due to countrywide fuel wood extraction		4368
CO_2 emission from soil carbon (from all types of land -use)		3247
Total emission from: LULUCF		8177
Total Removal	**(1178)**	

** TNC considers emissions from deforestation only due to a chunk of forest land (per Table 3.51) being allocated to some institutions. Apart from that and due to the unavailability of spatial information on the deforestation/ degradation of forest sector at the time of inventory, the GHG estimations from these categories were not considered.

3.21. Conclusion

The LULUCF part of this Third National Communication, based on the most recent ground level inventory of the National Forest Resources (NFA 2005-2007) as well as on the latest field level Assessment of Carbon Sequestration in Soils of Bangladesh (2010-2013) has made the following conclusions:

Total forest cover is 1950,296.4 ha in 2012;

Land use changes in the period 2006–2012 through afforestation is 88,336.4 ha of which 35,758 ha are mangrove and 52,578.4 ha are non-mangrove plantation including strip plantation;

Total forest cover as a percentage is 13.22 % in 2012;

Total Gross Tree Volume is 189.7 million m3;

Total Commercial Tree Volume is 134.6 million m3;

Total aboveground biomass is 756.81 million tons in 2012;

Total underground biomass is 151.36 million tons and corresponding underground carbon is 75.80 million tons in 2012;

Total aboveground carbon stock is 378.98 million tons in 2012;

Total underground carbon stock in soil is 407.28 million tons in 2012.

Total carbon stock in underground soil and underground biomass is (407.28+75.80) or 483.08 million tons in 2012.

Total aboveground and underground carbon stock in Bangladesh is (378.98+483.08) or 862.06 million tons in 2012.

3.22 GHG Emissions from Waste Sector

3.22.1 Methane (CH_4) emission from municipal solid waste (MSW) disposal

In the context of Bangladesh, as all landfill sites are unmanaged and function as open dumps, these sites can be optimal for landfill gas emission. Every day huge amounts of municipal solid waste are dumped, producing significants amount of CH_4 for emission into the atmosphere. A significant amount of waste products remain scattered and because of aerobic conditions, the scattered waste produces little or no methane.

Methodology

The Methodology is based on IPCC 2006 guidelines.

Only CH_4 emissions are estimated. The key data inputs are as follows; note where default data are available:

Amount of annual waste generated or disposed (historical and current)

Waste composition (Country Specific data is used, Waste Database 2014)

Environmental variables (climate zones of dry temperate, wet temperate, dry tropical, or moist and wet tropical)

Age and type of landfill operations (unmanaged shallow, unmanaged deep, managed landfill)

Default values for the following inputs are available and typically used when estimating CH_4 generation: Degradable organic carbon (DOC), methane correction factor (MCF), fraction of DOC dissimilated (DOCf), methane generation rate constant (k), and the fraction of methane in the landfill gas (F).

For more information, please refer to Volume 5: Waste of the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html. The specific chapters that focus on estimating GHG emissions from solid waste disposal and wastewater treatment and discharge are included below.

Solid Waste – see Volume 5: Waste, Chapters 2 and 3

Wastewater Treatment and Discharge – see Volume 5: Waste, Chapter 6

Urbanization

According to the Population and Housing Census 2011, a total of 35,094 684 (adjusted) persons live in urban areas, equal to 23.43% of the total population. Urbanization has been taking place in Bangladesh in three main ways:
i) Area Expansion;
ii) Rural-Urban Migration; and
iii) Population Growth.

The proportion of Bangladesh's urban population reached 23.43% (adjusted) in 2011 from 2.43% in 1901. The proportion (Table 3.61) was almost similar during the period 1901-1921 after which it started increasing and the rate of increase was relatively high in the periods 1961-1974 (137.6%), 1974-1981 (115.8%) and 1981-1991 (65.9%). Though the urban population has shown a substantial increase in the last three decades, Bangladesh continues to be predominantly a rural country with about 76.57% of its population living in villages (Table 3.60)

At present the urban area of the country includes 12 city corporations, 304 pourashva / municipalities and 189 upzilla headquarters.

City Corporations

There are 12 city corporations in Bangladesh. Division-wise lists of the city corporations in Bangladesh as well as their major solid waste disposal facilities (Table 3.55) under those city corporations are given below.

Table 3.55: Division wise City Corporations

Division	Name of City Corporation
Dhaka Division	Dhaka North City Corporation (DNCC) Dhaka South City Corporation (DSCC) Gazipur City Corporation (GCC) Narayanganj City Corporation (NCC)
Chittagong Division	Chittagong City Corporation (CCC) Comilla City Corporation (COCC)
Barisal Division	Barisal City Corporation (BCC)
Khulna Division	Khulna City Corporation (KCC)
Rajshahi Division	Rajshahi City Corporation (RCC)
Rangpur Division	Rangpur City Corporation (RACC)
Sylhet Division	Sylhet City Corporation (SCC)
Mymensingh Division	Mymensingh City Corporation

Table 3.56: Population of City Corporation areas in Bangladesh 2006-2012[8]

	Dhaka	Chittagong	Khulna	Rajshahi	Sylhet	Barisal	Rangpur	Narayan Ganj	Comilla	Mymensingh	Gazipur
2006	6,148,706	2,302,945	716,920	419,284	371,517	260,544	274,182	263,862	343,070	308,561	167,931
2007	6,312,985	2,358,836	706,204	425,378	393,181	274,091	280,756	268,355	356,036	324,832	176,957
2008	6,477,265	2,414,727	695,489	431,473	414,845	287,638	287,330	272,849	369,002	341,104	185,983
2009	6,641,545	2,470,619	684,773	437,567	436,509	301,184	293,904	277,343	381,968	357,375	195,009
2010	6,805,825	2,526,510	674,058	443,662	458,173	314,731	300,479	281,836	394,935	373,647	204,035
2011	6,970,105	2,582,401	663,342	449,756	479,837	328,278	307,053	286,330	407,901	389,918	213,061
2012	7,138,350	2,639,529	673,887	455,934	502,525	342,408	313,771	290,895	421,293	406,898	222,486

Table 3.57: Total Urban Population in Bangladesh 2006-2012[9]

Year	Total Urban Population
2006	33,086,318
2007	33,487,991
2008	33,889,664
2009	34,291,338
2010	34,693,011
2011	35,094,684
2012	35,496,357

Table 3.58: Solid Waste Disposal Facilities at the Major City Corporations in Bangladesh

City Corporation	Base Year	Facility description	Management Practice Category	Management Practice
DNCC	2007	Amin bazar dumpsite 52.88 acres 3 million m3 area 10 m depth uniform	Unmanaged – deep (>5 m waste) and /or high water table	Leachate drainage exists but not functioning Compacting and dressing practice exists Hazardous waste prohibited No liquid waste disposed No industrial waste deposited No sludge waste deposited
DSCC	**1993**	Matuail Sanitary landfill 100 acres Capacity of waste volume 6.5 million cubic metres Depth of the landfill waste about 15-23 metres	**1993-2006** Unmanaged – deep (>5 m waste) and /or high water table **2007 onwards** Managed – semi-aerobic	Weigh bridge operation, adequate compaction of waste Periodical soil covering, leachate treatment and other necessary facilities established. Hazardous waste is not disposed in the landfill No liquid waste disposed No industrial waste deposited No sludge waste deposited
Chittagong	**1965** **2010**	Halishahar Sanitary landfill site is 50 years old Total land area is 15 acres the height is around 30 feet minimum to 70 feet maximum Arifin Nagar landfill site has been active since 2010 Total land area is 19.5 acres Dump height is around 30 feet minimum to 50 feet maximum	Unmanaged – deep (>5 m waste) and /or high water table	Hazardous waste is not disposed in the landfill No liquid waste disposed No industrial waste deposited No sludge waste deposited

8 Population and Housing Census 2011

9 Population and Housing Census 2011 (Interpolation based on 2001 and 2011 population data)

City Corporation	Base Year	Facility description	Management Practice Category	Management Practice
Khulna	**2007**		Unmanaged – deep (>5 m waste) and /or high water table	Hazardous waste is not disposed in the landfill No liquid waste disposed No industrial waste deposited No sludge waste deposited
Rajshahi		Nawdapara' dump site 3.5 feet (1.07 m) deep with an area of 15.98 acres 280 metric tons/day waste is collected and disposed of in the waste disposal area	Unmanaged – deep (>5 m waste) and /or high water table	Hazardous waste is not disposed in the landfill No liquid waste disposed No industrial waste deposited No sludge waste deposited
Barisal		Puran Para landfill near Kawnia (Moyla Khula). Total landfill area is 22,300 square metres The area and height of dumping municipal solid waste is 22,296.73 square metres and 4.27 metres respectively	Unmanaged – deep (>5 m waste) and /or high water table	Hazardous waste is not disposed in the landfill No liquid waste disposed No industrial waste deposited No sludge waste deposited

Waste Generation [10]

The total amount of waste generated every day in Bangladesh has been increasing annually since 1991. Whereas in 1991 the urban areas of Bangladesh were generating approximately 6,493 tons per day of municipal solid waste, by 2005 that figure had more than doubled to reach 13,330 tons per day. In 2014, it is estimated that Bangladesh generated 23,688 tons per day in its urban areas. At the same time, due to rapid urbanization, the total urban population of Bangladesh has been increasing, from 20.8 million in 1991 to 32.76 million in 2005 to 41.94 million in 2014. It is estimated that the total urban population will be as high as 78.44 million by 2025, and the total waste generation is expected to reach 47,000 tons per day. There is an obvious link between a larger urban population and greater amounts of waste generated. Interestingly, since 2005, the rate of change of total waste generated daily has exceeded the rate of change of the population growth, due to an increased average daily per capita waste generation rate.

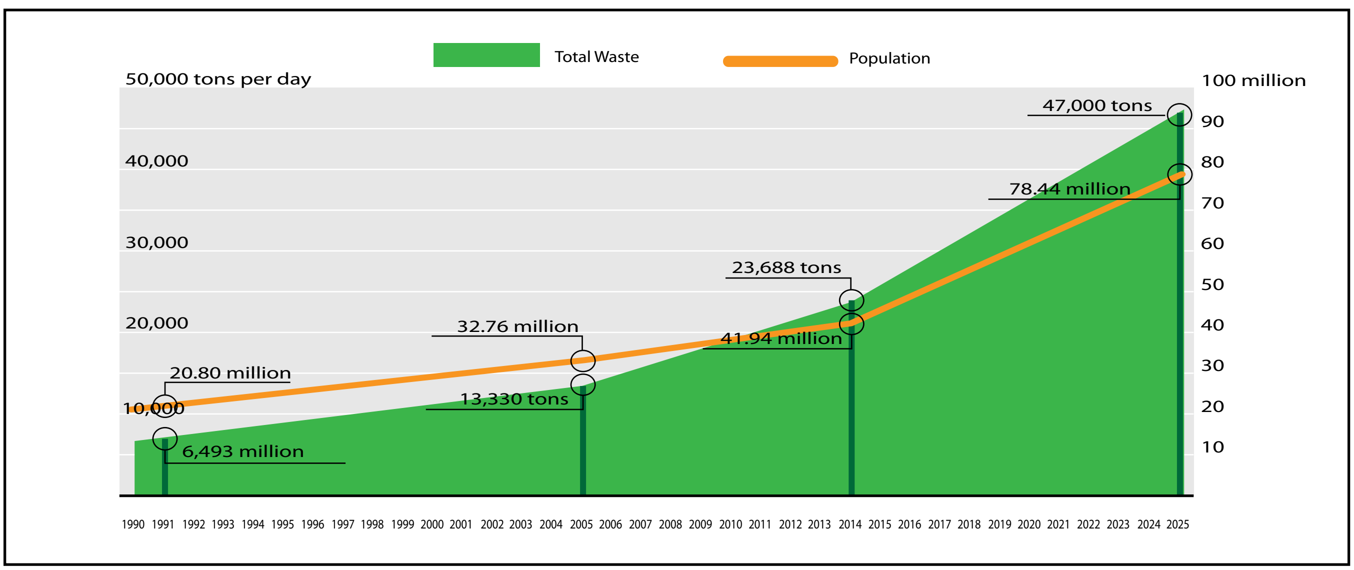


Figure 3.20: Total Waste Generation vs. Urban Population[11]

10 Bangladesh Waste Database 2014, Wasteconcern.org

11 Ibid, Page 7

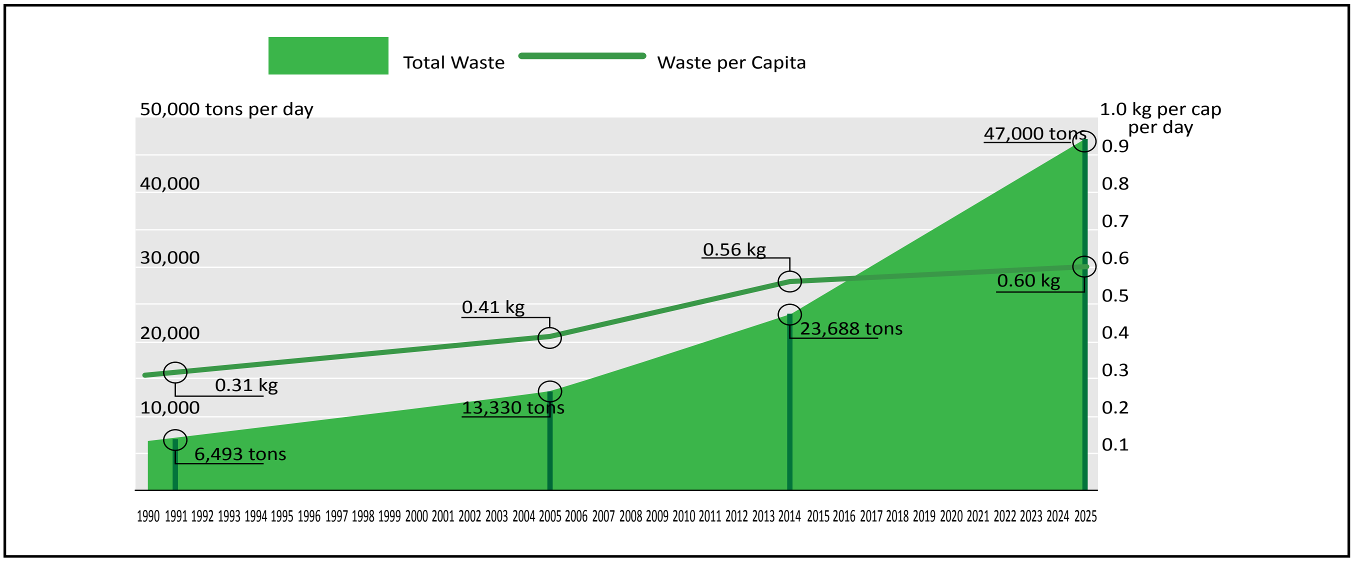


Figure 3.21: Total Waste Generation vs. Per Capita Waste Generation Rate

GHG Emission from MSW disposal:

In order to calculate GHG emission from MSW disposal, the latest version of the IPCC Waste Model was used. The waste composition method was applied instead of the bulk waste method. Key inputs were considered as follows:

Annual MSW disposal amounts

One of the key inputs to the model is the total amount of solid waste disposal per year. The model requires the input of data from 1950. From 1950 to 2005 the total solid waste disposal was calculated by multiplying the total population, per capita waste generation, disposal rate and urban population rate. The total population was taken from the source mentioned in Footnote 8. Per capita waste generation was considered as 0.2 kg/person/day for the period 1950-1990; 0.31kg/person/day for the period of 1990-2005; and 0.41 kg/person/day for the period of 2006-2012 [Waste Concern Database 2014]. The disposal rate was considered as 74% [IPCC default] and the urbanization rate was considered as 30% [UN data].

For the period 2006-2012, city corporation waste disposal data was collected and used to calculate the GHG inventory. The data gap was addressed using the IPCC GL 2006; Vol 1, Chapter 5 Time Series Consistency.

For municipal populations the amount of MSW disposal was calculated by multiplying the municipal population, per capita waste generation and disposal rate.

Methane Correction Factor

The city corporation MSW disposal sites are mostly unmanaged – deep (>5 m waste) with the exception of the Dhaka South City Corporation disposal site which has been managed as a semi-aerobic site since 2007 (Table 3.59). While DSCC data was available from 2012, for 2007-2011 combined data for DSCC and DNCC was interpolated from available data to address the data gap. Hence the managed semi aerobic category is included in 2012 only. The remaining municipality disposal sites are considered unmanaged shallow.

Table 3.59: Distribution of waste by waste management type

Year	Total MSW Disposal in MT	City Corporation Unmanaged – deep (>5 m waste)		City Corporation Managed Semi aerobic (DSCC)		Municipalities Unmanaged – Shallow
2006	3,476,711	978,633	28.15%			71.85%
2007	3,489,263	1,007,366	28.87%			71.13%
2008	3,530,378	1,034,298	29.30%			70.70%
2009	3,571,492	1,061,231	29.71%			70.29%
2010	3,612,607	1,088,163	30.12%			69.88%
2011	3,698,803	1,191,886	32.22%			67.78%
2012	3,749,428	798,134	21.29%	433,912	11.57%	67.14%

Table 3.60: Methane correction factor

	MSW					
	Un-managed, shallow	Un-managed, deep	Managed	Managed, semi-aerobic	Uncategorized	Distribution Check
	MCF	MCF	MCF	MCF	MCF	
IPCC default	0.4	0.8	1	0.5	0.6	
Country-specific value	0.4	0.8	1	0.5	0.6	

Average Composition of Waste:[12]

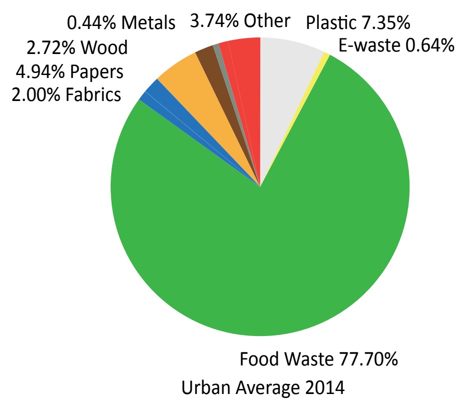


Figure 3.22: Average composition of waste in the landfill site

The average composition of waste in landfill is as follows: food waste: 77.70%; textiles: 2.56%; paper waste: 4.94%; wood waste: 2.72%; and plastic and other materials: 12%. Based on the above data input methane emission from solid waste disposal in Bangladesh have been calculated as below:

Table 3.61: Methane Emission from Solid Waste Disposal in Bangladesh

Year	Methane Emission in Gg
2006	80
2007	84
2008	87
2009	90
2010	92
2011	95
2012	97

3.22.2 Methane emission from domestic waste water

Methodology

For CH_4 emissions – The key data needs are listed below, and those to be collected are highlighted in yellow. For all variables with IPCC default values available, the IPCC guidance states that country-specific values may be used

12 Bangladesh Waste Database 2014, Wasteconcern.org , Page 11

if available. The use of all IPCC default values represents an IPCC Tier 1 emission estimation method; the use of some country-specific values instead of default values represents an IPCC Tier 2 method.

IPCC Variable	Description	Default Value(s) Available
U	Fraction of population located in rural, urban-low, and urban-high income groups	Yes[1]
T	Fraction of population using specific wastewater treatment/discharge pathway or system for each income group and inventory year	Yes[1]
B_0	Maximum CH_4 producing capacity in kg CH_4/kg BOD	Yes
MCF	Methane correction factor (fraction) for each treatment/discharge pathway or system	Yes
P	Country population for each inventory year	No
BOD	Country per capita BOD for each inventory year in g/person/day	Yes[2]
I	Correction factor for additional industrial BOD discharged into sewers	Yes
S	Organic component removed as sludge for each inventory year in kg BOD/year	Yes[3]
R	Amount of CH_4 flared or recovered for energy use for each inventory year in kg CH_4/year	Yes[3]

1 *Default values available for many countries.*
2 *Default values available for many countries/regions; data for a neighboring country may be selected.*
3 *Default is 0, value only required if data are available.*

CH_4 emissions from domestic wastewater:

Total CH_4 emissions from domestic waste water stand at 695 Gg in 2006 and 764 Gg in 2012.

Table 3.62: Methane Emission from Domestic Wastewater in Bangladesh

Year	Population	(kg CH_4/yr)	Gg CH_4/Yr
2006	146,517,110	694,560,551	695
2007	148,893,738	705,826,894	706
2008	151,289,991	717,186,269	717
2009	153,700,334	728,612,437	729
2010	156,118,464	740,075,520	740
2011	158,570,535	751,699,498	752
2012	161,083,804	763,613,585	764

3.22.3 Nitrous Oxide (N_2O) Emissions from Domestic Waste Water

Methodology:

For Nitrous Oxide (N_2O) emissions – The key data needs are listed below, and those to be collected are highlighted in yellow. For all variables with IPCC default values available, the IPCC guidance states that country-specific values may be used if available. The use of all IPCC default values represents an IPCC Tier 1 emission estimation method; the use of some country-specific values instead of default values represents an IPCC Tier 2 method.

IPCC Variable	Description	Default Value(s) Available
P	Country population for each inventory year	No
Protein	Annual per capita protein consumption for each inventory year in kg/person/year;	No[1] (data available from FAO)
F_{NPR}	Fraction of nitrogen in protein in kg N/kg protein	Yes
$F_{NON-CON}$	Factor for non-consumed protein added to wastewater	Yes
$F_{IND-CON}$	Factor for industrial and commercial co-discharged protein into the sewer system	Yes
N_{SLUDGE}	Nitrogen removed with sludge for each inventory year in kg N/year	Yes[2]
T_{PLANT}	Degree of utilization of centralized wastewater treatment plants in percent (optional)	No
$F_{IND-COM}$	Fraction of industrial and commercial co-discharged protein	Yes

1 *Data available from FAO.*
2 *Default is 0, value only required if data are available.*

N2O Emissions from Domestic wastewater:

Table 3.63: Nitrous Oxide Emission from Domestic Wastewater in Bangladesh

Years	Total Population	Total nitrogen in effluent (NEFFLUENT) kg N/year)	Total N_2O emissions (kg N_2O/year)	Total N_2O emissions (Gg N_2O/year)
2006	146,517,110	647,092,816	5,084,301	5.0843
2007	148,893,738	657,589,194	5,166,772	5.1668
2008	151,289,991	668,172,245	5,249,925	5.2499
2009	153,700,334	678,817,525	5,333,566	5.3336
2010	156,118,464	689,497,196	5,417,478	5.4175
2011	158,570,535	700,326,768	5,502,567	5.5026
2012	161,083,804	711,426,620	5,589,781	5.5898

3.22.4 Methane Emission from Industrial Waste Water in Bangladesh

Methodology:

Only CH_4 emissions are estimated. The key data needs are listed below, and those to be collected are highlighted in yellow. For all variables with IPCC default values available, the IPCC guidance states that country-specific values may be used if available. The use of all IPCC default values represents an IPCC Tier 1 emission estimation method; the use of some country-specific values instead of default values represents an IPCC Tier 2 method.

IPCC Variable	Description	Default Value(s) Available
I	Primary industries that produce CH_4 in the country (e.g. pulp and paper industries, meat/poultry processing, alcohol/beer/starch production, organic chemical production)	No
J	Wastewater treatment/discharge pathways or systems used for industrial wastewater in the country	No
P	Total industrial product for each industry and inventory year in tons/year	No
W	Total amount of wastewater generated for each industry and inventory year in cubic meters/ton of product	Yes[1]
COD	Industrial degradable organic component in the wastewater for each industry and inventory year in kg COD/cubic meter	Yes[1]
S	Organic component removed as sludge for each industry and inventory year in kg COD/year	Yes[2]
B_0	Maximum CH_4 producing capacity for each industry, inventory year and treatment/discharge pathway or system if available in kg CH_4/kg BOD	Yes
MCF	Methane correction factor fraction for each industry, inventory year and treatment/discharge pathway or system if available	Yes
R	Amount of CH_4 recovered for each industry and inventory year in kg CH_4/year	Yes[2]

1 D*efault values available for many industry types.*
2 *Default is 0,* value only required if data are available.

For more information, please refer to Volume 5: Waste of the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html. The specific chapters that focus on estimating GHG emissions from solid waste disposal and wastewater treatment and discharge are included below.

Wastewater Treatment and Discharge – see Volume 5: Waste, Chapter 6

Methane Emissions from Industrial Wastewater:

Production data from key industries related to methane emissions from industrial wastewater are as follows. (Data in red is assumed data calculated based on IPCC GL 2006; Vol 1, Chapter 5 Time Series Consistency.)

Annual Production	2006	2007	2008	2009	2010	2011	2012
Pulp and Paper manufacture[13],	75,000	280,000	350,000	440,000	550,000	575,000	600,000[14]
Meat processing (slaughterhouses)[15]	226,000	206,000	208,000	216,800	252,800	255,800	466,400
Alcohol, production MT[16]	33	33	33	35	38	378	421
Starch production[17]	6,000	6,500	6,800	7,200	9,000	10,800	14,400
Food processing (dairy products[18], etc.)	2,270,000	2,280,000	2,650,000	2,290,000	2,370,000	2,950,000	3,460,000
Vegetable oil[19]	124,078	125,668	127,278	128,909	145,179	137,048	198,193

Table 3.64: Methane Emissions (in Gg) from Industrial wastewater in Bangladesh (for selected industries)

Selected Industries/Methane emission	2006	2007	2008	2009	2010	2011	2012
Pulp and Paper manufacture	2.73	10.21	12.76	16.04	20.05	20.96	21.87
Meat processing (slaughterhouses)	0.30	0.27	0.28	0.29	0.34	0.34	0.62
Alcohol, production MT	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Starch production	0.03	0.03	0.03	0.03	0.04	0.05	0.06
Food processing (dairy products, etc.)	1.07	1.08	1.25	1.08	1.12	1.39	1.63
Vegetable oil	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total	**4.14**	**11.60**	**14.33**	**17.45**	**21.55**	**22.76**	**24.21**

3.22.5 Conclusion

The above results can be summarized as follows:

Table 3.65: Summarized Results

Year	CH_4 Emissions from Solid waste disposal (Gg)	CH_4 Emission from Domestic wastewater	N_2O Emission from Domestic wastewater (Gg)	CH_4 Emission from Industrial wastewater
2006	80	695	5.08	4.14
2007	84	706	5.16	11.60
2008	87	717	5.24	14.33
2009	90	729	5.33	17.45
2010	92	740	5.41	21.55
2011	95	752	5.50	22.76
2012	97	764	5.58	24.31

[13] FY 2006 - FY 2010 Production Data source: www.paper onweb.com/Articles/Snapshot_ Bangladesh _2013_WireFabric.pdf

[14] Paper Sector in Bangladesh: Challenges and Scope of Development; Journal of Chemical Engineering, IEB Vol. ChE. 26, No. 1, December 2011

[15] Table 4.63, Statistical Year Book of Bangladesh 2011, Table 4.65 Statistical Year Book of Bangladesh 2012. Assuming only 20% meat is processed at slaughterhouses,

[16] Expert Opinion f rom Industry Experts

[17] Expert Opinion from Industry Experts

[18] Table 4.63, Statistical Year Book of Bangladesh 2011; Table 4.65 Statistical Year Book of Bangladesh 2012

[19] Statistical Year Book, 2011, 2012; mustard oil and vegetable oil combined

Table 3.66: Summary of Bangladesh GHG emissions in 2012

Inventory Year: 2012			
	Emissions (Gg)		
Greenhouse gas source and sink categories	**CO_2 Emissions (Gg)**	**CH_4 Emission**	**N_2O Emission**
Total National Emissions and Removals			
1 - Energy	69867.27	93.18	3.69
1. - Fuel Combustion Activities	69867.27	93.18	3.69
A- Electricity Generation	29130.01	0.57	0.08
B- Manufacturing Industries and Construction	20018.41	1.35	0.20
C-Transport	8441.99	89.87	3.35
D- Other Sectors	12276.85	1.40	0.06
2 - Industrial Processes and Product Use	1121.13		
A - Mineral Industry	674.61		
B - Cement production	674.61		
C - Chemical Industry	446.51		
D - Ammonia Production	446.51		
3 – A - Agriculture			
A - Enteric Fermentation		536.86	
B - Manure Management		123.04	17.14
C- Rice Cultivation		603.55	
D -Direct Nitrous Oxide (N_2O) from Fertilizer application			17.62
E - Indirect Nitrous Oxide (N_2O) emissions from N based fertilizer			5.73
F -Total Indirect N_2O Emissions – Volatilization			5.79
G -Total Indirect N_2O Emissions - Leaching/Runoff			1.67
3.B - Land-use Change and Forestry			
A - CO_2 emission from soil	3247		
B - Conversion of forest land to other land use	561.53		
C - CO_2 emission due to fuel wood removal for Consumption	4,368		
4 - Waste			
A - Solid Waste Disposal		97	
B - Methane emission from domestic waste water		764	
C - Nitrous Oxide mission from domestic wastewater			5.59
D - Methane emission from industrial waste water		24.31	
Memo Items (5)			
International Bunkers	601.05	0.006	0.017
A - International Aviation (International Bunkers)	577.68	0.004	0.017
B - International Water-borne Navigation (International bunkers)	23.37	0.002	0.001
Memo Items			
CO_2 from Biomass burning for Energy purpose	53837.92		
Total CO_2e emission from all sources in Gigagrams	**152269**		
Total CO_2e emission from all sources in million tons	**152.27**		
Total Aboveground Biomass Carbon Stock in million tons as per major National Land Use Categories (NLUC)	**-378.98**		

In 2012 per capita emission from all sectors is 0.98 tons CO_2 eq and 0.27 tons carbon eq.

Chapter 4

Programme Containing Measures to Mitigate GHG Emissions

4.1 Introduction

Bangladesh is a country with a low level of absolute, per capita, per GDP unit of green house gas (GHGs) emissions compared to other developing countries (see Chapter 3 on Inventory of GHG emissionS). The UNFCCC, from the beginning, exempted the LDCs of which Bangladesh is one, from mitigation of climate change i.e., lowering emissions of GHGs. At Bali COP in 2007, there was, for the first time, a decision exhorting LDCs as well as other developing countries to voluntarily contribute to GHG emission efforts and they were requested to prepare Nationally Appropriate Mitigation Actions (NAMA) towards that end. The Warsaw COP in 2013 took one more step towards making it mandatory for all countries to lower GHG emissions by adopting the decision that each country should prepare its Intended Nationally Determined Contribution (INDC) towards global efforts for mitigation. While the INDC issue will be discussed later in this chapter, it should be noted here that the 2015 Paris Agreement has ratified the process and that mitigation is now mandatory for all countries although the level of efforts and the outcome may vary depending upon national circumstances. This chapter on mitigation is being approached from this perspective.

4.2 Objectives

The main objective of the present study is to examine, analyse and finally recommend the GHG mitigation potentials of the key emitting sectors. The sectors include Energy, Industry, Agriculture, LULUCF, waste and some others. The specific objectives are:

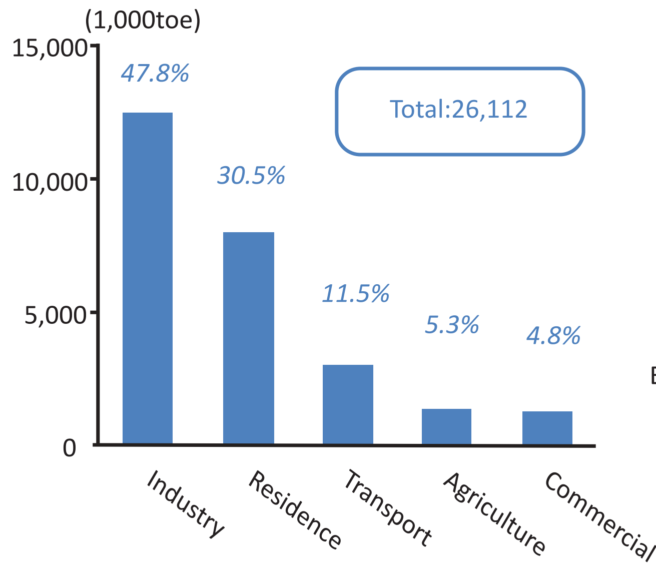
- To assess programmes and measures that will mitigate climate change and are consistent with the government's climate change strategy and implementation roadmap;
- To provide policy makers with an evaluation of technologies and practices that can mitigate climate change and contribute to national development objectives;
- To identify potential projects/programmes for investment;
- To understand the costs of the identified mitigation options that need financial and technological support from the developed countries for implementation;
- To evaluate the cost-benefit of the identified mitigation options and arrive at a tentative plan for avoiding GHGs in terms of cost/per tonne CO_2.

4.3 Mitigation Options

Primary energy consumption in Bangladesh is one of the lowest in the world. In 2008, the country's per capita annual energy consumption was about 182kgoe and per capita electricity generation was 236kWh. Due to intensive efforts to increase coverage, about 80% of the country's population now has access to electricity. Bangladesh's power generation installed capacity was 15000 MW as of November, 2016 and the maximum generation reached 9,036 MW.

To estimate the long-term power demand considering the future change of the daily load curve, a daily load curve up to an estimated 2041 MW is superimposed on the maximum power demand with consideration given to the potential demand up to 2041 MW. The transition of power demand at intervals of five years from 2015 shows an increase in power demand from 2015 to 2041. The maximum power demand could be 8921, 12949, 19191, 27434, 36634 and 49034 MW at five year intervals from 2015. The government plan is that the installed capacity will be increased to around 60,000 MW by 2041 (Power System Master Plan, 2016). The scenario indicates that increasing amounts of GHGs will be emitted from the power sector. A strategic plan is therefore required to mitigate the emissions and keep them at a level consistent with the policy of pursuing a low carbon development pathway.

A rapidly growing country like Bangladesh needs a huge amount of energy to achieve its development target. In the past decade, primary energy consumption increased over 100% and this trend is likely to continue in the future. It is also evident in the latest sector-wise energy consumption (industrial, residential, transport, agriculture and commercial) prospects estimated in the energy efficiency master plan, and recently adopted by the Power Division under the Ministry of Power, Energy and Mineral resources. As shown in Figure 4.1, industry has the biggest share at 47.8%, followed by residence and transportation at 30.5% and 11.5%, respectively.



Notes:
1. Primary energy basis: excluding biomass
2.Electricity: 2867 kcal/k WH (thermal efficiency 30% basis

Source: Compiled by JICA Project Team based on the folliwing data;
Electricity:2013-14, Power Cell, Power Division, Ministry of Power, Energy and Mineral Resources | Gas: 2013-14, MIS of petrobangla, Oil; 2012-13,BPC, | Coal:2012,IEA

Figure 4.1: Primary Energy Consumption by Sector (as of 2013-14)

From the macro point of view, the amount of national energy production stands at 27,187 ktoe, while the amount of primary energy use was 33,550 ktoe, including imported fuel[20].

Bangladesh is developing fast, and rapid industrialization is taking place. It is expected that there will be a shift in the industrial sector from labour intensive industries like RMG to energy-intensive industries. As a result, energy consumption in the industrial sector is expected to increase rapidly. Also, as growth in GDP per capita is expected to facilitate more and more vehicle ownership and transport development in various modes, it is estimated that energy consumption in the transport sector, as in other sectors, will increase significantly.

The business-as-usual (BAU) scenarios for all sectors were analysed during the preparation of the INDC. GHG emissions are expected to increase by 150% by 2030 from the 2011 level, an increase from 136.14 $MtCO_2e$ in 2011 to 339.69 $MtCO_2e$ in 2030 (Table 4.1). The outcomes of the data analyses for TNC for the year 2011 and 2012 are more or less the same. In the INDC the LULUCF sector was not considered. However, in the TNC it is included, although time series data is not available for this sector.

Bangladesh's continued efforts in the area of Climate Change Mitigation

Bangladesh has achieved notable successes in the area of climate change mitigation. It has been able to diversify its power generation mix with renewable energy (RE), and has enacted energy efficiency and conservation master

20 IEA country statistics

plans to promote energy efficiency in industry, thus contributing to a reduction in GHG emissions and the development of sustainable sources of energy to promote low carbon economic growth. Current RE installation has reached nearly 452 MW, which is 2.82% of the total power generation capacity of 16043 MW. The next table shows the total installed RE capacities in terms of different technologies.

Technology	Off -Grid (MW)	Off -Grid (MW)	Total (MW)
Solar	202.93	14.95	217.88
Wind	2	0.90	2.90
Hydro	-	230	230
Biogas to Electricity	0.68	-	0.68
Biomass to Electricity	0.40	-	0.40
Total	206.01	245.85	451.86

The Government of Bangladesh has taken a number of initiatives for the efficient usage of energy to reduce energy consumption, which are as follows:

- Introduction of subjects of energy efficiency measures, and alternative and renewable energy have been introduced in national text books, and in the curricula of, schools, madrasas and colleges;
- Ongoing installation of solar panels in all government, non-government and autonomous institutions;
- Ongoing installation of energy saving CFL, T-5 tube lights in place of incandescent bulbs and replacement of electric ballasts by magnetic ballasts programmes;
- Free CFL distribution program has been conducted to demonstrate the energy saving and cost saving benefits of CFL and consumers are now being encouraged to use other energy efficient lights like LED;
- Introduction of Energy Audit System among large designated consumers is in process;
- Gradual replacement of inefficient brick kilns to efficient brick kilns;
- Launching of a targeted programme to convert gas driven simple cycle power stations into combined cycle power stations;
- A revision of the building code incorporating energy efficiency and solar energy issues into a new building code;
- Replacement of inefficient rice per-boiling system with improved rice per-boiling system;
- Initiation of a public awareness programme for energy conservation;
- Gradual discontinuation of incandescent bulbs and electric heaters;
- Limiting the use of air conditioners, or keeping temperature 25 degrees Celsius and above;
- Standardization of LED and solar products;
- Energy Star Labeling Programme for both imported and locally manufactured electrical appliances;
- Discouraging the use of neon sign in markets and shopping malls at night.

Table 4.1: BAU emissions up to 2030 for all sectors included in the INDC analysis

Sector	GHG emission ($MtCO_2e$)		% change
	2011	2030 BAU	
Power	20.98	91.42	335.75
Transport	15.78	36.61	132.00
Industry	26.46	105.73	299.54
Households	11.25	21.26	88.93
Commercial buildings	0.45	3.35	637.94
Agriculture	3.01	4.70	56.46
Waste	13.38	21.42	60.13
Non-energy emissions from agriculture	39.20	43.96	12.14
Industrial process emissions	5.61	10.97	95.42
F-gases	0.01	0.28	1907.14
Total	**136.14**	**339.69**	**149.52**

The estimated BAU emissions for power, transport, and industry together are expected to increase by 264% between 2011 and 2030 or from 63.22MtCO$_2$e to 233.76MtCO$_2$e (Table-4.2).

Table 4.2: BAU emissions to 2030 for power, transport and industry

Sector	GHG emission (MtCO$_2$e)		% change
	2011	2030 BAU	
Power	20.98	91.42	335.75
Transport	15.78	36.61	132.00
Industry	26.46	105.73	299.54
Total	**63.22**	**233.76**	**269.74**

Considering the above-mentioned scenario, the following GHG areas of mitigation actions were considered:

Power generation, transmission and distribution
Agricultural sector
Transport – road, rail, water and aviation
Energy intensive industries – public and private
Residential/commercial – lighting, cooling, motors, cooking and buildings
Cross-sectoral options (boilers; hollow bricks; DSM)
Renewable (solar PV, biomass and wind)

4.4 Method of Investigation

4.4.1 Scopes of Mitigation

The main principle undermining the approach to mitigation is always considered to be that it must not compromise sustainable development. From the outset, Bangladesh has stressed that while it would pursue a path of low carbon development, that by no means implies that there would be a reduction in absolute levels of GHG emissions. In fact, as the country aspires to middle-income status by mid-2020 if not earlier, its economic activities will gear up several-fold with concomitant demand for energy services. Thus, while wasteful intermediate (in production activities) and final consumption will be curbed by all means, levels of emissions will be impacted. The second principle that needs to be kept in mind is that under no circumstances should food security be jeopardized. In agriculture therefore, any mitigation activities have to be carefully planned and implemented. The third principle is that, given the above two national priorities, an attempt must be made to try to mitigate in sectors where emissions and inefficiency in production and consumption are highest. Other considerations to be made include cost, technology and ease of management.

In light of this, a literature review was conducted to find out what has been happening in Bangladesh in this regard. In doing so the BCCSAP, ALGAS, INC, SNC, INDC and other available documents were reviewed to evaluate mitigation potentials from various activities/ sectors deemed feasible during the preparation of those documents.

Published and other materials available to the public were reviewed. On-line information was also cautiously interpreted. While official documents including BCCSAP and INDC were critically reviewed, other materials were studied to establish the evolution of ideas regarding mitigation over time, and to research actions and ideas concerning energy efficiency and energy and resource conservation, which may have implicit implications for emission reduction (for example, waste disposal methods which may lower methane emission) whether or not it is explicitly stated in the objective of the action. In addition, attempts were made to establish whether any ideas on paper had been implemented in practice, for example in solar home systems or in energy efficient CFL and LEDs.

The next step was to make two projections for GHG emissions for the future based on a modeling exercise. One of the projections is based on the continuation of BAU policies and programmes while the other incorporates GHG mitigation measures. The difference between the two gave the potential of mitigation over the BAU situation. The technical details of the assumptions, sectors, and modeling framework etc. are detailed in the next section.

4.4.2 Modeling Approach

GHG inventory for the years 2006-12 along with that estimated in some earlier years provided the basic background against which a present and short-term future mitigation scenario can be devised. The GHG inventory provides information on the importance of different sectors by emission levels and that of specific activities within each sector. This also provides the initial set of sectors and activities that may need to be examined more closely.

Modeling GHG mitigation potentials along with roles for renewable and coal-based power generation

The main technical exercise was carried out under this set of activities. For the purpose of this assignment the following GHG areas of mitigation activity are considered.

- Power sector
- Transport
- Energy intensive industries – public and private
- Agricultural sector (including crop, livestock and poultry)
- Forestry
- Waste generation and disposal
- Residential/commercial
- Cross-sectoral options
- Renewables (solar PV, biomass and wind)

Preliminary ideas regarding the main gases emitted are as follows:

Power sector: generators - CO_2 from coal, oil, natural gas and nuclear energy with a specific emphasis on clean coal technologies;

Transport: road transport - CO_2 from diesel and petrol, CH_4 from CNGs;

Industries: electricity and resulting CO_2;

Agriculture: CO_2 from use of electricity, methane due to flooded fields and nitrous oxide due to fertilization and manure; methane from manure management;

Forestry: as sink for GHGs;

Waster sector: methane and nitrous oxide;

Residential/commercial: CO_2 from power consumption such as lighting and cooling;

Cross-sectoral: energy efficient brick making;

Renewables: avoidance of CO_2 and N_2O emission for use of power.

4.4.3 Modeling Methodology

Modeling future GHG emissions was carried out using the LEAP model. This is an energy model that calculates GHG emissions based on fuel consumption, electricity consumption and generation capacity. For non-energy sectors (e.g. agriculture and waste), GHG emissions were calculated off-model, with the resulting GHG figures inputted into LEAP.

For the energy-related sectors, BAU emissions are calculated by combining fuel consumption with the appropriate emission factors in LEAP. Where possible, fuel demand was calculated by considering current activity (e.g. numbers of appliances, numbers of vehicles etc) and current efficiency (e.g. current efficiency of appliances, current fuel efficiency of vehicles etc) and making assumptions about how these will change over time. In some cases, lack of detailed data meant having to estimate GHG emissions from fuel consumption data, without disaggregating it by activity.

The BAU has been calculated as a 'without measures' scenario, meaning that rather than predicting the future effect of government policy, it forecasts emissions on the assumption of no further action taken.

For mitigation options, a long list of possible mitigation measures was produced based on a review of key documents, including the Second National Communication, Bangladesh's Technology Needs Assessment and the Bangladesh Climate Change Strategy and Action Plan, INDC, and by adding other possible measures where the project team deemed it appropriate. This long-list was then reduced to a short-list by assessing each measure against four criteria – abatement potential, cost, technical feasibility and co-benefits. The short-list of mitigation measures, and the reasons for including them, are outlined with the help of the LEAP modeling.

4.5 Business-As-Usual (BAU) Mitigation Scenarios

Power sector

The power sector is modeled by first specifying the available generation capacity. The LEAP model then takes the electricity demand from the energy demand sectors and delivers this by introducing generation units according to the specified merit order.

This order is assumed to be:

Existing Government owned power generation units and all must-take renewable + nuclear
New hydro
New fossil units
New biomass
Existing IPP units
Existing rental units
Any interconnection

4.5.1. Power Sector

BAU Scenario

The exercise was started by recreating the current Bangladeshi power sector to the best extent possible. Generating capacity for the period 2012 to 2016 was taken from a table of the baseline report developed for INDC, 2015. Forecast of future additions to generating capacity beyond 2016 was taken from Table 3.4 of the Power System Master Plan. It was assumed that all existing steam thermal units would be retired by 2030. This gives a total generating capacity of 37,539 MW by 2030. It emerged from The Power System Master Plan 2010 and the Power and Energy Sector Road Map updates that to meet the demand with reasonable reliability, installed capacity must be increased to 23,000 MW and 37,000 MW by 2021 and 2030 respectively. The assumption was made that no further renewable capacity would be added under the the BAU scenario.

4.5.1.1 Mitigation Scenarios

The following assumptions were made for the power sector measures:

Table 4.3: Mitigation assumptions for the power sector

Mitigation action	Metric	Assumptions					Rationale
		Base year (2011)	BAU (2030)	Low (2030)	Medium (2030)	High (2030)	
Biomass generation	MW of electricity generating capacity	3	3	7	26	38	The potential of biomass based electricity generation mostly depends on availability as well as its long term supply up to generation end. The existing and future level of availability especially of bagasse and rice husks are being accounted for in the three assessed scenarios.

Mitigation action	Metric	Assumptions					Rationale
		Base year (2011)	BAU (2030)	Low (2030)	Medium (2030)	High (2030)	
Biogas generation	MW of biogas generated electricity	2.5	2.5	5	10	20	Bangladesh achieved the baseline generation capacity after 30 years of endeavour. Given the technological breakthrough, only massive awareness among stakeholders on the technology and its benefits and government incentive support can ensure its success.
Wind energy	MW of wind capacity	2	2	60	500	800	The Government of Bangladesh has set a target of 1300 MW Power Generation Capacity from Wind Energy within a period of 10~15 years. One of the key barriers to streamlining wind potential is the un-availability of country specific proven wind data, Bangladesh also lacks proven and quality wind data to implement such an ambitious target within the stipulated time.
Utility scale solar (solar farms and rooftop)	MW of capacity from solar farms	0	0	220	800	1000	The maximum capacity targeted by the Government of Bangladesh within 10~15 years is 1700 MW. Given the present trend of cooperation with the private sector and the actual pace of implementation low, medium and high possibility scenarios were envisioned.
Solar home PV (incl. commercial)	MW of solar home PV capacity	148	148	190	250	290	The low, medium and high possibility scenarios were built on IDCOL SHS current programmes and forecasted installation rate.
Other solar (mini-grids, irrigation, etc.)	MW of other solar capacity	2.5	2.5	25	75	100	The low, medium and high possibility scenarios were built on IDCOL Mini-grid and Solar Irrigation roll-out programme present and forecasted installation rate.
Build only supercritical coal power stations	% of coal generating capacity that is supercritical coal plant	0	0	25%	50%	100%	The low and medium possibility scenarios were considered on the present level of committed fund from international donors /developing agencies. The high possibility scenario will only be possible if there is sufficient financing from domestic and international sources to implement the projects.
Repowering of steam turbines	MW of additional CCGT generation capacity due to repowering (replacing coal)	0	0	250	600	800	A total 1100 MW potential was identified in the Power Cell study and all three scenarios duly considered the level of fund flow and commitment from donor community to support such replacement.

4.5.2 Transport Sector

BAU Scenario

The Second National Communication for Bangladesh shows that 88% of transport sector GHG emissions in Bangladesh come from road transport, 7.5% from waterborne transport, and 2% each from rail and aviation. The focus of the analysis was therefore on the road transport sector. This, combined with data limitations, meant that a simpler modeling approach was taken for the three smaller sub-sectors.

For converting CO_2 values to energy, the following conversion facts were used.

Table 4.4: Energy to CO_2 conversion factors from LEAP

Fuel	Energy density (GJ/tonne)	Density (kg/litre)	CO_2 factor at 100% oxidation (Tonne/TJ)	Fraction oxidised	Energy per CO_2 emission (GJ/Gg)
Diesel	43.33	0.87	20.2	99%	13647.4
Gasoline	44.80	0.74	18.9	99%	14586.1
Jet kerosene	43.33	0.87	20.2	99%	13647.4

Road transport

Historic vehicle numbers were taken from the BBS 2012a Statistical Yearbook. These numbers were then projected forward based on an extrapolation of the growth between 2008 and 2012 (the period that shows close to linear growth). Data on annual vehicle consumption and mileage was taken from surveys of transport operators carried out for this study. Annual fuel consumption was converted to fuel efficiency in km/unit of fuel. (See Table 4.5 below). An assumption was made that these efficiencies and mileages would stay constant until 2030.

Table 4.5: Annual mileage and fuel efficiency assumptions for road vehicles

Vehicle Type	Fuel	Fuel Unit	Annual Mileage (km)	Fuel Efficiency (km/unit fuel)
Bus	Diesel	Litre	112547	3.28
Minibus	CNG	Litre	72000	0.35
	Diesel	Litre	72000	2.40
Microbus	Gas	SM^3	22500	5.00
Truck	Diesel	Litre	99000	3.43
Jeep	Diesel	Litre	90000	3.45
Car	Gasoline	Litre	10000	7.00
Taxi	Gasoline	Litre	72000	5.50
Auto-Rickshaw	CNG	Litre	30000	0.91
Motor Cycle	Gasoline	Litre	11863	55.00

Rail

Energy demand for the rail sector in the baseline year was calculated from the 2012 CO_2 emissions from the Second National Communication (assuming 100% diesel fuel), giving a demand of 1,583 TJ.

This is assumed to remain constant up to 2030. This assumption is based on the fact that the BBS 2012a Statistical Yearbook shows that the numbers of railway rolling stock have been largely stable over time since 2000.

Waterborne transport

Energy demand for the waterborne transport sector in the baseline year was calculated from the 2005 CO_2 emissions reported in the Second National Communication (assuming 100% diesel fuel), projected to 2012 in line with the historic growth in waterborne traffic shown in BBS 2012a.

The growth in energy demand is based on the growth in total traffic, with this calculated by taking total waterborne traffic between 2005 and 2012 and then extrapolating linearly to 2030, generating an annual growth rate of about 7%.

Aviation

The BBS 2012a Statistical Yearbook provides total sales of aviation fuel from 2007 to 2012. These sales were converted to CO_2 emissions using the values shown in Table 4.20 of BBS, 2012a (assuming all aviation fuel is jet kerosene) and split between domestic and international using the ratio for 2005. Domestic aviation data was projected by linearly extrapolating from the domestic aviation values for 2008 and 2012 to 2030. This gives an annual growth rate of about 2.6% for domestic aviation, which is slightly lower than that generally accepted for international aviation (between 3% and 5%).

4.5.2.1 Mitigation scenarios

Two mitigation measures were modeled for the transport sector:

- Modal shift from road to rail – assuming a certain percentage shift in the different mitigation scenarios.
- Improvement of road traffic congestion – leading to a higher fuel efficiency of vehicles. Examples of measures considered are the building of an express elevated way and a metro rapid transit system in Dhaka, including subway and bus rapid transit system.

Table 4.6: Mitigation assumptions for the transport sector

Mitigation action	Metric	Assumptions					Rationale
		Base year (2012)	BAU (2030)	Low (2030)	Medium (2030)	High (2030)	
Improvement of road traffic congestion	% improvement in fuel efficiency	0	0	5	10	15	The efficiency improvements from optimal running of vehicles is much less than those from the purchase of more fuel efficient vehicles. [The present strategic road sector plan considers many flyovers, alternative roads to reduce the traffic congestion in the major cities. However, because of un-planned urbanisation, the traffic congestion could only be reduced up to the extent mentioned in different scenarios.
Modal shift from road to rail	% modal shift of passenger -km	0	0	10	20	25	All the scenarios duly factor in the keenness of the Government of Bangladesh to promote rail and water as relatively cheap and fast modes of goods and cargo transportation.

The 'improved efficiency of vehicles' measure was modeled by simply reducing the fuel/km of all road vehicles by the relevant percentage for each scenario.

The 'modal shift from road to rail' measure was modeled by first converting the vehicles-km for road vehicle types into passenger-km by multiplying the former for assumed average occupancy figures for the main road vehicles. These assumptions are shown in Table 4.7.

Table 4.7: Average occupancy assumption

	Bus	Minibus	Microbus	Jeep	Car	Taxi	Auto-rickshaw	Motor Cycle
Passengers per vehicle	40	10	5	2	2	2	2	1

[Source: Expert judgment]

Trucks were not considered as they would not be a target of mass rapid transport solutions. The passenger-km was calculated for the BAU and then for the three mitigation scenarios by reducing the BAU figure by the appropriate percentage (10%; 20%; 25%). The passenger-km for the rail sector in the BAU scenario was taken from the World Bank online database. Considering that the sum of passenger-km of road and rail had to remain constant, the passenger-km for rail for the three mitigation scenarios was calculated by subtracting the relevant road passenger-km for the low, medium and high ambition scenarios from the overall road-rail passenger-km.

4.5.3. Industry

BAU Scenario

GHG emissions under the BAU scenario were calculated by combining:

- Projections of industrial output for each industrial sub-sector consistent with the growth rate needed to attain middle-income status by 2021; and
- An energy intensity per output for each industrial sub-sector, from the E&CC Master Plan, with an assumption that this energy intensity per output does not change up to 2030 under the BAU scenario.

4.5.3.1 Mitigation Scenarios

GHG emissions under the three mitigation scenarios were calculated by assuming:

- The level of energy efficiency improvements possible in each industrial sub-sector by 2030 (both for existing plants and for new plants); and
- The proportion of the sub-sector that would take up the energy efficiency measures by 2030.

The energy efficiency improvements are based on expert judgment, arrived at following intense discussions. The proportion of the sub-sector taking up the energy efficiency measures was based on the timetable for energy audits set out in the EE&C Master Plan. Note that it was taken into account that even if X% of a sub-sector has had an energy audit by 2030, less than X% might actually act upon the audit and implement energy efficiency measures. Hence assumptions were made on the proportion of sub-sectors taking up energy efficiency measures for lower, medium, and higher ambition scenarios.

Table 4.8: Mitigation assumptions for industry's energy demand

Sector	Average efficiency improvement from BAU (%)		% of sector undergoing energy audit by 2030	% of audited sector undertaking energy efficiency improvements by 2030			% of sector with new plants installed by 2030	
	Existing plant (following energy audit)	New plant		Low ambition scenario	Medium ambition scenario	High ambition scenario	BAU Scenario	Abatement scenarios
Cement	20	30	50	30	50	70	20	30
Fertilizer	7.5	15	50	30	50	70	20	30
Garments	8	12.5	30	20	30	50	20	30
Textiles	10	15	50	30	50	70	20	30
Steel	30	60	70	50	70	90	20	30
Pulp and paper	10	20	50	30	50	70	20	30
Tiles	15	30	30	20	30	50	20	30
Bricks	0	12	10	Not modeled because EE potential is 0	Ditto	Ditto	0	Low: 5 Medium: 10 High: 20
Frozen food	10	17.5	50	30	50	70	20	30
Chemicals	5	10	70	50	70	90	20	30
Jute	15	0	50	30	50	70	0	0
Other industries	10	10	50	30	50	70	20	30

Taking cement as an example, in the low ambition scenario, 30% of the sector will have new plants or technology in place (last column), which will help reduce energy consumption by 30% (column 3) in 2030. Of the remaining 70% of the plants, 50% will undergo an energy audit (column 4), but only under one-third (30%) will undertake energy efficiency improvements (column 5) that will lead to a 20% reduction of energy consumption (column 2). This calculation has been repeated for medium and high scenarios by changing the proportion of the audited plants undertaking improvements from column 5 to columns 6 and 7 respectively.

4.5.4 Households

BAU Scenario

The households sector was split into urban and rural households and modeled separately.

Electricity use

Electricity use in households was determined using the following approach:

- Data on current and projected numbers of lights and appliances and their efficiencies was taken from a peer reviewed 2014 report [21];
- The projected numbers of lights and appliances are based on specific GDP growth assumptions, adjusted to fit in with the higher GDP growth rate needed to meet middle-income status by 2021;
- According to BBS 2014, 48.84% of rural households and 88.70% of urban households are using grid electricity for lighting purposes. It is assumed that this represents the proportion of households with any grid connection;
- The above percentages were used to establish the number of devices per household;
- That figure was multiplied by the standard energy efficiency for each device to get the total electricity demand of a household;
- It is assumed that there are no autonomous energy efficiency improvements in the BAU scenario.
  Other fuels

Other fuels were modeled in a simpler manner:

Natural gas, LPG, kerosene, diesel, wood, animal waste and vegetable waste.
Data on vegetable waste, animal waste, and wood and kerosene consumption per household was taken from BBS, 2014, Table 4.25.

Table 4.9: Energy-Bio-mass and Non-Biomass

		Heating					
Energy Type	**All Uses**	**Cooking**	**Parboiling**	**Other**	**Cooling**	**Lighting**	**Amusement**
Biomass (kg)							
Fuel wood	1,186.21	1,064.84	28.60	92.77	—	—	—
Tree leaves	501.51	470.67	29.99	0.85	—	—	—
Crop residue	708.18	538.86	164.41	2.72	—	—	—
Dung cake/stick	523.90	503.68	16.07	4.16	—	—	—
Sawdust	8.40	8.36	0.02	0.02	—	—	—
Non-biomass							
Candle (piece)	15.86	—	—	—	—	15.86	—
Kerosene (liter)	28.98	1.76	—	0.07	—	27.16	—
Natural gas (Cubic-meter)	9.59	9.59	—	—	—	—	—
LPG/LNG (liter)	0.05	0.05	—	—	—	—	—
Grid electricity (kWh)	143.83	0.25	—	4.00	49.50	80.74	9.34
Solar PV (kWh)	0.53	—	—	—	0.04	0.48	0.01
Storage cell (kWh)	0.55	—	—	—	—	0.14	0.41
Dry-cell battery (piece)	15.01	—	—	—	—	—	—

21 Market Research on Equipment and Appliances, New Vision Solutions Ltd, 2014.

Data on consumption of kerosene for cooking purposes was adjusted to account for the fact that only 46.45% of rural and 10.70% of urban households use kerosene for lighting and 1.04% of rural and 0.83% of urban households use kerosene for cooking (BBS 2014).

Data on diesel was taken from BBS 2014, Table 4.26 where the 2013 figure for oil of the residential sector was shown to be 343,000 MT. It was assumed that the 2011 amount was consumed by 80% of urban households by running backup power generators. The consumption per household was then modeled assuming: a) a 10% improvement in fuel efficiency of backup generators by 2030; b) only 50% of urban households will need to use a backup generator in 2030 due to expansion and improvement in the reliability of the national power grid.

Table 4.10: 2013 Annual Energy Consumption by Sector and Fuel Type

	Industry	Transport	Residence	Commercial	Agriculture	Total
Grid electricity (GWh)	12,292	0	18,264	3,556	1,713	35,825
Gas (MMCM)	9,612	1,136	2,875	252	23	13,898
Oil (MMT)	189	2,288	343	20	985	3,825
Coal (1,000TOE)	666	0	0	0	0	666

Source[22]

Data on wood, agricultural and forest waste and animal waste consumption for cooking and parboiling was adjusted to account for the percentage of households using these fuels for cooking purposes (BBS 2014, Table 3.23). The same percentage of households using non-electric energy for cooking and for parboiling was assumed. It was also assumed that there will be a 10% market penetration of biomass based improved cooking stoves (i.e. about 2.4 times more efficient than traditional ones) by 2030.

Growth of biomass demand in households was assumed to be in line with the historic trend included in the Second National Communication and is shown in its Table 4.15.

Table 4.11: Source of Cooking Fuel (%)

Fuel Type	2011	2004	1991
Wood	34.8	31.76	44.27
Kerosene	1.0	1.79	0.57
Gas/LPG	12.6	9.09	2.36
Electricity	0.4	0.76	0.88
Straw/Leaf/Dried cow dung	51.2	55.91	-
Bio-gas	0.1	-	-

The data presented in Table 4.11 for natural gas and LPG looked too low. Therefore, the total figure for natural gas for the residential sector was divided by the correct percentage of rural and urban households using gas for cooking obtained from Table 3.23 of BBS 2014. The Figures in Figure 4.2 were inclusive of both natural gas and LPG consumption. It was assumed that all gas cooking in rural households uses LPG, while the modeling for urban households incorporated the phase of the LPG on the understanding that the GoB has decided not to encourage new natural gas connections. The number of urban households using natural gas was therefore kept at 3 million. In addition, a 10% switch of biomass (firewood) users to LPG by 2030 was assumed, as the country develops and some of the wealthier users will want to switch to a more 'modern' fuel for cooking.

22 Electricity: 2013-14, Source: Power Cell, Power Division, Ministry of Power, Energy and Mineral Resources
Gas: 2013-14, Source: MIS of Petrobangla July 2014
Oil: 2012-13, Source: BPC
Coal: IEA 2012 data

The growth rate of total natural gas/LPG demand was modeled over historic rates (2011-2013) from official sources like Table 6 of BBS 2012 and Table 11 of the BAU report. Finally, the LPG demand's forecasts from the journal Energy & Power[23] (see following graph) were used.

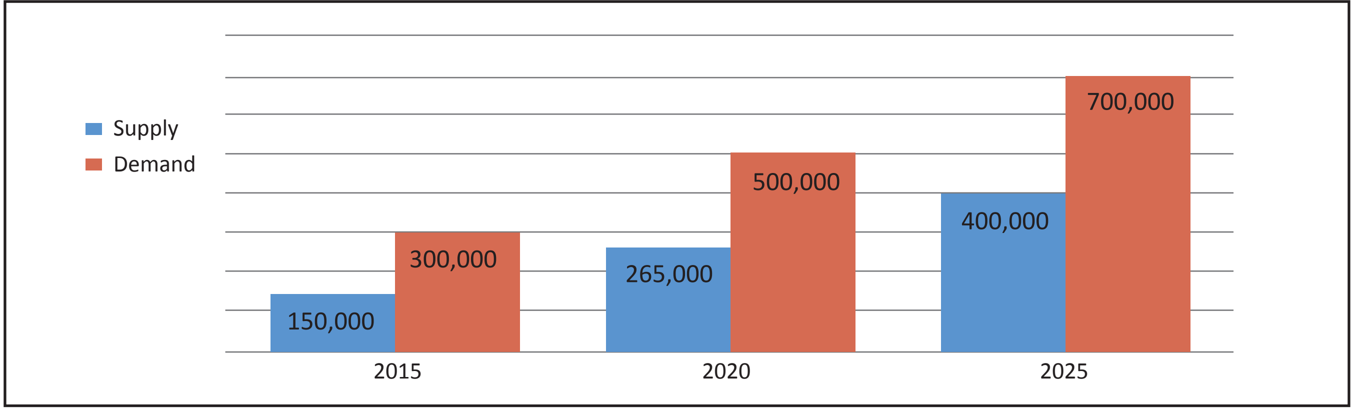


Figure 4.2: Forecasted LPG supply and demand gap (Metric Tonnes of LPG)

4.5.4.1 Mitigation Scenarios

The mitigation measures analysed are:

- Energy efficient equipment and appliances
- Energy efficient lighting
- Introduction of domestic gas metering
- Improved gas cookstoves
- More efficient biomass cookstoves
- Replacement of biomass with LPG for cooking in rural areas

Energy Efficient Green building

Energy efficient appliances

Potential efficiency improvements for individual appliances were taken from the 2014 New Vision Solutions report, Table 8.

This report does not contain suggested efficiencies for certain appliances, for these a 10% improvement was assumed.

Market penetration of energy efficient appliances was assumed as set out in Table 4.12 below. The market penetration rates set out in the E&CC Master Plan were taken as the medium ambition scenario, as it was felt that these would be too challenging to be met in the low ambition scenario. Relative lower and higher market penetration figures were then assigned based on expert judgment.

Table 4.12: Assumptions on market penetration of appliances

Appliance	Energy efficient technology	Market penetration		
		Low ambition	Medium ambition (Master Plan targets)	High ambition
Lighting	LED	30%	50%	70%
Refrigerator/ freezer	Variable speed compressor, high performance heat insulation	35%	55%	70%
TV	LCD with LED back light	15%	25%	40%

23 Energy & Power, Figure on p. 160, Vol 13, Issue 1, June 15-30.

Appliance	Energy efficient technology	Market penetration		
		Low ambition	Medium ambition (Master Plan targets)	High ambition
AC	High COP with large heat exchanging coil and variable speed compressor	20%	50%	65%
Washing machines	Not in master plan	10%	20%	30%
Rice cookers	Not in master plan	10%	20%	30%
Water dispensers	Not in master plan	10%	20%	30%
Water pump	High efficiency motor	8%	15%	25%
Computers	Not in master plan	10%	20%	30%
Water heaters	Not in master plan	10%	20%	30%
Iron	Thermostat	3%	5%	8%
Fan	High efficiency motor	15%	25%	40%
Other	Not in master plan	10%	20%	30%

Energy efficient lighting

This measure was modeled by assuming the following changes in numbers of types of light bulbs per household.

Table 4.13: Assumptions on numbers of light bulbs

Bulb	BAU 2030		Low 2030		Medium 2030		High 2030	
	Bulbs per HH	%	Bulbs per HH	%	Bulbs per HH	%	Bulbs per HH	%
Incandescent	1.22	16.25%	0.75	10%	0.37	5%	0.00	0%
CFL	3.90	52.0%	2.28	30.4%	1.87	25%	1.12	15%
LFL	2.22	29.6%	2.22	29.6%	1.50	20%	1.12	15%
LED	0.16	2.13%	2.25	30%	3.74	50%	5.24	70%
Total	7.49	100%	7.49	100%	7.49	100%	7.49	100%

A simplifying assumption that the efficiency of individual lights does not change over time was used.

Introduction of domestic gas metering

It was suggested that this mitigation measure should not be quantitatively modeled, but could be mentioned in the INDC qualitatively. There is an ongoing pilot programme sponsored by the GoB, but there is currently some re-evaluation of this measure because it seems it would not be cost-effective and there are some concerns about the reliability of the available technology for the metres.

Improved gas cookstoves

The potential efficiency improvements of gas cookstoves are taken from a USAID-funded study on willingness to pay for cookstoves[24] . This suggests a heat utilisation efficiency of 46.3% for conventional natural gas cookstoves and 57.8% for energy efficient natural gas cookstoves, that is a 125% efficiency improvement of energy efficient models as compared to standard technology ones. For market penetration, the rates in Table 4.14 have been assumed (based on expert judgment generated by this study):

24 http://cleancookstoves.org/resources_files/consumer-preference-bangladesh.pdf

Table 4.14: Assumptions on market penetration of gas cookstoves

Type of appliance	Market penetration of gas cookstoves (%)			
	BAU	Low	Medium	High
Standard	100	90	80	60
Energy efficient	0	10	20	40

More efficient biomass cookstoves

The potential efficiency improvements of biomass cookstoves are taken from the same USAID-funded study on willingness to pay for cookstoves[25] . This suggests a heat utilisation efficiency of 11.9% for traditional biomass cookstoves and 28.6% for energy efficient biomass cookstoves, that is a 240% efficiency improvement of energy efficient models as compared to standard technology ones.

For market penetration, the rates shown in Table 4.15 have been assumed (based on expert judgment and taking into account the current and planned effort of the GoB to promote improved biomass cook stoves):

Table 4.15: Assumptions on market penetration of biomass cookstoves

Type of appliance	Market share of biomass cookstoves (%)			
	BAU	Low	Medium	High
Standard	90	80	65	30
Energy efficient	10 (2.8m households by 2030)	20 (5.7m households by 2030)	35 (10m households by 2030)	70 (20m households by 2030)

Replacement of biomass with LPG for cooking

The TNC project team assumed the market switch from biomass to LPG for cooking shown in Table 4.16, based on expert judgment.

Table 4.16: Assumptions of share of households using fuels for cooking

Type of fuel	Share of households by fuel used for cooking (%)			
	Rural 2011	Urban 2011	Rural 2030	Urban 2030
Natural gas + LPG	4.5% (all LPG)	46.48%	14.5% (all LPG)	56.48%
LPG	4.5%	6.46%	14.5% (increase of 10% from biomass)	39.89% (increase of 10% from biomass)
Natural gas	0%	40.02% (3m of Households)	0%	16.59% (3m of Households - kept constant)
Biomass	94%	52%	84% (decrease of 10% in wood consumption to LPG)	41% (decrease of 10% in wood consumption to LPG)
Kerosene	Remainder	Remainder	Remainder	Remainder

The 10% switch from biomass consumption in rural and urban households was assumed to occur using standard and energy efficient LPG cookstoves respectively for the BAU and the mitigation scenarios. This is more of a social change due to an increase in wealth of the population rather than a mitigation measure, so no difference was introduced in the assumptions relating to mitigation scenarios.

25 http://cleancookstoves.org/resources_files/consumer-preference-bangladesh.pdf

4.5.5 Commercial Buildings

BAU Scenario

The annual energy consumption data in 2013 for the commercial buildings sector, split by fuel type, was taken from a range of sources: electricity demand from the power division of the Ministry of Power, Energy and Mineral Resources; gas from Petrobangla; and oil from BPC. This demand was projected to 2030 based on the forecasted GDP growth rate for the services sector from the National Sustainable Development Strategy (Table 3.2). This was then multiplied by a factor of 1.5 according to the indication in the NSDS that: *"in a typical developing economy a one percent increase in GDP leads to a 1.5 percent increase in electricity demand."* In the absence of other data, this growth factor was assumed for all fuels, and not just for electricity.

4.5.5.1 Mitigation Scenarios

It was decided to model the effect of all mitigation measures together, i.e. energy efficient appliances, lighting, cooling measures, and rainwater harvesting. The figures chosen for modeling the energy efficiency improvement for the overall sector in the three scenarios are 12%, 20%, and 25% for the low, medium and high ambition scenarios respectively. It was assumed that the potential of energy efficiency in the commercial sector is 50%, as referred to in the EE&C Master Plan. However, it was felt that the full potential was not reasonably achievable because of limitations in building design and other technical factors. Consequently, it was considered that half of the full 50% potential (i.e. 25%) was achievable in the higher ambition scenario.

4.5.6 Energy use in Agriculture

The overall fuel consumption for the BAU was modeled in line with GDP growth, but instead of 1:1 growth GDP/fuel, 1:0.5 was used. No mitigation measures were modeled for this sector.

4.5.7 Non-energy emissions in agriculture sector

BAU Scenario

Non-energy GHG emissions in agriculture were modeled in four categories:

Rice cultivation
Enteric fermentation
Manure management
Agricultural soils

In the period 2005-06, a total of 10.529 Mha (million hectares) of land was under paddy cultivation of which 9.8%, 4.8%, 46.8% and 38.6% were aus, broadcast (B) aman, transplanted (T) aman and boro respectively. The cultivated paddy area increased gradually from 2006 to 2012. The cultivated area of broadcast aman and transplanted aman rice decreased slightly over the last seven years but the area under boro cultivation increased sharply. That given to aus remained almost unchanged in the seven year period. The total paddy area increased by about 9.5% between 2006 and 2012.

Table 4.17: Cultivated Area of Different Rice Crops from Year 2006 to 2012

Crop Name	2006	2007	2008	2009	2010	2011	2012
Aus	1.034	0.906	0.919	1.066	0.984	1.113	1.138
B Aman	0.505	0.484	0.308	0.403	0.476	0.426	0.384
T Aman	4.923	4.932	4.74	5.095	5.187	5.22	5.196
Boro	4.066	4.258	4.607	4.716	4.707	4.77	4.81
Total Rice	***10.529***	***10.579***	***10.574***	***11.279***	***11.354***	***11.529***	***11.528***

Source: Yearbook of agricultural Statistics of Bangladesh, 2014

In the year 2006, total methane emission from rice cultivation was estimated at about 437.7 Gg CH4. The methane emission from rice cultivation gradually increased and the amount in 2012 stood at 497.6 Gg. The increase is attributed to the increased rice cultivation area, especially that for boro rice.

Emission from N- based fertilizer

In 2006 the amount of direct N_2O emissions from N based fertilizer and CO_2 emissions from urea fertilizer were estimated to be 18.0 Gg and 183374.0 Gg respectively. The direct N_2O emissions from N based fertilizer and CO_2 from urea decreased to 17.6 Gg and 162507 Gg respectively. The reduction in emission may be due to the 24% decline in the B aman area as shown in Table 4.17.

Enteric Fermentation

Livestock population data was collected from the Department of Livestock Services (DLS). The total number of livestock population by year is presented in Table 4.18. In 2006, the livestock population was estimated to comprise 14.14 million dairy cows, 8.66 million non-dairy cows, 1.21 million buffaloes, 20.75 million goats, 2.68 million sheep and 245.97 million poultry birds. The livestock population increased gradually in response to increase in domestic demand for meat, eggs and milk and milk products.

Table 4.18: Number of Livestock and Poultry in Bangladesh

Livestock/Poultry	Number (in Lakhs)					
	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Cattle	228.7	229.0	229.76	230.5	231.21	231.95
Buffalo	12.1	12.6	13.04	13.49	13.94	14.43
Goat	207.5	215.6	224.01	232.75	241.49	251.16
Sheep	26.8	27.8	28.77	29.77	30.02	30.82
Total Livestock	**475.1**	**485.0**	**495.58**	**506.51**	**516.66**	**528.36**
Chicken	2068.9	2124.7	2213.94	2280.35	2346.86	2428.66
Duck	390.8	398.4	412.34	426.77	441.20	457.00
Total Poultry	**2459.7**	**2523.1**	**2626.28**	**2707.12**	**2788.06**	**2885.66**

Source: Department of Livestock Services, Ministry of Fisheries and Livestock

In the Initial National Communication (MoEF, 2002), the total methane and nitrous oxide emissions from manure management were estimated at 251.90 Gg CH_4 and 28.88 Gg N_2O respectively for the year 2001. However, in the Second National Communication (MoEF, 2012), the total methane and nitrous oxide emissions were estimated at 258.54 Gg CH_4 and 33.83 Gg N_2O respectively for the year 2005.

Current total enteric methane emission has been estimated at about 495.6 Gg CH_4 for 2006 considering enteric methane emission factor (EFt) and for 2012 at about 537.9 Gg CH_4. The calculation was made using ALU software.

Assumptions for BAU are as follows:

Rice cultivation:

- Increase in irrigated area and High Yielding Varieties (HYV) will continue to 70% of rice area by 2030;
- Uplands and rain-fed areas will fall (by 50% and 57% respectively), as more efficient irrigated systems replace rain- fed systems;
- Total rice area will remain unchanged. The additional gains in productivity will be absorbed by increasing demand from a growing population and potential export markets.

Enteric fermentation:

As a result of increased mechanization (e.g. increased use of tractors for tillage), the number of draft animals is likely to decrease. It has been estimated that the non-dairy herd will fall by 20% by 2030;

Consumption of milk and meat is likely to increase but it is assumed that this increased demand for dairy products will be met by improvements in production efficiency, hence there is no change in the numbers of dairy cattle;

As genetics improve to enhance productivity, it is assumed that dairy cows will increase in size, leading to an increase in the emissions factor for dairy cows by 20%;

It is assumed that the numbers of cattle and emissions factors for all other categories of animal (buffalo, sheep, goats, swine) will stay the same through 2030.

Manure management:

Livestock number changes are estimated as per the enteric fermentation category. This means the number of dairy cattle will stay the same but that of non-dairy (draft) cattle will fall by 20%;

Dry storage will remain at 80% based on estimations in the Second National Communication.

Agricultural soils

Fertilizer usage will increase at a rate of 4.2% per year[26] ;

A 50% increase in organic uses of nitrogen fertilizer has been assumed.

4.5.7.1 Mitigation Scenarios

The following mitigation measures were considered:

- Alternate wetting and drying irrigation for rice cultivation
- Increased mechanisation leading to reduced draft cattle numbers
- Improved use of organic manures

The assumptions made for each measure are as follows:

Table 4.19: Mitigation assumptions for agriculture (non-energy related emissions)

Mitigation measure	Metric	Assumptions for 2030			Rationale
		Low scenario	Medium scenario	High scenario	
Alternate wetting and drying	% of rice cultivation area that adopts AWD	10%	15%	20%	Almost no AWD currently assumed but with relatively straightforward policy intervention the assumptions made for the scenarios are realistic within the timescales.
Increased mechanization	% reduction in draft cattle numbers	30%	40%	50%	The project team felt that this could be a realistic target with appropriate policy intervention.
Improved use of organic manures	% increase in organic manure use	45%	40%	35%	Expert judgement on what is feasible.

4.5.8 Waste Sector

In the context of Bangladesh, as all the landfill sites function as unmanaged and open dumps, these sites can be optimal for landfill gas emission. Every day huge amounts of MSW are dumped at the sites, and this produces significant amounts of CH_4 for emission into the atmosphere. A large proportion of the waste generated remains scattered and because of aerobic conditions, the scattered waste produces little or no methane.

According to the 2011 Population and Housing Census, a total of 35,094,684 (adjusted) persons live in urban areas and make up 23.43% of the total population. Urbanisation has been taking place in Bangladesh in three main ways:

i) Area Expansion;
ii) Rural-Urban Migration; and
iii) Population Growth.

26 From FAO report “Towards Sustainable Agriculture and Improved Food Security and Nutrition.

The proportion of Bangladesh's urban population reached 23.43% (adjusted) in 2011 from 2.43% in 1901. The proportion of the urban population was almost similar from 1901 to 1921 and thereafter it started increasing at relatively high rates: 137.6% for the period 1961 to 1974, 115.8% from 1974 to 1981, and 65.9% from 1981 to 1991. Despite the increase in urban population in the last three decades, Bangladesh continues to be a predominantly rural country with about 76.57% of its population living in villages.

At present the urban area of the country includes 12 city corporations, 304 pourashva / (municipal corporations) and 189 upazilas.

Waste Generation: [27]

The total amount of waste generated every day in Bangladesh has been increasing annually since 1991. Whereas in 1991 the urban areas of Bangladesh generated approximately 6,493 tons per day of municipal solid waste, by 2005 that figure had more than doubled to reach 13,330 tons per day. In 2014, it is estimated that Bangladesh generated 23,688 tons per day in its urban areas. At the same time the total urban population of Bangladesh increased from 20.8 million in 1991 to 32.76 million in 2005 and to 41.94 million in 2014. It is estimated that the total urban population will be as high as 78.44 million by 2025, and the total waste generated is expected to reach 47,000 tons per day. There is an obvious link between a larger urban population and greater amounts of waste generated. Interestingly, since 2005, the rate of change of total waste generated daily has exceeded the rate of population growth, due to an increased average daily per capita waste generation rate.

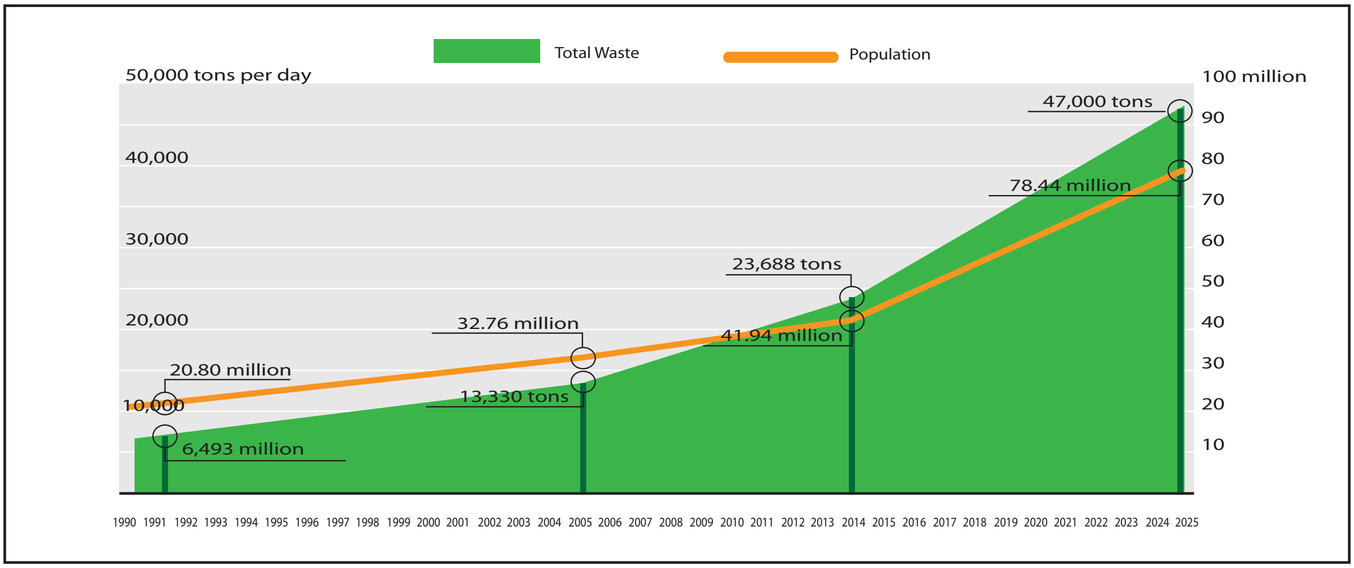


Figure 4.3: Total Waste Generation vs. Urban Population[28]

Per Capita Waste Generation:[29]

In 1991, the daily waste generation rate per person was estimated to be 0.31kg per capita per day (World Bank, 1998). By 2005, this rate had increased to 0.41kg per capita per day (Enayetullah et al. 2005), and as revealed by this latest study, in 2014 the rate of daily waste generation per person was estimated to be 0.56kg per capita per day. According to projections made before the change of millennia, the daily waste generation rate is expected to reach 0.60kg per capita per day by 2025 (UMP, 1999). A more recent projection by the World Bank estimates that daily waste generation will reach 0.75kg per capita per day by 2025 (Hoornweg and Bhada-Tata, 2012).

27 Bangladesh Waste Database 2014, Wasteconcern.org
28 Ibid, Page 7
29 Ibid, Page 8

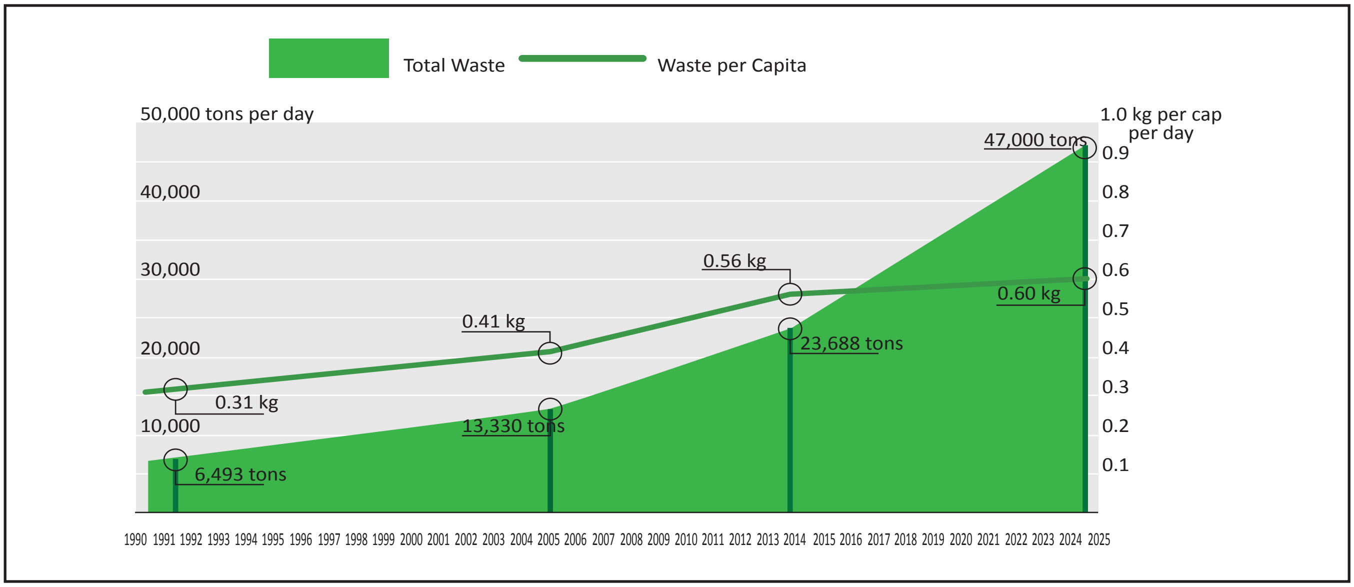


Figure 4.4: Total Waste Generation vs. Per Capita Waste Generation Rate

BAU Scenario

This scenario:

Calculated GHG emissions from municipal solid waste (MSW) and waste water;

Calculated emissions from disposal of industrial waste;

Calculated MSW from waste composition and waste arising. Waste estimates exist only for urban areas, hence this was the focus of analysis – waste arising in urban areas was estimated at 23,688t per day in 2014 and 47,000t per day by 2025;

Assumed that waste would continue to be managed as at present, meaning:

- Majority of waste will continue to go to unmanaged shallow landfills (67%)
- Remaining waste will go to unmanaged deep landfills (33%).

4.5.8.1 Mitigation Scenarios

Institutional arrangements for a safe and scientific residual waste collection system are not yet fully in place. Moreover, limited application of mitigation measures makes the situation more difficult. The timescale over which mitigation options are to be assessed is the next 15 years.

Introducing any large-scale treatment facilities to treat residual waste, such as incineration, would take a significant period of time and be a very expensive option compared to current practice. In order to develop a facility, the main stages required would be: creation of a business case; identification of a site; procurement of the contract; and construction of the facility. This could take anywhere from between four to seven years. Additionally, the infrastructure to collect and deliver the waste to the site would need to be in place. At the same time, due to a shortage of available government land and the higher value of private land around cities it is gradually becoming almost impossible to develop new dumping areas at regular intervals.

The separation of materials such as wood (2.0%) and paper (5.8%) would not reduce emissions significantly given the small proportion they make up of waste and the fact that the likely capture rates from rolling out a separate collection would be low. Separate areas could be introduced but these may be scavenged for the material deposited (making them not cost effective) and they may not be successful in separating significant quantities of material.

The main option available at present would be to build sanitary landfills and incorporate gas collection and energy generation. Developing new engineered landfills is generally the least expensive option to managing waste. Additionally, it would also reduce the health risks by reducing the unmanaged dumping of waste. Moving to engineered deeper landfills will create more methane and potentially increase emissions; to counter this, energy recovery will need to be implemented or as a minimum, flaring of the captured gas. A dry fermentation process of managing waste can also be introduced, which can generate electricity and organic manure. It is a relatively low cost technology compared to incineration and the facility takes less time to build.

Composting or organic material was also analysed as a mitigation option, as this is already being rolled out in some cities across Bangladesh and could potentially be scaled up.

The following mitigation options were analysed for MSW:

- Increased composting of organic waste
- Capture of landfill gas with flaring
- Capture of landfill gas with electricity generation
- Introduction of dry fermentation technology to generate electricity

The assumptions are shown in Table 4.20:

Table 4.20: Mitigation assumptions for the waste sector

Mitigation measure	Low ambition	Medium ambition	High ambition
Composting - % diverted from landfill (of the 33% that is currently collected and landfilled)	0	30	50
LFG with flaring	None	Yes - 30% capture	None
LFG with energy recovery	None	None	Yes – 70% capture
Dry fermentation with energy recovery	None	50% capture	90% capture

For the high ambition scenario, it is assumed that composting will be used from 2020 and that 50% of the 33% that is collected and landfilled will go to composting sites. The modeling assumes that the 50% is diverted from landfill. There may be some composting outputs that go back to landfill but this is likely to be inert materials and will not impact on emissions. For the medium ambition scenario, it was assumed that only 30% of waste currently collected and landfilled is diverted to composting. At present, composting schemes are being introduced but the exact scale and expansion level is currently unknown. Therefore 50% and 30% diversion levels were chosen based on the composition, waste volume and relatively basic technological nature of composting, which allows for shorter construction times.

Landfill gas recovery and dry fermentation options were modeled from 2020. The medium ambition scenario assumes 30% and 50% of methane emissions are captured from landfill and dry fermentation technologies respectively. For the high ambition scenario, it assumes 70% and 90% of methane emissions are captured and used to produce electricity in gas engines. Additionally, for both the flared and electricity generation options for landfill technology, 10% of the remaining methane is oxidised in the landfill cap. When electricity generation is in place it leads to greater methane collection levels compared to flaring (70% versus 30%). This is because improved methane capture systems are installed and better maintained to ensure greater levels of methane are captured, as the electricity produced presents a financial benefit and as such the operator will look to optimise income generation.

For waste water, a 25% increase in the use of centralised treatment was assumed, which is currently in the order of 17%. The modeling also assumes, with the increase in treatment capacity, the plants move from not well-managed to well-managed, reducing emissions further. Developing new waste water treatment infrastructure requires significant planning and expenditure and at present there is no significant improvement planned. Therefore, only a modest 25% increase was assumed.

4.5.9 LULUCF Sector

Bangladesh covers an area of 147,570 sq.km and is bordered by India on the west, Myanmar and India on the east and the Bay of Bengal on the south. As per the decision of the International Arbitral Tribunal (2012-2014), Bangladesh currently has 118,813 sq km of marine area (DoE, 2015). Approximately 80% of the total land area of Bangladesh is considered to be floodplains (BBS, 2011). Hilly terrain covers only some 12% of the total land area in the north-east and south-east, with average elevations of 244m and 610m, respectively (UN-REDD 2012). The Perspective Plan of Bangladesh (2010-2021) entitled 'Making Vision 2021 a Reality' (GED 2012a), reported that the recorded state-owned forest land (not necessarily supporting tree cover), and potential forest/tree growing areas, has been identified as seven million acres ,(2.82Mha) which is 20% of the land area.

Category of Forest Land

The forest land of Bangladesh is broadly categorized as state forest land (2.53 Mha) and private forest land (0.27 Mha). Of the state forest land, 1.53 million Mha are under the jurisdiction of the Forest Department (FD), MoEF. They include reserved, protected, acquired, and mangrove forest lands as well as newly accreted char lands in the estuaries of major rivers. The remaining 0.73 Mha of land designated as Un-Classed State Forest (USF) are under the control of the Ministry of Land. Village forests (homestead land) form the most productive tree resource base in the country and account for 0.27 million hectares.

Table 4.21: Category of Forest Land

Category of forestlink	Area (million ha)	% of totalland
Forest land managed by Forest Department	1.53	10.54
Unclassed state forest	0.73	5.07
Village forest	0.27	1.88
Total	2.53	17.49

From 2006 to 2012, the Bangladesh Forest Department implemented land use change (LUC) by establishing 88,336.4 ha afforestation and enhancing the forest cover up to 992, 336.4 ha. In this regard, the FD established 35,758.0 ha of mangrove plantation and 52,578.4 ha of non-mangrove, including strip, plantations throughout Bangladesh (Table 4.22).

Table 4.22: Land Use Change (LUC) through Afforestation

Sl. no	Year of Plantation	Total Plantation, ha	Non-mangrove (including Strip) Plantation, ha	Mangrove Plantation, ha
1	2007-2006	**10956.0**	7029.0	3927.0
2	2008-2007	**13231.2**	9677.2	3554.0
3	2009-2008	**11484.0**	4449.0	7035.0
4	2010-2009	**11992.6**	7213.6	4779.0
5	2011-2010	**18750.6**	13261.6	5489.0
6	2012-2011	**21922.0**	10948.0	10974.0
Grand Total		**88336.4**	**52578.4**	**35,758.0**

Annual land use changes and changes by different types of afforestation are shown in Figures 4.5 and 4.6 respectively.

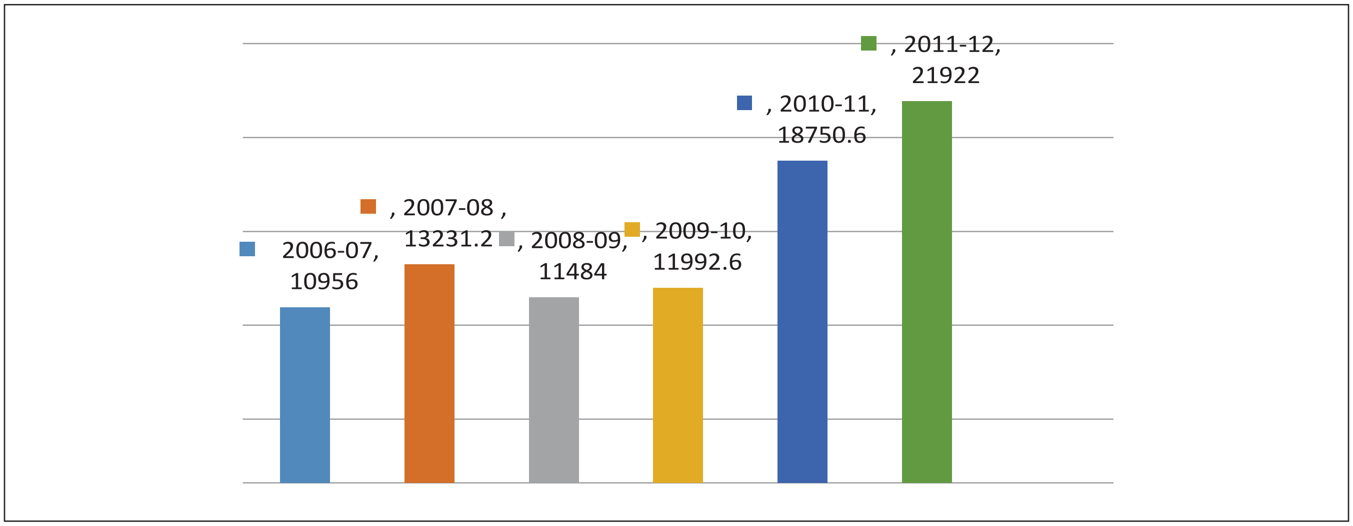


Figure 4.5. Scenario of Annual Land Use Change (in ha) through Afforestation 2012 -2016

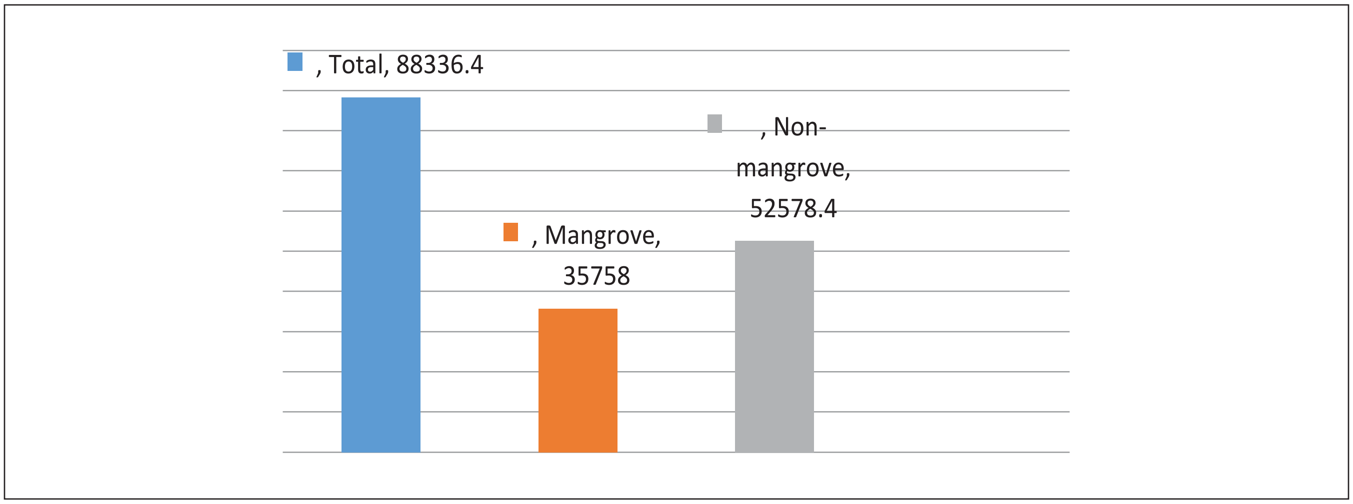


Figure 4.6. Total Land Use Changes (in ha) through different Types of Afforestation 2012 -2016

Table 4.23: National Land Use Classes (LUC) and Total Area under Forest Cover

Land Use Classes and Areas per NFA 2005- 2006 (LUC in 000 ha)		Area under Forest Cover* in ha as per NFA 2005-2006	LUC in ha 2006 - 2012	Total Area under Forest Cover in ha in 2012	Forest Cover per National LUC, %
International LUC	National LUC				
Forest 1442	Forest 1442	904,000	88336.4	992336.4	68.86
Other Wooded Land 289	Cultivated Land 8327	252,000	-	252,000	3.03
Other Land 11004	Village Land 2862	522,000	-	522,000	18.24
	Built Up Areas 104	-	-	-	-
Inland Water 2022	Inland Water 2022	-	-	-	-
Total	**14757**	**1678,000**	**88336.4**	**1766,336.4**	**11.97**

*** Forest cover with trees attaining over 30% tree cover in each LUC**

Table 4.24 Forest Cover Loss and Gain

Year	Forest Cover Loss (as per FAO), ha		Forest Cover (FC) Status in 2012, ha		
	Total	Annual	Total FC	FC loss	Existing FC
2010-2005	3400	680	47663.8	2720	44943.8
2012-2010	1320	660	40672.6	1320	39352.6
Total Loss and Gain, ha			88336.4	4040	*84296.4

*** Remaining Total Forest Cover:** 1762 = 84296.4+1678000, 296.4 ha or 11.94%

Based on annual forest cover loss (FC Loss) in Bangladesh, as established by FAO (680 ha/yr during 2005-2010 and 660 ha/yr during 2010 –2012), it was found that a total of 4,040 ha of forest cover was lost between 2006 and 2012. As a result, the remaining total forest cover in Bangladesh in 2012 was 1,762,296.4 ha or 11.94% of the total area of Bangladesh (Table 4.24).

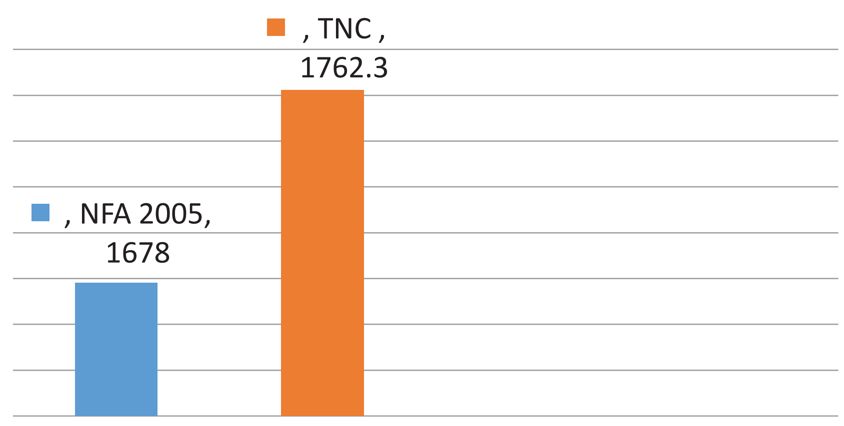


Figure 4.7: Total Area under Forest Cover (in 000 ha) identified by NFA 2005 and TNC for 2012

GHG Emissions from the LULUCF sector

Net emissions from the LULUCF sector were estimated at about 13MtCO_2eq in 2000, mainly from forest and grassland conversion (3.6MtCO_2eq), emissions and removal from soil (16MtCO_2eq) and emission ranges in forest and other woody biomass stocks as carbon sequestration (5.9MtCO_2eq). Emissions were estimated to have increased a significant 12% by 2010, due to a substantial decrease in cropland and forestland area and a considerable increase in settlement from 2000 to 2010 for the growing population. A number of government development strategies, especially the 20% increment of production forest by 2021, will discontinue this trend by decreasing emissions to 12MtCO_2eq and 13MtCO_2eq by 2020 and 2025 respectively from 15MtCO_2eq in 2010. Such development actions are expected to contribute to a sequestration of CO_2, which amounts to -6.4 and 6.4MtCO_2eq, in 2020 and 2025 respectively.

4.5.9.1 Mitigation Scenarios

A mitigation scenario assumes the following:

- Continuation of coastal mangrove plantation with resilience co-benefit;
- Continuation of coastal afforestation programme with resilience co-benefit;
- Continuation of social and homestead plantation measures;
- Wide scale adoption of co-management to increase forest coverage especially in the reserved forest;
- New plantation especially on char land or on barren island land;
- New re-afforestation programme especially in the degraded forest areas; and
- Wet-land forest restoration programme with resilience co-benefit,

4.6. Cost of Mitigation

The table below includes the assumptions made in terms of capital fixed costs (Capex) and O&M variable costs (Opex).

Table 4.25: Assumptions for estimating investment needs for key mitigation measures

Mitigation measure		Estimated investment required (million USD, 2011-2030)	Capex (2011-2030)	Opex (2011-2030)	Reference
Switching to 100% super-critical coal power generation		16,500	$1,500/kW	2-3% of Capex	Expert opinion as technology is still under development
Developing utility-scale solar energy		1,300	$ 1.4 Million/MW	2% of Capex	Recent trend in offers received by the Bangladesh Power Division
Scaling up wind energy		600	$2 million/MW	1% of Capex	Vestas 60 MW offer to BPDB
Repowering steam turbine with CCGT		630	$623/kW	1% of Capex	Awarded offer of Ghorashal 3rd Unit for re-powering
Expanding the Solar Homes Programme		117	Average $200/30Wp system	30% of Capex as battery replacement occurs every after 5 yrs	IDCOL enlisted PO's sales offer
Other solar	Solar Irrigations Pumps	60	$40,000 per 8 KWp pumps with distribution system	$1,500 per pump	IDCOL Solar Irrigation Programme
	Solar Mini-grids	25	$5000/kWp	0.5% of Capex	IDCOL mini-grid programme
	Solar Nano-grids	27	$4500/kWp	0.5% of Capex	PO's nano-grid implementation target
	Pico-solar	10	$4/Wp	nil	IFC-GIZ launched programme
Scaling up biomass production from sugar		17	$4000/kWp	0.25% of Capex	BUET study “feasibility on cogeneration”
Building an elevated expressway in Dhaka with the aim of decongestion of the main urban traffic arteries		26.5			Dhaka Elevated Expressway – Summary Report
Dhaka mass rapid transit system		2,700			Dhaka Mass Rapid Transit System Feasibility Study

4.7 Institutional Arrangements for Mitigation

The Government of Bangladesh considers climate change as a priority concern and is committed to take urgent and long-term actions to reduce the vulnerability of its people and the risk to national development. The Ministry of Environment, Forest and Climate Change (MoEFCC) is the main focal government ministry to deal with climate change issues. The MoEFCC set up a National Climate Committee in 1994 for policy guidance and to oversee the implementation of obligations under the UNFCCC. In addition to the MoEFCC and DoE, other key ministries and agencies involved in climate issues are: the Ministry of Power, Energy and Mineral Resources including Power Cell, the Power Development Board, SREDA and other power generation, transmission and distribution utilities; the Ministry of Food and Disaster Management including the Department of Disaster Management and the Comprehensive Disaster Management Programme; the Ministry of Water Resources including the Bangladesh Water Development Board, the Water Resource Planning Organization and the Flood Forecasting and Warning Centre; the Ministry of Local Government and Cooperation, which includes the Local Government Engineering Department and the Department of Public Health Engineering; the Ministry of Agriculture including the National Agricultural Research Systems that develop new crops and demonstrate practices suited to different climatic conditions in the country; the Ministry of Livestock and Fisheries including the Department of Fisheries and the Fisheries Research Institute; and the Ministry of Health and Social Welfare (MoEFCC/ADB, 2014).

The GOB has instituted Climate Change Cells (CCC) in several ministries and line agencies headed by focal points whose task is to ensure that their activities reflect consideration for climate change. The MoEFCC is mandated to provide the overall coordination and integrate climate change risk management at both national and local levels.

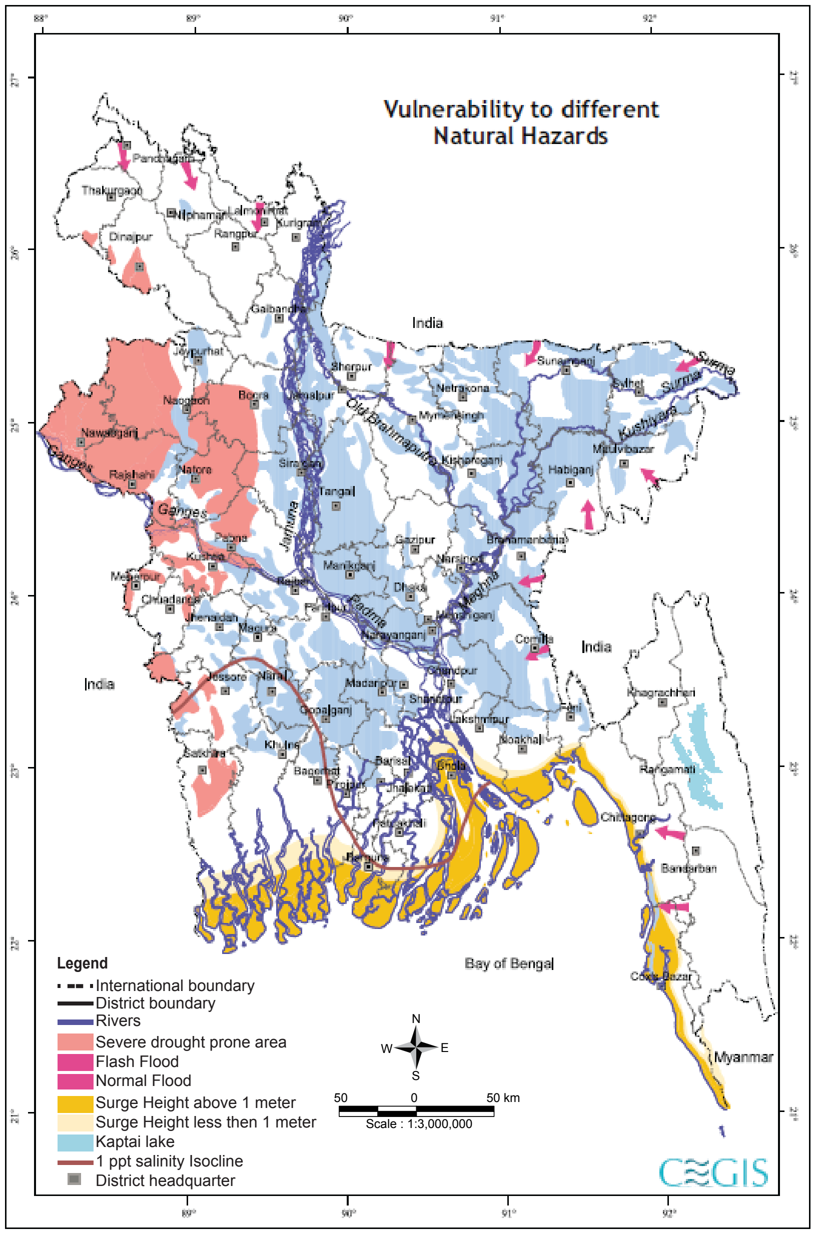
The MoEFCC has established a Climate Change Unit (CCU) to facilitate and coordinate with the CCCs. The CCU is tasked with focusing on building the capacity of the government to mainstream climate change issues, particularly development activities.

Chapter 5

Studies on Vulnerability and Impacts and Programmes containing Measures to Facilitate Adequate Adaptation to Climate Change

5.1 Background

Bangladesh is one of the most climate vulnerable countries in the world (German Watch, 2016). For the past two decades, Bangladesh has continuously faced the adverse impacts of climate variability and change that threaten sustainable development and economic growth in the country. The challenges posed by climate change contribute to making peoples' lives and livelihoods complex and vulnerable. Bangladesh is heavily exposed (Figure 5.1) to various types of natural hazards such as riverine floods, recurrent and flash floods, tropical cyclones and storm surges, droughts, salinity intrusion, sea-level rise, and riverbank and coastal erosions. Climate change is causing the duration, magnitude and frequency of such natural hazards to worsen and making poor rural communities more vulnerable than they already are. Despite being the ground zero of the impacts of climate change, Bangladesh has been working persistently to tackle its high level of vulnerability and at the same time, is working towards development for improving the socio-economic conditions of its vulnerable communities. Over the last decade, Bangladesh has played a strong and significant leadership role in the context of adaptations to climate change. The nation has not only introduced innovative approaches to adaptations in vulnerable communities, but has also actively mobilised resources to tackle the challenges posed by climate change.



Source: CEGIS, Dhaka.

Figure 5.1: Bangladesh's vulnerability to various types of natural hazards

5.1.1 Adaptation Actions

Over the last three decades, the Government of Bangladesh has invested over $10 billion to make the country more climate resilient and less vulnerable to natural disasters. Flood management embankments, coastal polders and cyclone shelters have been built, and important lessons learnt on how to implement such projects successfully with the active participation of communities and in the dynamic hydrological conditions of Bangladesh.

To enhance integration of climate change adaptation activities in all key policies and sectors, Bangladesh has recently established two innovative funds: the Bangladesh Climate Change Trust Fund (BCCTF) from the government's own budget and the Bangladesh Climate Change Resilient Fund (BCCRF) with the support of development partners. Bangladesh submitted the National Adaptation Programme of Action (NAPA) in 2005 (revised in 2009) and prepared a climate change action plan, the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009. With respect to vulnerabilities, the Government of Bangladesh has identified the following areas of intervention to address the adverse impacts of climate change:

Key areas of intervention to address adverse impacts of climate change	
1	Food security, livelihood and health protection (including water security)
2	Comprehensive disaster management
3	Coastal zone management including salinity intrusion control
4	Flood control and erosion protection
5	Building climate resilient infrastructure
6	Increased rural electrification
7	Enhanced urban resilience
8	Increasing resilience of vulnerable groups
9	Development of climate resilient cropping systems
10	Development of surveillance systems for existing and new disease risks
11	Ecosystem based adaptation (including forestry co -management)
12	Community based conservation of wetlands and coastal areas
13	Implementing drinking water and sanitation programmes in areas (e.g., coastal areas and flood and drought prone areas) at risk from climate change
14	Policy and institutional capacity building

Based on the above mentioned areas, the following adaptation actions are prioritised for Bangladesh:

Adaptation priorities for Bangladesh	
1	Improved early warning system for tropical cyclones, floods, flash floods and drought
2	Disaster preparedness and construction of flood and cyclone shelters
3	Tropical cyclones and storm surge protection
4	Inland monsoon flood-proofing and protection
5	Climate resilient infrastructure and communication
6	Climate resilient housing
7	Repair and rehabilitate existing infrastructure (including coastal embankments, river embankments and drainage systems, and urban drainage systems)
8	Plan, design and construct urgently needed new infrastructure (various types of shelters, low cost disaster resilient housing, protection schemes, water management structures, etc.)

9	Improvement of urban resilience through improvement of drainage system to address urban flooding
10	River training and dredging (including excavation of water bodies, canals and drains)
11	Development and dissemination of stress tolerant (salinity, drought and flood) varieties of rice; improved varieties of livestock and fisheries
12	Research and knowledge management
13	Adaptation based on local-level perspectives
14	Adaptation to climate change impacts on health
15	Biodiversity and ecosystem conservation
16	Capacity building at individual and institutional levels to plan and implement adaptation programmes and projects in Bangladesh

Source: GoB, 2015a and GOB, 2015b.

Climate Change Policy and Strategies in Bangladesh

Bangladesh has two major strategies to deal with climate change: the NAPA 2005 (updated in 2009); and the BCCSAP 2009. Until 2005, Bangladesh did not have any climate change strategy or plan and as the country experiences natural hazards/disasters almost every year, the government had been taking several measures in response to hazards/disasters. A wide variety of those measures implemented as part of key policies had the potential to reduce vulnerability to climate change (Tanner et al., 2007). NAPA 2005 was formulated with the strategic goal and objective of reducing the adverse effects of climate change (UNDP, 2016). However, NAPA 2005 considered only urgent and immediate priorities for adaptation and engaged sector-based line ministries (Alam et al., 2011).

In the post NAPA 2005 years, a significant shift occurred in the planning process in response to climate change. The influence of international climate change policies and politics on national policy processes became more prominent. At the same time, political awareness and awareness among stakeholders grew (Khan, 2012). Moreover, incentives were created by an expectation of significant climate change-related funding (Alam et al., 2011). All these were driving forces behind the formulation of a new strategy for climate change and also the updating of NAPA 2005.

In 2008, MoEF prepared the BCCSAP prior to the UK-Bangladesh Climate Change Conference in London. This BCCSAP was revised and adopted by the government in July 2009. It provided a ten-year programme (2009-2018) for capacity and resilience building in the country to meet the challenge of climate change. Following the adoption of the BCCSAP, Bangladesh allocated the equivalent of approximately $400 million in the years leading up to 2016. This money was channelled through the Bangladesh Climate Change Trust Fund (BCCTF) within the framework of the Climate Change Trust Act, 2010 in support of the implementation of the plan outlined in the BCCSAP. Initially a multi-donor trust fund (MDTF) was established in 2010 to secure funding from development partners. Both funds were managed by the Government of Bangladesh through appropriate management structures. In the case of the BCCTF, fiduciary responsibility was vested in the World Bank for the first five years.

Institutions for Climate Change

The National Environment Council (NEC) is the apex advisory body, chaired by the prime minister of Bangladesh. It provides strategic guidance. The National Steering Committee for Climate Change (NSCCC) is directly accountable to the NEC. The NSCCC is headed by the MoEF and consists of the secretaries to all line ministries, as well as representatives from civil society and from the private sector. This committee is responsible for preparing, coordinating and facilitating all national actions related to climate change and also developing and overseeing implementation of the BCCSAP 2009.

The Climate Change Negotiation Working Group (CCNWG) develops and coordinates the position of the country on climate change negotiations at the international level. The Ministry of Environment and Forests (MoEF) is the national focal point of the government as it hosts all climate change related institutions in the cry.

The climate change branch is housed in the MoEF. This branch provides policy, advice and support to the National Steering Committee for Climate Change.

5.1.2 Scope of work

Vulnerability and adaptation assessment activities are designed to conduct studies on vulnerabilities and impacts, and include programmes containing measures to facilitate adequate adaptation to climate change. They aim:

- to review the relevant national policy and strategic documents and identify key adaptation issues and gaps;
- to assess vulnerabilities to and impacts of climate change on different sectors and dependent livelihoods and the costs of adaptation;
- to prepare a comprehensive inventory of the initiatives and programmes which are being implemented by government and non-government agencies towards effective adaptation to natural hazards/disasters and climate change impacts; and
- to develop a comprehensive strategy on adaptation considering impacts and vulnerabilities of climate change and climate variabilities in Bangladesh.

5.2 Approaches and Methodology

The study contributed on the basis of the following steps:

5.2.1 Review of secondary literature

The study team collected and reviewed relevant literatures that include: peer reviewed journal papers and reports; authentic reports published by reputed government, non-government and international organizations; and policy and strategy documents.

5.2.2 Field data/information collection

A multi-disciplinary team consisting of climate change vulnerability and adaptation experts, sectoral and vulnerability experts, a policy and institutional expert, and a gender specialist, conducted a series of consultations at national and regional levels to collect and capture relevant data/information for the required deliverables. The aim was to consider different qualitative methods that include focus group discussions, in-depth interviews, expert consultations, etc. and geospatial tools to deliver the targeted outputs.

5.3 Climate Trend Analysis (National Circumstances)

5.3.1 Data Quality

Temperature and rainfall data sets collected from the Bangladesh Meteorological Department (BMD) used for the analysis of trends suffers from various limitations. Missing values are a major problem in both temperature and rainfall data sets. This is indeed a major stumbling block to creating a consistent data base following the standard of the World Meteorological Organization (WMO). Due to a lack of metadata, many of the questionable observations could not be verified. Although the Bangladesh Meteorological Department (BMD) has 35 stations, the record lengths vary significantly as the stations were set up in different years. For annual temperature and rainfall analyses, this study considered 1961 as the base year as per the IPCC guidelines. For temperature and rainfall, 18 and 13 stations, respectively, have consistent records until 2014, with a very small number of missing values. Missing values were filled in by the regression method and the unusual records have been removed and filled in by regression or from nearby stations. Secondary literature, which considers variable time-lines, was also assessed for temperature and rainfall extremes.

The BMD has recently taken initiatives to improve its climatological database. An automated logger and radar-based rainfall data unit have been established to gather three-hourly observations in some parts of the country (GoB, 2012). Such efforts need to be strengthened in order to have shorter time step-based data sets with increased coverage. Once such a data collection system is operational, the country will be able to embark upon systematic climate change analysis.

5.3.2 Primary Elements

5.3.2.1 Temperature

Bangladesh is generally experiencing rising temperatures. The mean annual temperature rose by 0.0056°C/year from 1961 to 2014 (Figure 5.2). The nature of the trend varies regionally in the areas vulnerable to natural hazards (Table 5.1 and Figure 5.1). Out of 18 stations under consideration, 14 show increasing trends among which 10 were found to be statistically significant. Although the remaining four stations demonstrate increasing trends, they are statistically insignificant. Some of the stations also demonstrate decreasing trends in mean temperature (Figure 5.3).

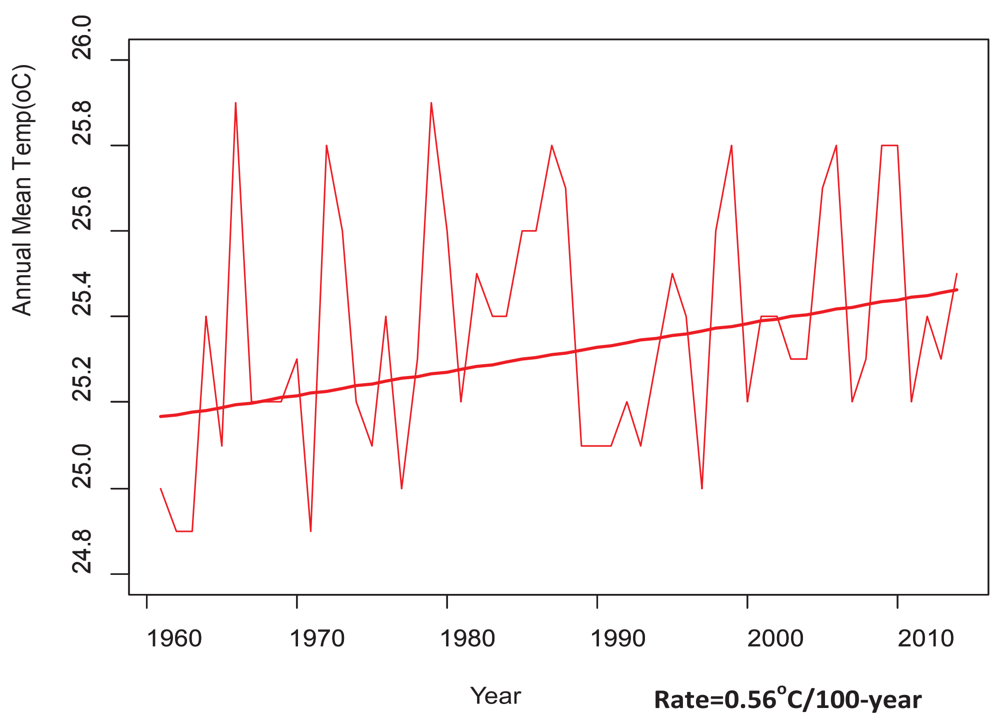


Figure 5.2: Trend in annual mean temperature in Bangladesh (1961-2014). The trend line demonstrates Sen's slope estimator.

Table 5.1: Meteorological station-wide trends in annual mean temperatures and annual rainfall in Bangladesh

Station Name	Vulnerable Zone	Annual Mean Temperature Trend	Annual Rainfall Trend
Barisal	Cyclone, tidal surge and salinity	Increase	Decrease
Bogra	Drought	Increase*	Increase
Chittagong	Cyclone, tidal surge	Increase*	-
Comilla	Flood	Decrease	Decrease
Cox's Bazar	Cyclone, tidal surge	Increase*	Decrease*
Dhaka	Flood	Increase*	Decrease

Station Name	Vulnerable Zone	Annual Mean Temperature Trend	Annual Rainfall Trend
Dinajpur	Drought	Decrease	-
Faridpur	Flood	Increase*	Decrease
Ishurdi	Flood	Increase	-
Jessore	Drought	Increase*	Decrease
Khulna	Drought, cyclone, tidal surge and salinity	Increase	-
Maijdee Court	Cyclone, tidal surge and salinity	Increase*	Decrease
Mymensingh	Flood	Decrease	Increase
Rangamati	-	Decrease	Increase
Rangpur	Drought	Increase*	Increase
Satkhira	Drought, cyclone, tidal surge and salinity	Increase*	-
Srimongal	Flood	Increase*	Increase*
Sylhet	Flood	Increase	Increase

*Significant at 5% level.

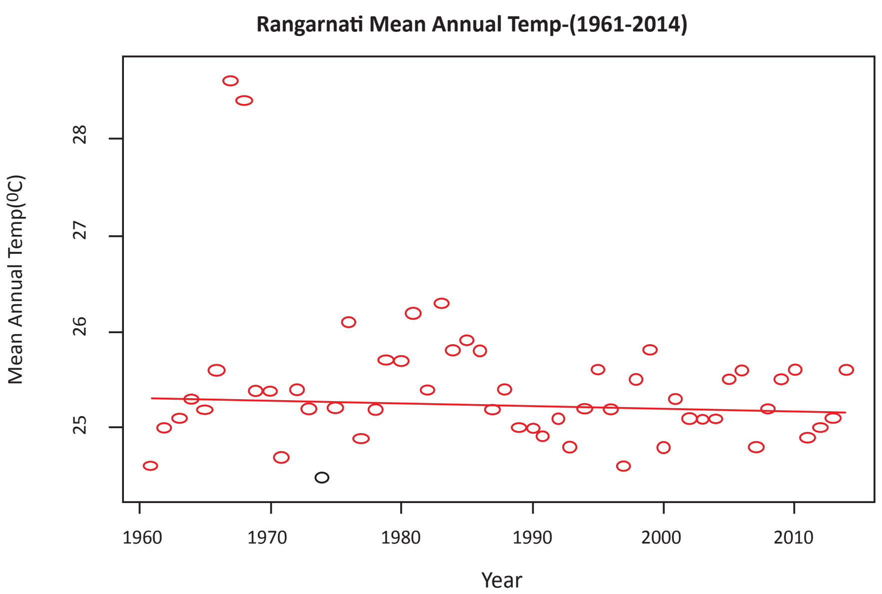


Figure 5.3: Decreasing trend in mean temperature for the Rangamati station in the south-eastern region. The trend line demonstrates Sen's slope estimator

Nishat and Mukherjee (2013) analysed seasonal temperature trends for Bangladesh. Their analysis shows that over the past few decades, most of Bangladesh experienced warmer winters with a prominent increase in the minimum temperature (Nishat and Mukherjee, 2014). Hotter summers were also experienced during the pre-monsoon and monsoon months with a prominent rise in the maximum and minimum temperatures. An increase in the minimum temperature by 0.45°C and 0.52°C was observed during the winter (December, January and February) and monsoon (June, July and August), respectively. Maximum temperatures were also observed to have increased during the pre-monsoon (MAM) and post-monsoon (JJA) months by 0.87°C and 0.42°C, respectively. A rise in the minimum temperature during the winter season (DJF) was observed in 25 out of 34 climate observatories of the BMD. A rise in the maximum temperature during the hot summer months of JJA was observed in almost all the stations (except Rangpur), and was prominently observed in the range of 0.03–0.05°C/year in Syedpur, Sitakunda, Sylhet and in Tangail stations (Nishat and Mukherjee, 2014).

Although on average the winter temperature has increased in Bangladesh, episodes of cold spells are not uncommon (GoB, 2012). During a cold spell, the average temperature could drop to as low as 4oC. The most affected region during such a hazard is northern Bangladesh which is located close to the foothills of the Himalayas. People in this region used to suffer from income and food poverty or monga during agricultural lean seasons (between transplantation and harvest of the aman rice crop) (Zug, 2006; Ahamad et al., 2013). They suffer significantly during a cold spell due to a lack of warm clothing and shelter (Shonchoy, 2011). The Government of Bangladesh and non-government organizations have recently initiated income generation programmes to reduce the poverty and financial hardships of the people of this region with a particular focus on the people facing food insecurity during agricultural lean seasons (Paul et al., 2013). Monga has now been virtually eliminated.

5.3.2.2 Rainfall

In Bangladesh, about 75% of the annual rainfall occurs during the monsoon months (June-September). The monsoon is both hot and humid and the country experiences torrential rainfall throughout the season. Cooler days are however observed during and following heavy rainfall events. Post-monsoon is a very short season with little or no rainfall and a falling of night time minimum temperature occurs. Mean annual rainfall in Bangladesh from 1961 to 2014 was 2,378 mm and the range was 1,746 to 2,993 mm.

Rainfall trend analysis based on data from 13 stations demonstrates increasing trends only in six stations. Figure 5.5 shows the trend in the mean annual rainfall in Bangladesh. Among them, a statistically significant increasing trend has been detected in the flash flood prone Srimongal station located in the high rainfall north-east hydrologic zone of the country. The remaining seven stations show a decreasing trend. The only significant decreasing trend was detected in the Cox's Bazar station located in the eastern hilly hydrologic region of the country (Figure 5.4).

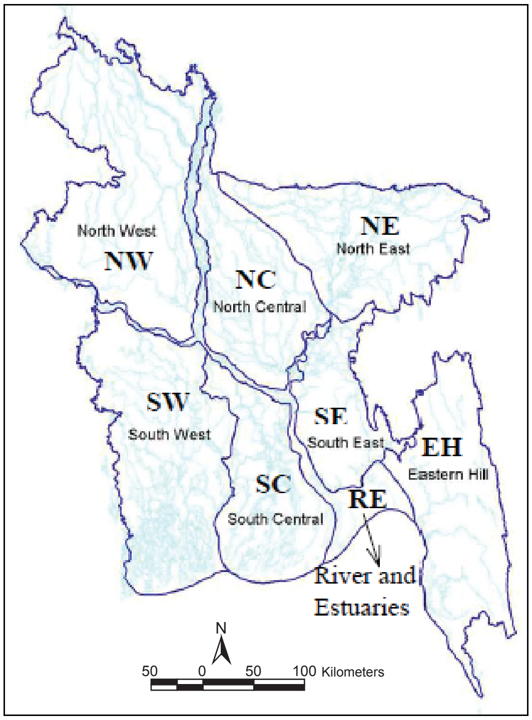


Figure 5.4: Hydrological Regions of Bangladesh (MPO, 1986).

In Bangladesh, an overall increase in the mean seasonal rainfall is observed in all seasons (Nishat and Mukherjee, 2014). The maximum mean seasonal rainfall increase observed during the pre-monsoon (MAM) and monsoon (JJA) is around 100 mm. Although the winter season (DJF) experiences the minimum rainfall, a positive trend is observed in 27 out of 32 rainfall stations of the BMD. This trend is prominent in the coastal stations: Sitakunda, Patuakhali, Kutubdia and in Khulna in the range of a 1.2–2.1 mm/year increase. Increase in the pre-monsoon (MAM) seasonal rainfall is also evident in 30 out of 32 stations of the BMD, and is also prominent in the coastal stations of Kutubdia, Mongla, Rangamati and Sandwip stations in the range of 8–13 mm/year increase in mean seasonal rainfall. Increase in the monsoon (JJA) rainfall is observed in 18 out of 32 meteorological stations, and is also prominent in the coastal stations: Kutubdia, Mongla, Sitakunda and in Teknaf in the range of 21–42 mm/ year increase in mean seasonal rainfall. Post-monsoon (SON) rainfall is also observed to have increased in 24 out of 32 meteorological stations, and is prominent in the coastal observatories of Khepupara, Kutubdia, Mongla and in Teknaf stations in the range of 12–24 mm/year (Nishat and Mukherjee, 2014).

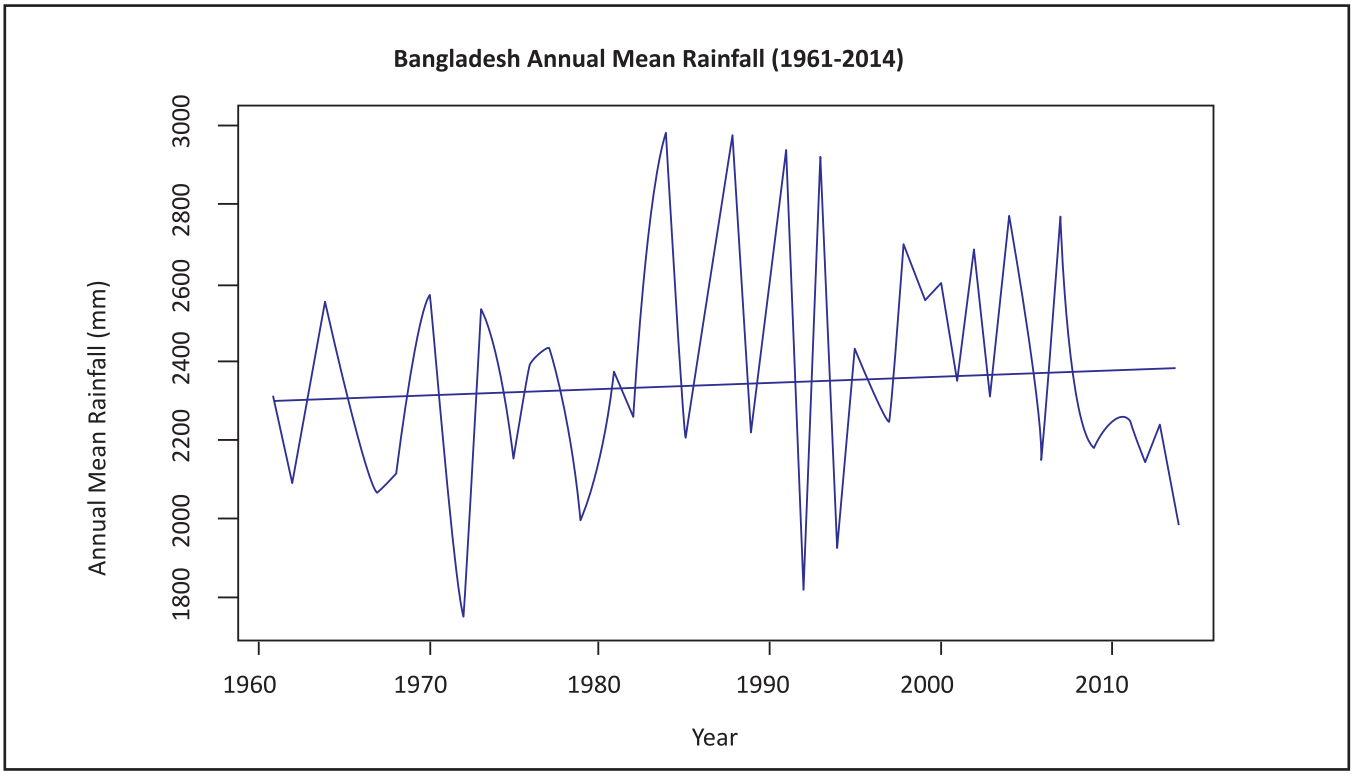


Figure 5.5: Trend in mean annual (average of 13 stations) rainfall in Bangladesh from 1961-2014. The trend line demonstrates Sen's slope estimator.

5.3.2.3 Temperature and Rainfall Extremes

5.3.2.3.1 Temperature Extremes

Bangladesh experiences significant variability in extreme temperatures. Rahman et al. (2015) analysed maximum and minimum temperatures in five meteorological stations: Dhaka, Cox's Bazar, Rajshahi, Bogra and Sylhet. Temperature records were considered for the years from 1953-2012 for Dhaka, 1948-2012 for Cox's Bazar, 1972-2012 for Rajshahi, 1958-2012 for Bogra, and 1957-2012 for Sylhet. With the application of the Mann-Kendal test, they found a significant increasing trend in maximum temperature in Cox's Bazar and Sylhet, and a significant decreasing trend in maximum temperature in Dhaka and Bogra. A significant increasing trend in minimum temperature was detected in Dhaka and Cox's Bazar whereas a significant decreasing trend was observed in Rajshahi (Table 5.2)

Table 5.2: Linear trends for annual maximum and minimum temperature in selected meteorological stations in Bangladesh

Station	Annual Maximum Temperature Slope (%)	Annual Minimum Temperature Slope (%)
Dhaka	-2.5*	4.9*
Cox's Bazar	2.1*	3.8*
Sylhet	2.1*	1.6
Rajshahi	-0.4	-4.8*
Bogra	-5.7*	0.6

Source: Rahman et al., 2015. *Significant at 5% level.

5.3.2.3.2 Rainfall Extremes

Bangladesh often experiences long durations of heavy rainfall associated with 'norwester' thunder storms and cyclonic storms (Rafiuddin et al., 2010). In September 2004, 341mm of rain fell within a 24-hour period in Dhaka, causing severe urban flooding that halted regular urban activities (Dasgupta et al., 2015). On 11 June, 2007 around 408 mm of rainfall was measured in Chittagong, the Port City located in the south-eastern region of Bangladesh, and the extreme rainfall resulted in serious urban flooding and landslide that killed at least 124 people (Aminuzzaman, 2014). On July 28, 2009 around 333 mm of rains fell in Dhaka within a 12-hour period that caused serious flooding by inundating most of the city (Dasgupta et al., 2015). On that particular day, over a period of six hours, about 290 mm of rainfall occurred.

Islam et al. (2014) analysed extreme rainfall in Bangladesh from 1961 to 2010. They found an approximately equal proportion of increasing and decreasing trends of various precipitation indices. Only a small number of precipitation indices demonstrated significant trend as rainfall is a highly variable climatic parameter. During the period of analysis, consecutive dry days (CDD) showed the highest significant increasing trend. Among the 27 stations included in the analysis, 24 of them demonstrated increasing trends in CDD with significant trends in only three stations. On the other hand, negative trends in the simple daily intensity index (SDII) were detected in 18 stations distributed throughout eight hydrological regions (Figure 5.6) delimited by the Master Plan Organization (1986) (Table 5.3). Among the 18 stations, significant negative trends were found in five stations. Very few significant trends were detected in rainfall greater than 10mm, 20mm, 100mm (R10, R20, and R100) and the yearly total precipitation amount (PRCPTOT). Analyses of the monthly maximum one day precipitation (RX1) and the monthly maximum five days precipitation (RX5) showed non-significant increasing trends in 18 and 20 stations respectively.

Table 5.3: Trends in simple daily intensity index (SDII) for individual stations in Bangladesh (1961-2010)

Hydrologic Region	Stations		SDII	Hydrologic Region	Stations	SDII
North East	Srimongal		-0.041	South Central	Barisal	-0.032
	Sylhet		-0.043		Khepupara	0.008
North West	Bogra		0.011		Madaripur	-0.113
	Dinajpur		-0.01		Patuakhali	-0.185
	Ishurdi		-0.022	River and Estuary	Bhola	-0.044
	Rajshahi		-0.098*		Hatiya	0.035
	Rangpur		0.047		Sandwip	-0.189

North Central	Dhaka		0.024	Eastern Hilly Region	Chittagong	0.05
	Mymensingh		-0.001		Cox's Bazar	-0.074
South East	Chandpur		-0.143*		Rangamati	-0.007
	Comilla		-0.154*		Sitakunda	0.035
	Feni		-0.007		Teknaf	0.224
	Maijdeecourt		-0.146*			

Source: Islam et al., 2014. *Significant at 5% level.

5.4 Climate Change and Challenges of Development

Climate variability and change inflict damages to natural and socio-economic systems. It is considered an externality to production and consumption of goods and services. Key economic sectors (e.g., agriculture and infrastructure) in climate vulnerable countries are affected by extreme weather events. According to the 5th Assessment Report of the IPCC, extreme weather events such as floods, cyclones, rises in sea level and droughts could occur with higher intensity and frequency unless measures are taken to reduce the pace of current climate change. As a result, climate change impacts and the resultant vulnerabilities would be exacerbated, and additional costs in terms of losses of lives and damages to properties would be incurred. The extent of such losses and damages to any system again depends on the geophysical context, exposure, sensitivity and adaptive capacity. It is possible to reduce climate change related losses and damages by undertaking appropriate adaptation measures and building adaptive capacity. Implementation of these measures would incur costs that are generally referred to as “cost of adaptation”. *The UNFCCC defines costs of adaptation as “the cost of any additional investment needed to adapt to or exploit future climate change”* (UNFCCC, 2007). A full accounting of ‘adaptation cost’ however needs to consider the resources spent to develop, implement, and maintain the adaptation action along with the accruement of reduced damages or welfare increases involving monetary and non-monetary metrics (Chambwera et al., 2014). Figure 5.6 provides a graphical representation of the link between the cost of adaptation (on the x-axis) and the residual cost of climate change (on the y-axis). A fraction of climate change damage can be reduced at no cost (e.g., by changing sowing dates in the agricultural sector). With increasing adaptation costs, climate change costs can be reduced further. In some cases (left-hand panel), sufficiently high adaptation spending can take the residual cost to zero. In other cases (right-hand panel), some residual cost of climate change is unavoidable.

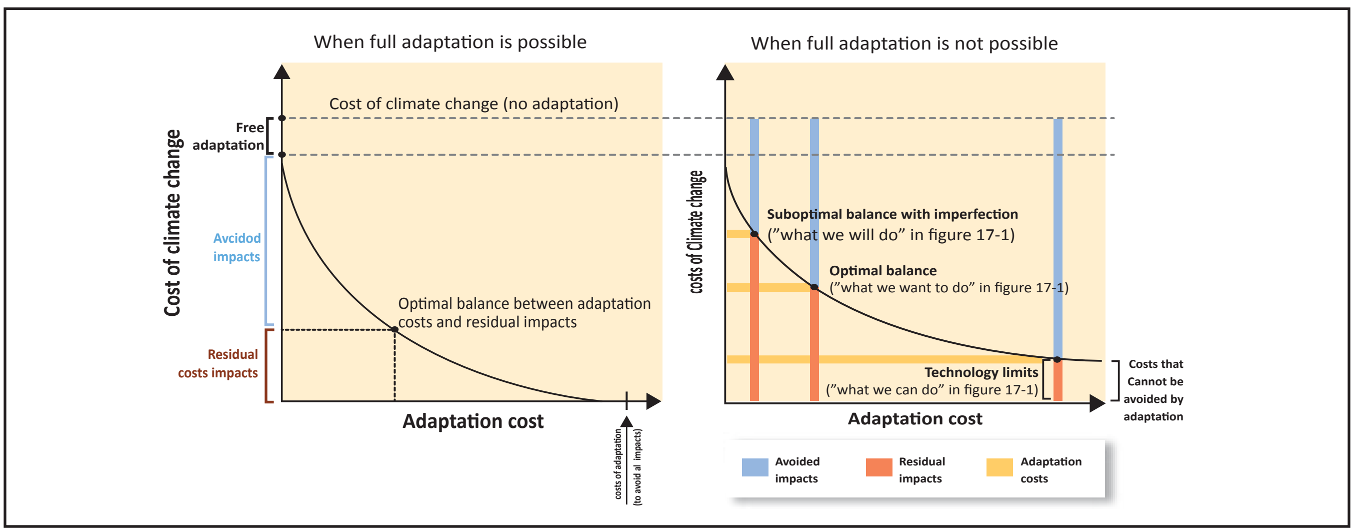


Figure 5.6: Graphical representation of link between the cost of adaptation (on the x-axis) and the residual cost of climate change (on the y-axis). The left panel represents a case where full adaptation is possible, while the right panel represents a case in which there are unavoidable residual costs (Source: Chambwera et al., 2014).

5.4.1 Climate Change, Poverty and Economy

Climate-related disasters exacerbate other stressors, often with negative outcomes for livelihoods, especially for people living in poverty *(high confidence)* (Olson *et al.*, 2014). Poor households are often disadvantaged with regard to access to land and they end up settling in areas vulnerable to natural hazards such as low-lying flood plains and coastal areas. Floods, drought, salinity intrusion, cyclones, rises in sea level and storm surges are disasters that cause loss of crops and livestock, damage pasturelands, increase fodder scarcity, destroy houses/shelters, decrease production and increase incidences of diseases and health risks (GoB, 2009). Through these processes, eventually the climatic hazards including subtle shifts and trends to extreme events affect livelihoods, particularly of the poor (Olson *et al.*, 2014).

Extreme weather often causes multiple deprivations and pushes the already poor in both rural and urban contexts into chronic poverty (Figure 5.7). This chronic poverty continues in a spiral when people are unable to recover and rebuild their assets. In the Bangladesh context, Jahan (2000) analysed the economic and financial damages and recovery of urban people in Dhaka during the 1998 flood which inundated 70% of the country. The flood affected the physical assets as well as the occupations and livelihoods of Dhaka City people considerably. A post flood survey demonstrated that low income groups constituted the major victims of the flood. Recovery from the flood damage was the most difficult part for the affected poor/disadvantaged households. Households which were considered to have recovered completely varied between 26% and 37% and belonged to petty businessmen, rickshaw-pullers, factory workers and day laborers (Jahan, 2000). Sidr, a category 4 cyclone devastated south-western coastal districts of Bangladesh in November 2007. The estimated loss was $1.7 billion equivalent to three percent of the total national GDP of Bangladesh of that year (GoB, 2008; Nadiruzzaman and Wrathall, 2015). Physical damages (to houses, infrastructure, etc.) constituted about two-thirds of all damages and one-third was economic loss. In many districts, more than half of the thatched-roof houses housing the extreme poor,were completely destroyed. Most economic losses were incurred in the private sector. About two million people lost their income and employment. Poverty rates are higher in the Sidr affected areas than the national average (GoB, 2008). The long-term recovery process moved at a slow pace although the Government of Bangladesh achieved its target of short-term recovery. Three years after the event occurred, affected households remained unable to reconstitute their assets and 'normalise' livelihoods to pre-Sidr levels. (Paul and Rahman, 2013).

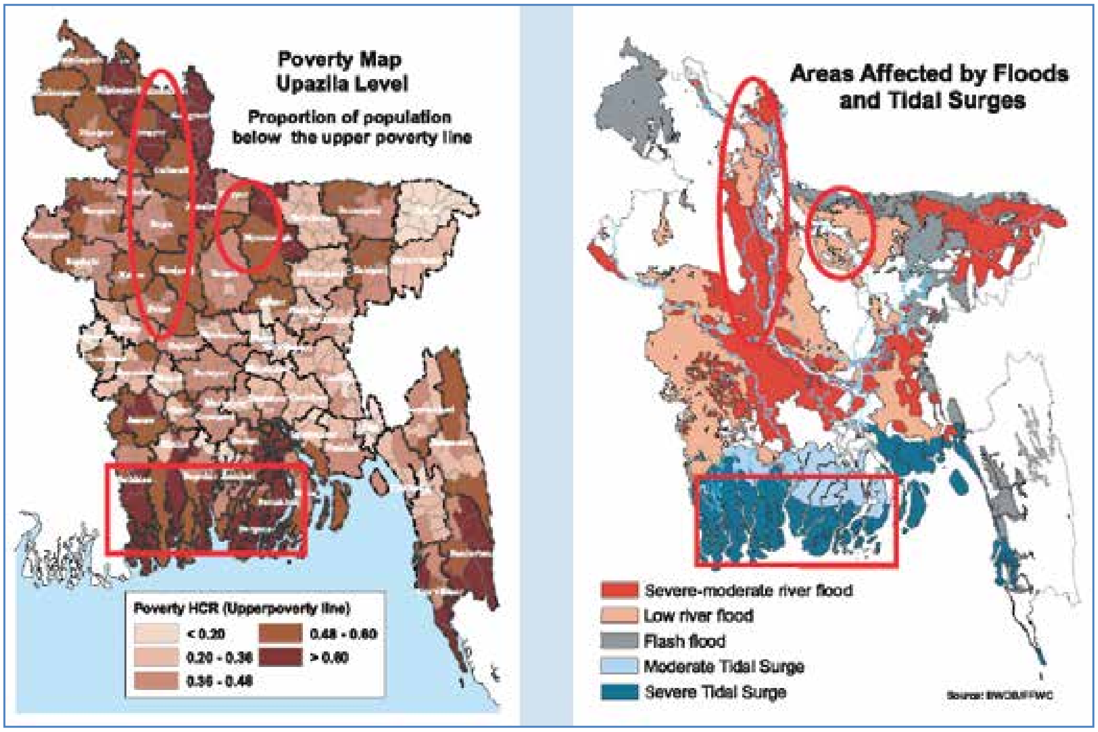


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Figure 5.7: Natural hazards and poverty map of Bangladesh
Source: BBS, World Bank, and WFP 2009

Poverty traps also arise from food price increases, restricted mobility, and discrimination. Poverty impacts also depend on the specific food crops for which prices increase. A 10 percent price increase for rice would increase poverty in Bangladesh by 0.67 percentage points (Hallegate et al., 2015).

The agriculture sector will remain the single most important contributor to the GDP in the next few decades in Bangladesh. The sector will remain vulnerable to climatic extremes in the future as well. Note that a reduction in crop yield as a result of total or partial damage due to extreme events constitutes the key impact facing the crop agriculture sector. The World Bank (2010) projected agricultural GDP to be 3.1 percent lower each year from the base year 2005 to 2050 due to the impact ($36 billion in lost value-added). With the broader economy-wide implications, climate change could cost Bangladesh $129 billion in total GDP over the 45-year period 2005–2050. This is equivalent to $2.9 billion overall lost each year to climate change or an average annual 1.6 percent reduction in total GDP. However, under less optimistic scenarios, the annual loss could be as high as $5.1 billion. Average loss in agricultural GDP due to climate change is projected to be a third of the agricultural GDP losses associated with existing climate variability. Without changes to current global climate policies, Bangladesh would experience annual economic costs equivalent to 2% of its GDP by 2050, rising to 9.4% by 2100 (ADB, 2014). If, however, global mitigation actions are successfully implemented, those losses could be limited to just over 2% by 2100.

How would the losses in agriculture sector impact poverty? It has been estimated that a 50% reduction of crop production would increase poverty by the same percentage. On the other hand, a particular disaster could reduce the 12% contribution to GDP of the agriculture sector. The magnitude of severity of an extreme cyclone is found to be more than that of a flood. A 60% damage of crops by a cyclone increases poverty at the same percentage affecting resources and livelihoods, and decreases economic growth by 15% for the respective period (GoB, 2009).

Floods and cyclones affect culture fisheries severely. Droughts could dry up open water bodies and that could lead to a loss of livelihoods for the poor fishermen and decrease the nutrition status of the rural poor. Moreover, frequent warnings of cyclones lead the fishermen to stay home for longer periods of time and thus their income decreases, increasing their poverty levels. The World Bank has estimated that a loss of an additional $66 million could occur in the fisheries sector due to climate change by 2050.

Extreme climatic hazards cause loss of livestock, damage pasturelands, increase fodder scarcity, destroy shelters, decrease production and increase management cost through incidence of diseases. It is also perceived that severe impacts of climate change and extremes on livestock affect poverty moderately but in many cases livelihoods of marginal farmers dependent on livestock are severely affected. The impacts of sea level rise affect poverty and economic growth of this particular sector severely. Drought, salinity intrusion and heat waves moderately affect the sector and consequently, both poverty and economic growth are moderately affected (GoB, 2009). The World Bank (2010) estimated damages and losses of an additional $56 million in the livestock sector due to climate change by 2050.

The impacts of extreme weather events particularly cyclones and storm surges on forestry affect poverty and economic growth differently than on other economic sectors. In 2007 Cyclone Sidr destroyed one-quarter of the Sundarbans mangrove forest and almost 100% of the afforested trees along its path. A large number of marginal and poor people living in the vicinity of the Sundarbans are dependent on the forest resources. Therefore, any destruction of the Sundarbans mangroves forest affects their livelihoods and financial well-being. It is perceived that salinity intrusion severely affects trees growing in forests especially in coastal regions. This has moderate impacts on poverty and economic growth. Other climatic shocks like flood and drought have moderate impacts on forestry which has low impacts on poverty and economic growth. Besides this, erratic rainfall and temperature variation have low impacts on forestry and lower impacts on poverty (GoB, 2009).

5.5 Sectoral Impacts, Vulnerability and Adaptation to Climate Change

5.5.1 Agriculture and Food Security

Climate Change and Agriculture: Why should Bangladesh be concerned?

Bangladesh is one of the most densely populated countries of the world with very limited arable lands. Therefore, food security is a challenge given that agriculture is always vulnerable to climatic variability and extremes. Currently, 2016-2017, agriculture (including the forestry and fishery sectors) contributes 14.73% to the GDP of the country but among the economic sectors, agriculture remains the largest employer in the country with 43% of the labour force directly employed in agriculture and around 41% of the population dependent on agriculture in one form or another for their livelihood (Bangladesh Economic Review, 2017). This sector is highly sensitive to climate variability and extremes. Future climate change will significantly impact on the temperature and precipitation regimes, especially on monsoon and winter precipitation dynamics. This alteration will increase the vulnerability of the agriculture sector due to the predicted increasing frequency and magnitude of floods and droughts, particularly in the Ganges, and in the Brahmaputra and Meghna (GBM) basins.

Why should Bangladesh be particularly concerned for its agriculture sector? Based on socio-economic projections, geographical location and likely future hazards, Yohe *et al.* (2006) concluded that Bangladesh will be *extremely* vulnerable to climate change under all scenarios. Although in the last four decades, the agriculture sector has made significant progress in crop production and food insecurity management through agricultural and fiscal interventions in the risk prone areas, these gains could be threatened with worsening climate change associated with extreme hazards as well as with the intrusion of saline waters in the coastal areas due to sea level rise. Some of the reasons for concern for the agriculture sector in Bangladesh are briefly summarised below:

An increase in global mean temperature can damage or cause irreparable loss of unique and threatened water resources systems. Mean temperature increase can cause agricultural yield losses. Glacial lakes, the Himalayan snow and glaciers and coastal and inland wetlands, may be irreparably harmed by changes in climate beyond certain thresholds. 71% of the dry season flow of the Ganges originates in Nepal and is mainly from glacier and snow melts. Glacier melt affects the long-term dry season water supply in the Ganges and Brahmaputra, and this will, in turn, impact agriculture and the supporting sectors due to a lack of adequate surface waters. River flows check intrusion of saline water in the coastal districts and water supply in the rivers in March and April is critical for agriculture in Bangladesh when rainfall is low but the rates of evaporation are high. Recent research findings both from within Bangladesh and from other parts of the world indicate that temperature change can reduce rice yield. Peng *et al.* (2004) found that for every 1°C increase in the growing season minimum temperature, a 10% reduction in rice yield occurs (Figure 5.8). In Thailand, it is reported that increasing temperature has led to a reduction in crop yield, particularly in the case of non-irrigated rice. A 4°C increase in maximum and minimum temperatures and 100 ppm CO_2 increase could reduce the boro rice yield by 22% (Basak, 2010).

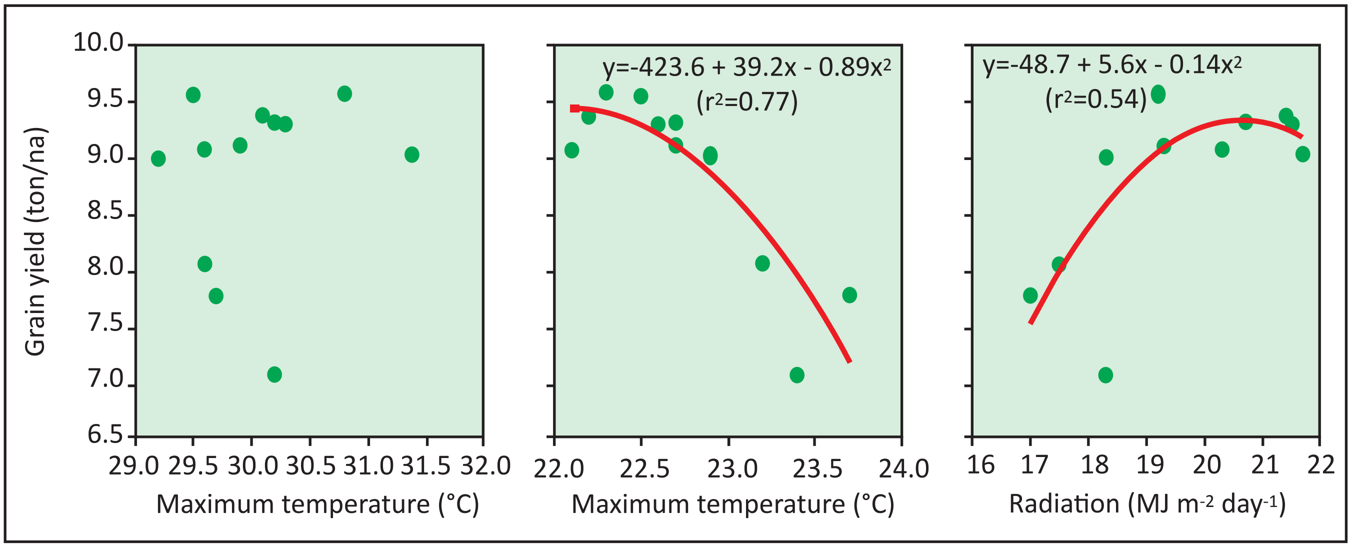


Figure 5.8: Relationship between crop yield and climate (Source: Peng et al., 2004).

Temporal and spatial distributional changes of water resource can harm the agriculture sector. The regional differences in impacts and vulnerability may be conspicuous depending on climatic and hydrological dynamics as well as geographical, population and ecosystem dynamics. At present, the great pressure on water resources is from rising human populations, particularly growing concentrations in urban areas and the resulting expanding economic activity. Possible increases in water requirements due to increased agricultural production to meet the growing needs of the burgeoning population and rapid economic growth to tackle widespread poverty would likely substantially increase the total water requirements. Freshwater availability in large river basins is projected to decrease due to climate change (IPCC, 2007). Note that for the South Asia region including Bangladesh the monsoon flow may increase but it does not mean that water availability will also automatically increase. Given that Bangladesh does not have any potential storage sites, the monsoon water will be wasted anyway. Some recent studies (Farquharson et al., 2007; Fung *et al.,* 2006) indicate the possibility of decrease in dry season flow in Bangladesh due to climate change. Groundwater storages would be impacted from reduced recharge, as soil storage would lose most of its moisture due to high evaporative loss from the soil. Rivers in Bangladesh have high seasonality and due to this factor, per capita freshwater availability will decrease. Domestic water and industrial water supplies would be impacted. There would be impacts on the agriculture sector of high evaporative water demand that could not be met by the river flows and the reduced ground water storages. There will also be intra-country regional variations in water availability.

There will be significant changes in land categories that are widely used for crop production. Mirza (2003 and 2005) estimated substantial changes in land categories F_1, F_2, F_3 and F_4 (Table 5.4, 5.5 and Figure 5.9) due to an increase in the magnitude of floods and extent of flooded areas. Changes in the inundation categories may result in reduced cropping intensity in Bangladesh. As a result of changes in the inundation categories, the agricultural sector of Bangladesh may suffer substantially as a result of loss to land productivity. The World Bank (2010) also estimated similar trend in the land class changes.

Table 5.4: Various land classes in Bangladesh and crop suitability

Land type of Inundation Class	Range of Inundation Depth	Crop suitability
Highland (F_0)	Less than 30 cm (flood free)	Land suited to HYV *T. aman* in wet season, wheat and HYV *boro* in *rabi* season
Medium Highland (F_1)	30 cm to 90 cm (shallow flooded)	Land suited to local varieties of *aus* and *T. aman* in wet season; wheat and HYV boro in rabi season
Medium Lowland (F_2)	90 cm to 180 cm (moderately flooded)	Land suited to *B. aman* in wet season and wheat and HYV *boro* in *rabi* season
Lowland (F_3)	greater than 180 cm (deeply flooded)	Land suited to *B. aman* in wet season and HYV *boro* in *rab*i season

Source: MPO (1986)

Table 5.5: Changes in the extent of mean flooded areas under climate change scenarios for the four GCMs, relative to current conditions

2°C Temperature rise

GCM	F_o (0-30cm)	F_1 (31-90 cm)	F_2 (91-180 cm)	F_3>180
CSIRO9	4.45 -(17%)	0.96 (0%)	1.63 (+30%)	2.07 (+32%)
UKTR	4.23 -(21%)	0.89 -(7.5%)	1.68 (+36%)	2.31 (+47%)
GFDL	4.27 -(20%)	0.91 -(5.4%)	1.68 (+36%)	2.25 (+43%)
LLNL	4.42 -(17%)	0.96 (0%)	1.64 (+32%)	2.08 (+32%)

4°C Temperature rise

GCM	F_o (0-30cm)	F_1 (31-90 cm)	F_2 (91-180 cm)	F_3>180
CSIRO9	4.42 (-17%)	0.95 (-2%)	1.63 (+31%)	2.11 (+34%)
UKTR	4.03 (-25%)	0.81 (-20%)	1.67 (+35%)	2.61 (+66%)
GFDL	4.09 (-23%)	0.85 (-12%)	1.68 (+36%)	2.48 (+43%)
LLNL	4.37 (-17%)	0.94 (-2%)	1.66 (+34%)	2.13 (+36%)

6°C Temperature rise

GCM	F_o (0-30cm)	F_1 (31-90 cm)	F_2 (91-180 cm)	F_3>180
CSIRO9	4.40 (-18%)	0.93 (-4%)	1.64 (+32%)	2.16 (+38%)
UKTR	3.86 (-27%)	0.73 (-25%)	1.61 (+31%)	2.91 (+85%)
GFDL	3.94 (-26%)	0.78 (-19%)	1.65 (+33%)	2.74 (+75%)
LLNL	4.32 (-19%)	0.93 (-3%)	1.67 (+35%)	2.18 (+39%)

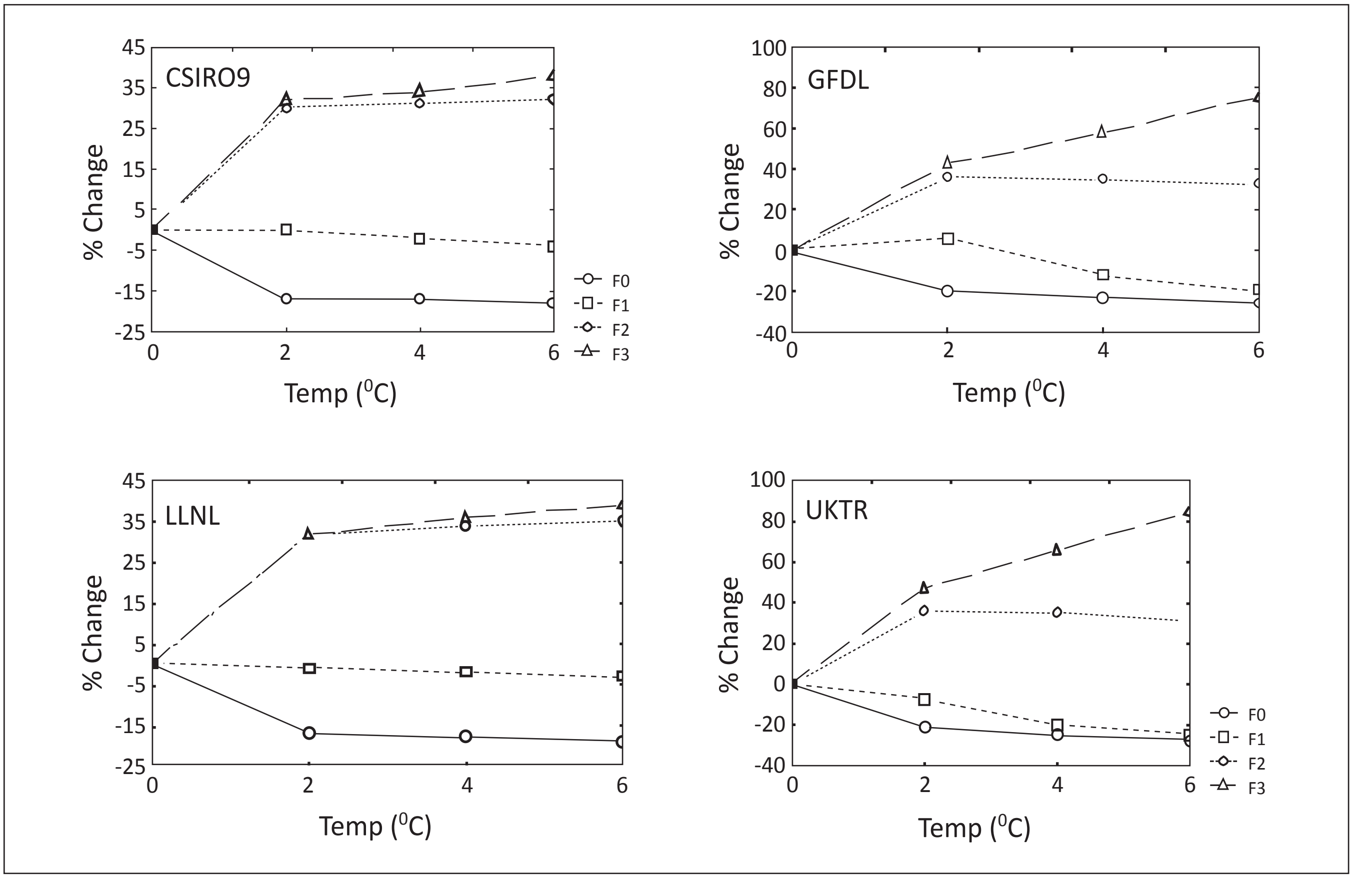


Figure 5.9: Changes in F_0, F_1, F_2 and F_3 inundation categories in Bangladesh under 2, 4 and 6°C rise in global mean temperature.

An increase in global mean temperature and the probability of extreme weather events can increase agricultural sector losses. As global mean climate changes, the probability of extreme weather events such as days with high or very low temperatures, extreme precipitation, floods, droughts, tropical cyclones, and storms will also change (IPCC, 2007a; IPCC, 2001). However, changes in the distribution of temperature and precipitation could make extremes much worse. Most of the climate models are in agreement about substantial changes in precipitation in the South Asia monsoon region. It is likely that flooding events will increase in the monsoon regions especially in the mega-delta areas of the Ganges, Brahmaputra and Meghna rivers (IPCC, 2007b). Erratic rainfall and rise in temperature can also increase the possibility of droughts. Increases in frequency and magnitude of these events can lead to further losses in the agriculture sector. For example, in Bangladesh, an extreme flood event of the magnitude of the 1998 flood could cause over 2 million tons of loss of rice crops. Droughts are also highly detrimental to both aus and *aman* rice crops.

Climate Change, sea level rise and intrusion of salinity can increase loss of agricultural lands and food insecurity in the coastal region. Sea-level rise and changing climate could affect coastal agriculture in Bangladesh in multiple ways. Rising sea-level will permanently inundate vast agricultural land, making it unsuitable for crop agriculture. This could also displace millions of people from their abodes and destroy their livelihoods. Salinity intrusion could progress further inland in the future than now through tidal inflow increasing soil salinity seasonally or permanently. The food security of this region will be threatened as the total cultivable land would be less than that it is presently, and soil and water quality decline will also reduce crop productivity (Murshid, 2012). A World Bank (2000) study suggests that increased salinity alone from a 30cm sea level rise will cause a net reduction of 0.5 million metric tons of rice production which could feed about 3 million people for a year.

Observed losses in the Agriculture Sector

In Bangladesh, crops are highly vulnerable to three types of hazards: floods, droughts and cyclonic storms and associated storm surges. Annually 22-30% of the country is usually inundated but a major flood event may inundate two-thirds or more of the country. Thus, for example, the 1998 flood inundated about 70% of the country. Every year, droughts of different magnitudes affect three to four million hectares of crop land. In the drought season (usually the dry months) rainfall is sparse during the critical growth stages of crops which as a consequence suffer from soil moisture deficits. Floods cause crop losses through inundation for prolonged periods. Crop losses from these episodes depend on the timing of the disaster (within the crop calendar), and on its magnitude and durations. A severe drought can, for example, devastate up to 70-90% of *T.aman* crop and the Rajshahi and Nawabgonj districts are particularly susceptible to severe droughts. The 1978-1979 drought affected 42% of the cultivated land and crop loss was estimated to be two million tons. Crop losses from the 1997 drought amounted to one million tons valued at $500 million (Selvaraju, 2006). Various locations in the country stayed up to 67 days above danger levels following the 1998 floods and that harmed crops significantly. In November 2007, Cyclone Sidr affected nearly ready for harvest crops in 0.9 million hectares in the south-west region of Bangladesh (IFRC, 2010). Many households also lost their food stocks because their homes were damaged. Two years later in 2009, Cyclone Aila completely destroyed 0.186 million hectares of crops and partially destroyed 0.49 million hectares of crop (DMB, 2010). Losses incurred in agriculture from the extreme floods in recent decades in Bangladesh are shown in Table 5.6

Table 5.6: Agricultural losses from extreme floods

Item/year	1988	1998	2004	2007*
Inundated area of the country (%)	60	68	38	42
Livestock killed (numbers)	172,000	26,564	8,318	40,700
Crops fully/partially damaged (million ha)	2.12	1.7	1.3	2.1
Rice production losses (million tons)	1.65	2.06	1.00	1.2

* Two waves of flooding occurred

Projected future changes

Cyclones and storm surges usually affect crop agriculture significantly and it is predicted that crops will respond to climate change differently, in particular to the warming of the climate system. High and extremely low temperatures would be detrimental to growth. Sea level rise related inundation and salinity ingress can harm crop agriculture in the coastal districts. High temperatures and a reduction in precipitation could cause the onset of droughts which could affect crop yield. The potential impacts of climate change on Bangladesh's agriculture sector are summarised in Table 5.7.

At the same time, elevated CO_2 may benefit crops but any potential benefit is not unconditional. The effects of elevated CO_2 on plant growth and yield depend on photosynthetic pathway, species, growth stage and management regimes such as water and nitrogen (Ainsworth and Long, 2005). For several species, crop yield may increase at 550 ppm CO_2 in the range of C3 crops (e.g., rice, wheat, etc.) and 0-10% for C4 crops (e.g., maize, sugarcane, etc.) (Ainsworth, 2004). The effects of elevated CO_2 measured in experimental settings and implemented in models may overestimate actual field- and farm-level responses, due to many limiting factors such as pests, weeds, competition for resources, soil, water and air quality, etc. (IPCC, 2007b).

Table 5.7: Potential Impacts of Climate Change on Agriculture

Climate Variables Temperature changes	Potential Impacts on the Agriculture Sector
Increases in very hot days and heat waves	Modification in crop suitability and productivity (heat stress). Increase in weeds, crop pests and disease outbreaks. Changes in crop water requirements. The quantity and quality of yield critically depend on the number of days that a crop is exposed to temperatures exceeding specific thresholds during critical growth stages (i.e., flowering, pollination, fruiting, or grain filling).
Fewer cold days and nights	Increased yields in colder environments. Reduction in the risk of frosts and subsequent crop failure.
Increase in intense precipitation events	Damages to crops. Increased water-logging, inability to cultivate lands. Damage to the drainage system due to flooding. Increased extent and intensity of erosion and water-logging. Increased pest incidence.
Increases in drought conditions	Lower yields from crop damage, stress, and/or failure. Loss of arable land as a result of land degradation Loss of arable lands Increased competition for water Increased risk of food insecurity
Increase in the frequency of floods	Crop failure and damage to crops due to flooding. Yield decreases. Increased risk of health hazards due to lack of nutrition
More frequent strong tropical cyclones	Damage to crops and rural infrastructure Frequent occurrence of cyclonic hazard de-motivates farmers to move away from farming
Sea level rise and storm surges	Damage to crops and rural infrastructure due to flooding. Seawater intrusion, loss of arable land, salinization of water supply (groundwater in particular).
Increase in CO_2 concentration	Increased biomass production and increased physiological efficiency of water use in crops and weeds. Increased efficiency of water use by crops. Potential increased weed competition with crops.

Many estimates of crop losses are available for South Asia and Bangladesh. Results of crop yield projection using the HadCM2 scenarios indicate that crop yields will likely decrease by up to 30% in South Asia even if the elevated CO_2 benefits are taken into account. Murdiyarso (2000) estimated a 3.8% rice yield loss in Asia 2100 considering the combined influence of CO_2 fertilization, thermal stress and water scarcity (in some regions).

Using statistical models, Amin *et al.* (2015) examined the sensitivity of various crops to different climatic parameters using data for the period 1972-2010. The results show that maximum temperature is the most important climatic parameter that statistically and significantly affected yields of all the food crops except *aus* rice. This finding differs with the results of maximum temperatures on rice reported by Peng *et al.* (2004). Minimum temperature insignificantly affected *aman* rice but benefited yields of the other three crops. Rainfall significantly benefitted the cropping area of aus rice, but significantly affected both the yield and the cropping area of *aman* rice. Humidity has positive effects on the yield of aus and *aman* rice but negatively influences the cropping area of *aus* rice. Sunshine statistically significantly benefitted only the boro rice yield. Overall, maximum temperature adversely affected the yield and cropping areas of all the major food crops and rainfall severely affected *aman* rice only.

In Bangladesh, Faisal and Parveen (2004) projected a drop in rice and wheat yield by 8% and 32% respectively by the year 2050 due to climate change. Yu *et al.* (2010) ran a number of scenarios from various climate models in the DSSAT crop model for Bangladesh. Impact assessment considered a host of factors: temperature and precipitation changes; CO_2 fertilization; flood changes and sea level rise. The projected median warming climate scenarios are 1.1°C, 1.6°C and 2.6°C by the 2030s, 2050s and 2080s, respectively. Median precipitation increases were projected to be 1%, 4% and 7.4%, respectively by the 2030s, 2050s and 2080s. The aggregate median loss of aus and aman is estimated to be -1.5% and 0.5%, respectively by 2050. A simulation of the *boro* rice crop using climate scenarios from the GCMs demonstrates a decline. The estimated median loss of 3% projected for the 2030s could increase to 5% by the 2050s. Wheat production is expected to be positive (+3%) until the 2050s. For *boro* and wheat, it was assumed that farmers will have unlimited irrigation facilities. These figures project a country-wide average but there will be high regional variations. The average losses in the Khulna region are -10% for *aus, aman* and wheat and -18% for *boro* by the 2050s due largely to saline water intrusion resulting from sea level rise. Table 5.8 presents median integrated production change (%) for the 2030s and 2050s. Another estimate shows a 16% reduction in rice yield in Bangladesh (CDMP-II, 2013).

Table 5.8: Median integrated production change (%) of crops for the 2030s and 2050s

Crop	2030s	2050s	2030s	2050s	2030s	2050s
	All SRES	All SRES	A2	A2	B1	B1
Aus	-0.27	-1.52	-1.11	-3.51	-0.14	0.01
Aman	-0.37	-0.62	-0.42	-1.49	-0.37	-0.40
Boro	-3.06	-4.74	-1.68	-5.54	-3.76	-3.54
Wheat	2.05	3.44	2.23	3.74	1.33	3.03

Source: Yu et al., 2010.

Observed Crop Losses from Droughts

While Bangladesh experiences significant rainfall annually, a seasonal spatial and temporal variation in the rainfall is very high. As a result, aridity of a maximum of six months could occur in the north-western parts of the country and a minimum of four months in the north-eastern parts of the country. Drought is, thus, a temporary, spatially irregular and non-periodic phenomenon usually affecting certain small parts of Bangladesh. In the recent past, the severe drought years have been 1965-1966, 1972-1973, 1978-1979 and 1982-1983. The 1978-1979 drought affected the entire country, whereas in other years, drought was more or less localised. From 1960 to 1991, there were 19 drought years, which affected as much as 47% of the country's area and 53% of the current population. The 1978–1979 drought in Bangladesh affected three crop seasons, reducing rice production by an estimated two million tons (Brammer, 1987). In the 1990s, drought conditions in the north-western part of Bangladesh resulted in a crop loss of 3.5 million tons (GoB, 2012). During the 2010 monsoon, Bangladesh experienced the driest monsoon since 1994 with a seasonal rainfall total of about 19% less than the long-term average due to the relocation of monsoon further south than usual. This occurred despite an active and strong monsoon in Pakistan, India and Sri Lanka (Rajeevan *et al.,* 2011).

The Bangladesh Agricultural Research Council (BARC) has delineated different areas of the country under different categories of drought for two periods: *kharif* (roughly March - October) and *rabi* (roughly October - March) (BARC, 1990). During the *kharif* season, precipitation exceeds evapotranspiration. Droughts in this season refer mainly to shortage of rainfall in the late growing period of *T. aman* rice, which causes serious yield reduction and shifts in harvesting time (which subsequently affects the *rabi* cultivation after T.). During the *rabi* period, evapotranspiration exceeds rainfall and soil moisture depends heavily on the remaining water after the *kharif* season. Water stress is felt frequently after mid-rabi season. During the pre-*kharif* period, drought conditions depend on the rainfall pattern which tends to be erratic during this period.

Projected Crop Losses from Droughts

Drought prone areas in Bangladesh under climate change scenario projections will be further affected in the dry season (Dastagir, 2015). The following possible consequences are projected under future climate scenarios: a sharp rise in evapotranspiration and diminishing rainfall will result in further reduction of river flow; salinity will further penetrate inland due to reduced river flows which would eventually restrict choice for the most preferred crops; reduced rainfall as well as decreased runoff will either limit irrigation or put increased economic constraints on economically poor cultivators; and production of wheat, *HYV aus* and *boro* rice varieties may no longer be economically viable (Dastagir, 2015) (Figure 5.10). Moinuddin *et al.* (2011) reported that about 12,220 km² of land would be re-classified into the very severe drought class (i.e., lowest soil moisture level) as compared to the existing 3,639 km² (i.e., more than a three-fold increase in area) under severe changes in the climatic systems during the *rabi* season. During the *kharif* season, four times more area would be re-classified to the very severe class from the severe and moderate areas. The worst affected regions would be the north-west, the north-central and the south-west, where both irrigated and rainfed crops would be affected (Moinuddin *et al.,* 2011). As irrigation water demand would escalate to mitigate drought conditions, increased water withdrawal from the already lean surface water systems could lead to further flow reduction in the rivers (Dastagir, 2015).

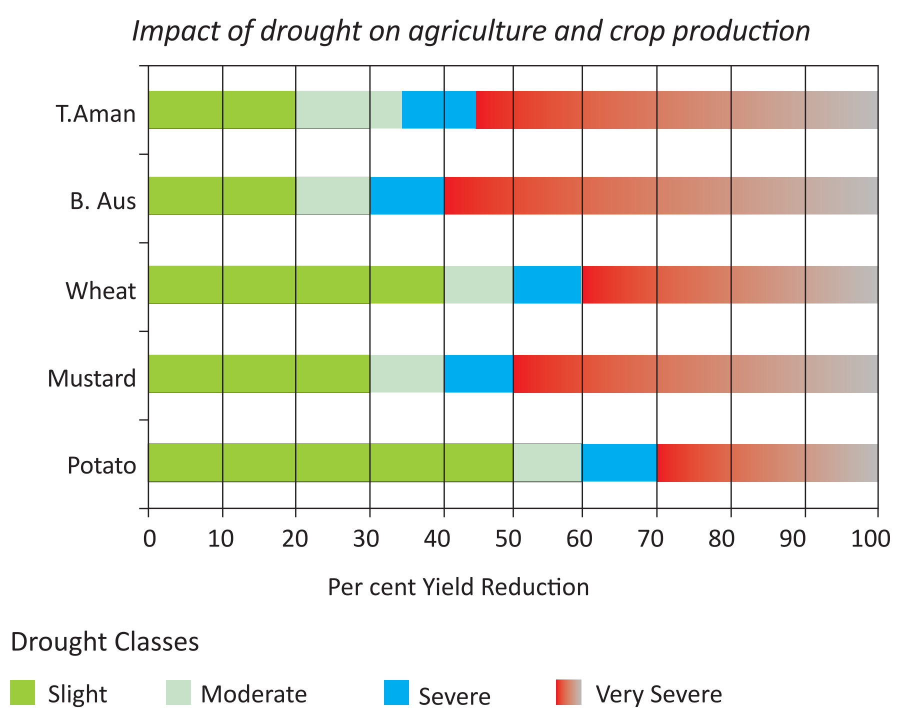


Figure 5.10: Impact of drought on agriculture and crop production

Observed Crop Loss from Salinity

The coastal area constitutes about 20% of Bangladesh and over 30% of the country's net cultivable area. According to salinity survey findings and salinity monitoring information, of a coastal area of 2.83 million hectares (ha), 0.95 million ha suffered from various levels of salinity in 2009. Given that in 1973, the area under salinity was 0.75 million ha, a 26.71% increase took place over a period of 36 years. Distribution of saline lands under very slight, slight, moderate strong and very strong salinity classifications is shown in Table 5.9.

Table 5.9: Estimation of salt affected areas (in '000' ha) in coastal region of Bangladesh

District	Year	Salinity Level				Salinity increase (1973-2009)	
		S_1 *(2.0–4.0ds/m)*	S_2 *(4.1–8.0ds/m)*	S_3 *(8.1–16.0 ds/m)*	S_4 *(>16.0ds/m)*	Area (000'ha)	%
Khulna	1973	3.90	92.54	13.95	9.80	21.39	17.80
	2000	29.04	38.32	59.49	19.61		
	2009	24.64	26.88	47.78	30.57		
Bagerhat	1973	8.30	77.08	3.60	0	48.03	53.98
	2000	35.66	42.56	41.23	6.74		
	2009	32.33	42.48	52.96	9.24		
Satkhira	1973	26.50	85.60	34.50	10.90	4.76	3.02
	2000	29.03	39.01	60.55	22.01		
	2009	31.00	32.96	69.72	28.58		
Pirojpur	1973	20.40	1.90	0.00	0.00	13.53	60.67
	2000	22.93	6.05	2.43	0.00		
	2009	23.11	9.94	2.78	0.00		
Barisal	1973	0.00	0.00	0.00	0.00	0	-
	2000	2.35	2.70	0.00	0.00		
	2009	8.12	2.54	0.70	0.00		
Bhola	1973	9.18	30.81	0.00	0.00	54.58	136.48
	2000	32.44	33.70	26.13	5.27		
	2009	42.11	28.84	20.62	3.00		
Patuakhali	1973	68.50	46.60	0.00	0.00	43.28	37.60
	2000	40.11	43.62	46.10	9.52		
	2009	57.73	39.90	44.98	15.77		
Barguna	1973	96.39	7.20	0.00	0.00	-2.67	-2.58
	2000	37.22	30.77	33.47	3.77		
	2009	32.11	30.90	32.60	5.31		
Noakhali	1973	6.30	39.90	1.80	0.00	4.52	9.42
	2000	13.04	16.93	15.83	7.75		
	2009	15.36	13.33	22.21	1.62		
Cox's Bazar	1973	7.20	16.20	17.30	14.00	1.65	3.02
	2000	2.83	11.08	35.55	10.50		
	2009	2.81	13.63	33.84	6.07		
Total	**1973**	**246.67**	**397.83**	**71.15**	**34.7**	**189.07**	**26.71**
	2000	**244.65**	**264,74**	**320.78**	**85.17**		
	2009	**269.32**	**241.4**	**339.9**	**100.16**		

Data source: SRDI and DAE, Government of Bangladesh

Projected Crop Loss from Increasing Salinity

Soil salinization in coastal Bangladesh is a major risk from climate change (Dasgupta *et al.*, 2015). Future climate change could increasingly intensify the salinity problem through sea level rise, increased tidal activity/inundation, increased irrigation, cyclonic storm surges and water logging. Soil salinity is a result of salt accumulation in the soil, which is affected by water salinity, drainage and evaporation (Clarke *et al.,* 2015). In the coming decades, soil salinity will significantly increase in the Barisal, Chittagong and Khulna districts. Dasgupta *et al.* (2015) assessed changes in soil salinity in coastal Bangladesh from 2001-2009, using salinity information recorded at 41 soil monitoring stations by the Soil Research Development Institute (SRDI). It projects a median increase of 26% in salinity by 2050, with increases of over 55% in the most affected areas. Soil salinity causes crop losses. The potential of crop losses under various salinity classes are: S1(10-20 %), S2(20-30%), S3(40-50 %) and S4 (50-60%). Future crop losses would occur from an increase of affected areas as well as from current saline lands which could become more saline. Increase in soil salinity may lead to a decline in yield by 15.6 percent of high-yielding-varieties of rice in nine coastal upazilas where soil salinity will exceed 4ds/m by 2050 and reduce the income of the farmers significantly (Dasgupta *et al.,* 2015). Another recent estimate shows that the country may lose 0.2 million tons of crops to saline intrusion in a moderate climate scenario, but this figure might be more than double under a severe climate scenario (Huq and Ayers, 2008). This will force the farmers to grow crops of economically lower returns (Climate change cell, 2006).

Adaptation Options for Agriculture Sector

Technological options:

Crop development. Develop new crop varieties, including hybrids, to increase the tolerance and suitability of plants to temperature, moisture, salinity and other relevant climatic developments;

Weather and climate information systems. Develop early warning systems that provide daily weather predictions and seasonal forecasts; and

Resource management innovations. Develop water management and farm-level resource management options to address the risk of moisture deficiencies, increasing frequency of droughts, changing temperature, and other relevant climatic conditions.

Government Programmes and Insurance:

Agricultural subsidy and support programmes;

- Introduce crop insurance programmes to influence farm-level risk management strategies with respect to climate-related loss of crop yields;
- Change investment in established income stabilization programmes to influence farm-level risk management strategies with respect to climate-related income loss;
- Modify subsidy, support, and incentivise programmes to influence farm-level production practices and financial management;
- Change *ad hoc* compensation and assistance programmes to share publicly the risk of farm-level income loss associated with disasters and extreme events.

Private insurance:

Develop private insurance to reduce climate-related risks to farm-level production, infrastructure, and income.

Resource management programmes:

Develop and implement policies and programmes to influence farm-level land and water resource use and management practices in light of changing climate conditions.

Farm Production Practices;

Crop selection and crop calendar:

- Change to a crop with greater resilience to water shortages or of greater economic value;
- Change planting dates to reflect alterations in seasonal rainfall discharge;
- Increase farm diversity of cropping mix;
- Increase cropping intensity where possible.

Water management:

- More efficient irrigation technologies to improve water productivity;
- Conjunctive use of surface water and groundwater;

- Deficit irrigation to reduce evapotranspiration;
- Reduction in storage losses due to evaporation;
- Alternate cultivation practices to reduce water requirements;
- Intensification of use of other agricultural input;
- Improved drainage.

Irrigation technologies:

Application of pressurized systems (e.g., sprinklers) to ensure appropriate water application rates and timing of application. Drip and trickle irrigation to supply water without having to saturate the root system.

Farm Financial Management:

Crop shares;
Income stabilization programmes

5.5.2 Water Resources of Bangladesh

Surface and ground water are the two sources of water in Bangladesh. As almost all the rivers flowing though the country originate outside of the border, more than 90% of the annual surface water run-off is generated externally. The remaining quantity comes from local rainfall. Groundwater is generated mainly recharge from rainfall in the monsoon months (June-September). Within Bangladesh, rainfall widely varies across the eight hydrological regions despite the fact that the country is rather small in size with limited physiographical diversity. The eight hydrological regions are: South West (SW), North East (NW), North Central (NC), Central Floodplain, North West (NW), South Central (SC), South East (SE) and Eastern Hills.

Analysis of the BMD data shows the range of annual rainfall (when averaged over the hydrological regions) in the country is 1,842 to 3,457 mm. The mean annual rainfall in the eight hydrological regions (Figure 5.4) is presented in Table 5.10. The country's mean rainfall is 2457 mm and it increases in a west to east gradient. Rainfall pattern in the country and the cross-boundary basins is highly seasonal. About 80% of the rainfall occurs in the monsoon period (June to September). This high seasonal variation is pronounced in the flows of the major rivers (Figure 5.11). Localized extreme rainfall results in drainage congestions and floods. However, severe floods are caused by transboundary high river flows through the Ganges, Brahmaputra and Meghna (GBM) rivers plus run-off generated by local rainfall. The combined peak flows of the GBM rivers could exceed 180,000 m3/sec, the second highest in the world (World Bank, 2010).

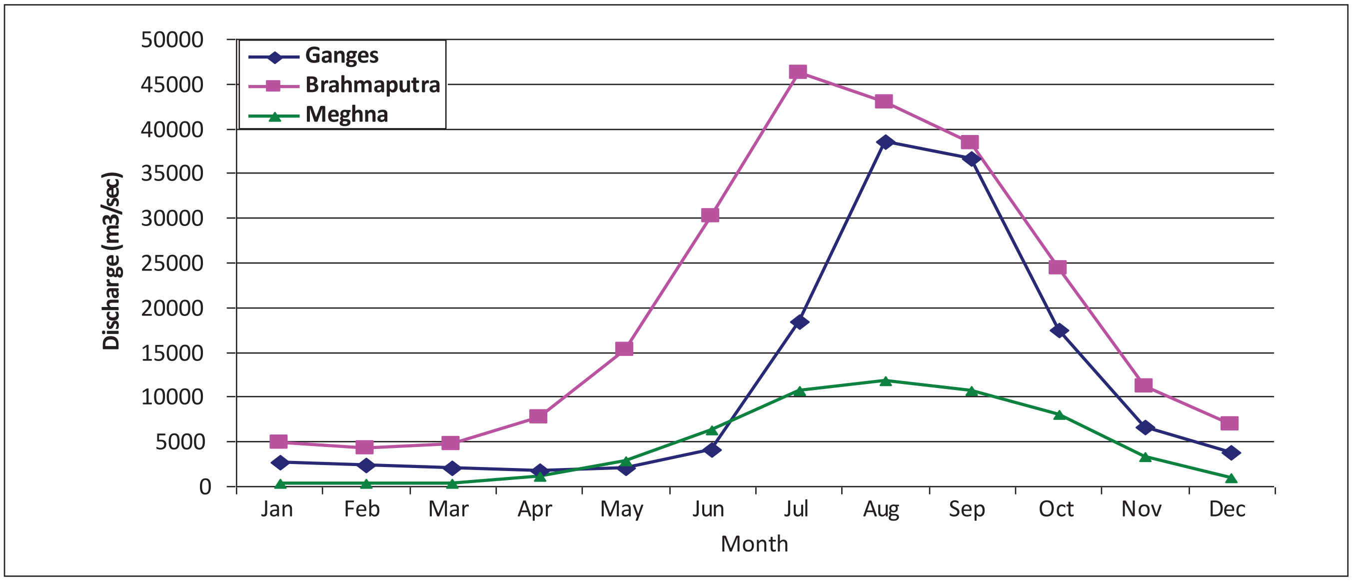


Figure 5.11: Seasonality of flows in the Ganges, Brahmaputra and Meghna basins. Data Source: Bangladesh Water Development Board.

Table 5.10: Average annual rainfall in various hydrological regions of Bangladesh (1981-2015)

Region	Stations	Average annual rainfall in mm
South East	Cox's Bazar, Teknaf, Kutubdia, Swandip, Chittagong, CTG-Ambagan, Sitakunda	3,457
North West	Dinajpur, Rangpur, Saidpur, Rajshahi, Irshawrdhi, Bogra	1,843
North Central	Mymensingh, Tangail	2,254
Central Floodplain	Dhaka, Faridpur, Madaripur, Comilla	1,955
South West	Chuadanga, Jessore, Khulna, Satkhira, Mongla	1,851
North East	Sylhet, Sreemangal	3,215
South Central	Barisal, Bhola, Patuakhali, Khepupara, Noakhali, Hatia, Feni, Chandpur	2,549
Eastern Hills	Rangamati	2,534
Average		**2,457**

Source: Bangladesh Meteorological Department (BMD)

The cross-border flows into Bangladesh are estimated to be 1010 billion cubic meters (BCM). An additional 340 BCM is generated from local rainfall. Losses from evaporation and evapotraspiration process are about 190 BCM or 14% of the total. Most of the surface water flows to the Bay of Bengal as there is virtually no scope of water impoundment due to the flatness of the country. The groundwater resource of the country is estimated to be 22 BCM and this is the major source of irrigation water.

Projected Impact on Water Sector Due to Climate Change

Increases in greenhouse gases will increase net radiation on the earth's surface which will lead to increases in temperature, evaporation and precipitation. Temperature has a profound effect on evaporation on both land and in the ocean. Due to increased evaporation, more water vapour will be available in the atmosphere. Increased global temperature will result in changes in evaporation and moisture content in the soil. Eventually this process will affect surface run-off and groundwater recharge. The water sector in Bangladesh will be highly vulnerable to the changes in climatic parameters, namely temperature and precipitation, frequency, intensity and magnitude of extreme events, and rising sea level. Human interventions in the large shared river basins may lead to further complexity. The key vulnerabilities of climate change for the water resource sector in Bangladesh are as follows:

Glaciers will continue to shrink in almost all parts of the world (IPCC, 2014). The melting glaciers of the Himalayas is a concern for Bangladesh's water supply especially in the dry season. Due to high variability of seasonal water supplies, dry season water is vital to supporting the ecosystem, agriculture and fisheries and navigation. The IPCC (2014) projected 45% and 68% Himalayan glacier loss by 2100 under the RCP4.5 and RCP 8.5 scenarios, respectively. While melting means an initial increase in water supplies which could extend for decades, the supply will decrease due to the shrinkage of the glacier mass. The sediment supply in the Ganges and Brahmaputra rivers could increase in the dry season and this may result in siltation and loss of capacity of the channels.

The rate of evaporation from the soil, open water and plants would increase due to rises in temperature. Therefore, soil storage would capture the larger amount of infiltrated water. This would result in reduction in deep percolation to shallow aquifers as the upper limit of infiltration is limited by soil type. As a result, groundwater recharge would likely be reduced (Farquharson *et al.,* 2007). In the dry season, groundwater storage is the source of base flow in the rivers in Bangladesh. Therefore, any reduction in groundwater storage would adversely affect dry season flow in the rivers in Bangladesh.

Climate change will cause increased temperature; increased sediment, nutrient, and pollutant loadings from heavy rainfall; increased concentration of pollutants during droughts; and disruption of treatment facilities during floods. All these factors will deteriorate raw water quality and pose risks to drinking water quality even if it is treated by conventional methods (IPCC, 2014).

Future rates of sea-level rise are expected to increase coastal flooding, erosion, and saltwater intrusion into surface and ground waters (IPCC, 2013).

All models and all scenarios project an increase in both the mean and extreme precipitation in the Indian summer monsoon due to an increase in supply of moisture from the ocean to the land despite a weakening of monsoon winds (IPCC AR5 WGI, 2013). Monsoon onset dates could be shifted to earlier dates and withdrawal of monsoon could be delayed. This implies a longer flooding season in Bangladesh.

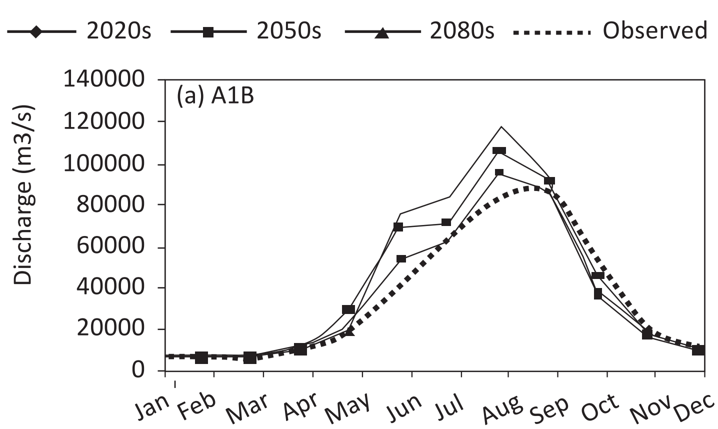
Increased temperature and higher rates of soil moisture loss could lead to longer and higher impact droughts in the country.

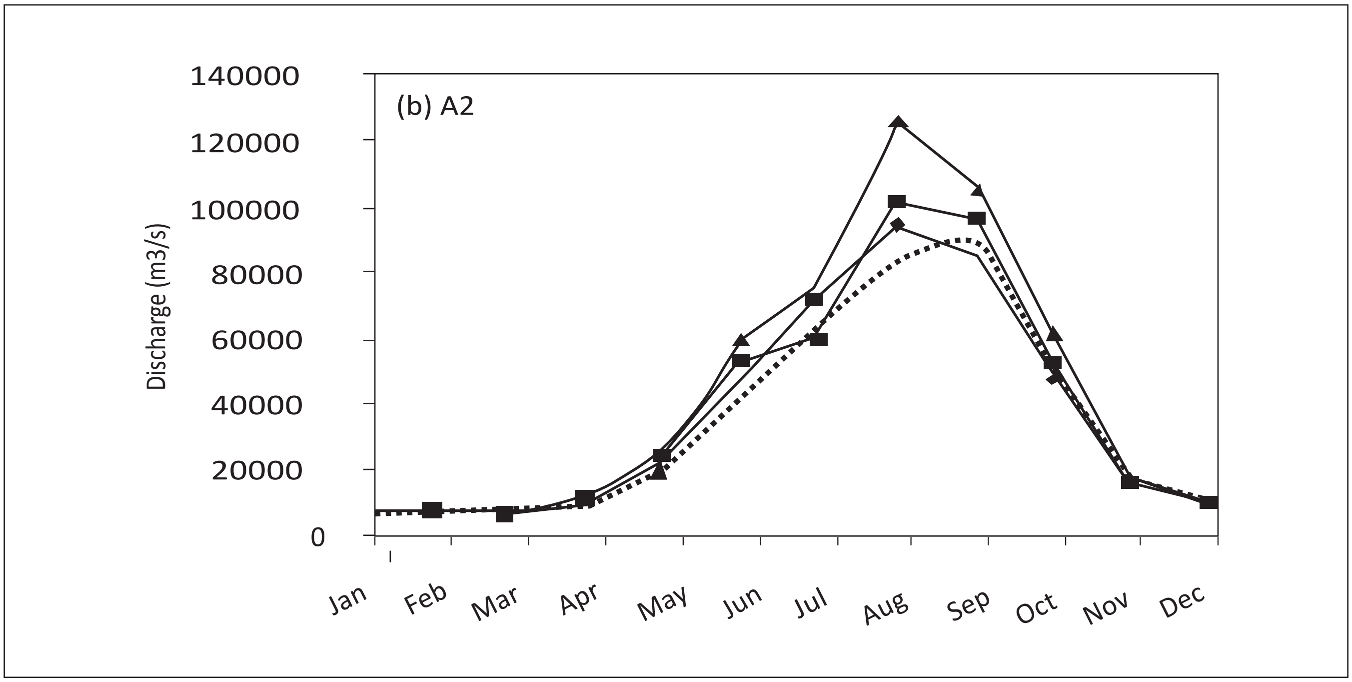
5.5.2.1 Projection on Hydrologic Extremes based on Observed Trends of Water Flow

Among the two hydrological extremes, floods are well studied (Mirza, 2005; Farquharson *et al.,* 2007; Chowdhury, 2009; World Bank 2010; Kamal *et al.,* 2013; Masood et al., 2015). Masood *et al.* (2015) used five Coupled Model Intercomparison Project Phase 5 (CMIP5) models for three time-slices: the (then) present day (1979-2003), the near future (2015-2039) and the distant future (2075-2099). Kamal *et al.* (2013) applied HadCM3 GCM model projects for SRES A1B, A2 and B1 Scenarios in the Artificial Neural Network Model. Bangladesh's Second National Communication (2012) reported changes in flooded areas for SRES A2 and B1 scenarios. Farquharson et al. (2007) used IPCC A2 and B2 scenarios from four GCMs and two RCMs. Mirza (2003 and 2005) used standardized scaled scenarios (Section 4.3.2) (constructed for the UKTR, CSIRO9, GFDL and LLNL global climate models) for the entire GBM basins to estimate impacts of climate change on mean floods. Both empirical and physically based (MIKE 11) hydrologic models were used in the study. Following are the major conclusions drawn on the nature of floods in future Bangladesh. Although different scenarios and time-lines were used in these studies, the conclusions have converged to one point - Bangladesh will likely be more impacted by floods in future.

Significant projected changes in the magnitude, extent and depth of floods

Many recent studies project significant changes in the magnitude, extent and depth of floods due to climate change. Kamal *et al.* (2013) applied A1B, A2 and B1 SRES scenarios in the artificial neural network model. The results displayed an increasing trend of monsoon flows in the 2020s, 2050s and 2080s with the reference period of 1961-1990. Comparison of projected monthly scenarios with the observed conditions showed that peak flows could increase by 4.5-39.1% in the monsoon in the lower Meghna river, the major drainage outlet of the GBM basins (Figure 5.12). Excess precipitation in the monsoon months and inadequate precipitation, together with higher temperatures in the dry season could result in the occurrence of flood peaks in earlier months. In addition to this, the rate of change of flows during the rising and recession of flooding would be much higher compared to current flood characteristics of the rivers. The results are an indication of flooding potential in the central part of Bangladesh in and around the confluence of the Ganges and Brahmaputra rivers where the largest increase in peak flows would occur.





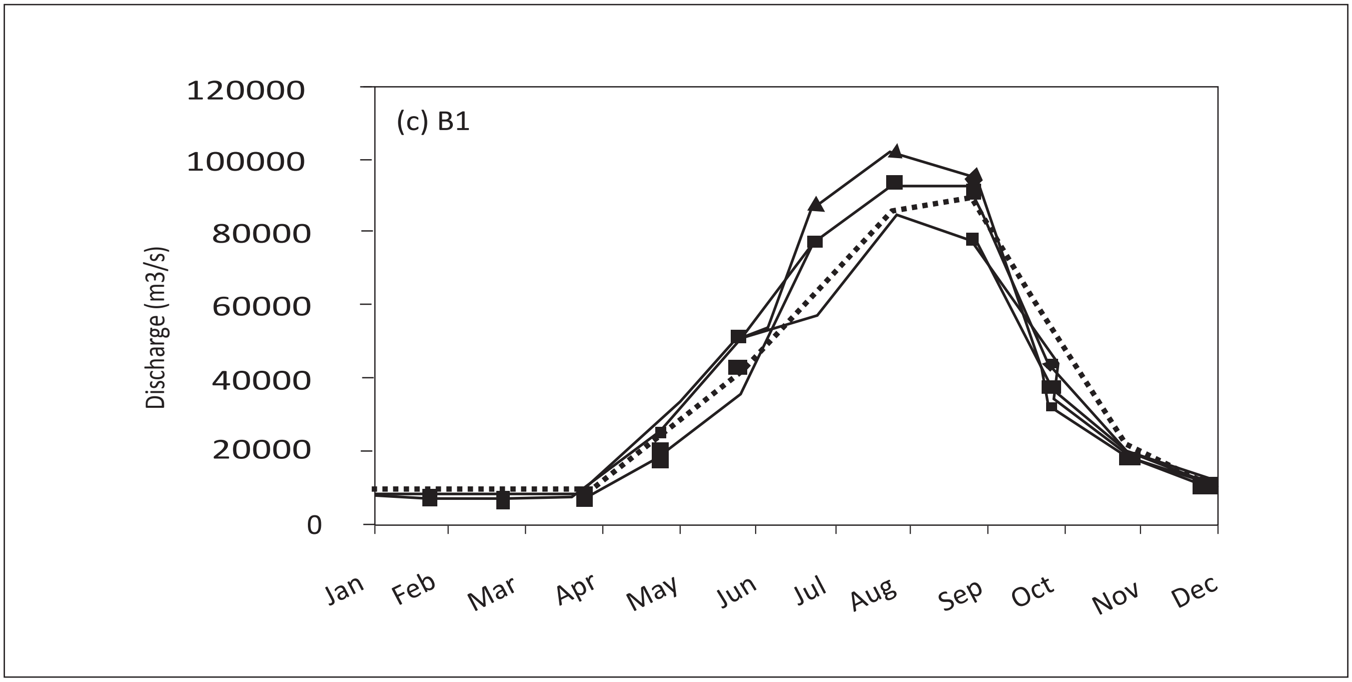


Figure 5.12: Projected streamflows for different climate change scenarios (Rajib *et al.,* 2013).

The World Bank (2010) used the Bangladesh National Flood Model maintained by the Water Modeling Centre, Dhaka to estimate intra-country hydrological changes from the changes in temperature and precipitation in Bangladesh and changes in water flows from the trans-boundary rivers into the country. The changes (Table 5.11) in flows for 2050 were determined from scenarios of precipitation and temperature projected by five GCMs[30]. The future flood estimates are modeled for the IPCC SRES A2 and B1 scenarios (World Bank, 2010).

30 The five GCMs are University Corporation for Atmospheric Research – CCSM, Max Planck Institute for Meteorology – ECHAM5, Hadley Center for Climate Prediction – UKMO, Center for Climate System Research – MIROC, and Geophysical Fluid Dynamics Laboratory – GFDL.

Table 5.11: Estimated average change (%) in monsoon (World Bank, 2010)

Months	2030s			2050s		
	Brahmaputra	Ganges	Meghna	Brahmaputra	Ganges	Meghna
May	7.5	9.3	0.0	17.4	11.8	12.3
June	5.4	11.9	3.1	10.9	16.7	7.7
July	3.4	13.5	0.0	6.9	15.0	3.6
August	5.5	8.8	3.7	9.5	12.0	7.8
September	3.7	7.3	-2.0	9.7	12.5	5.9

Mirza (2003 and 2005) reported 23-39% changes in mean flooded area in Bangladesh under 2-6°C global warming. Bangladesh's Second National Communication (2012) reported changes in flooded area in terms of lands classified on flood depths. In this classification F_0 is 0-30 cm; F_1 is 30-90 cm; F_2 is 90-180 cm; F_3 is 180-300 cm and F_4 is over 300 cm of maximum flood depth. Figure 5.13 shows the percentage changes in flooded area in each sub- region due to climate change in the 2030s and 2050s under the A2 and B1 scenarios. The results indicate an increase in flooded area by 6% by the 2030s and 14% by the 2050s. Therefore, in the case of extreme flood years, 80% or more of the country may be inundated at one time or another. Using the same land classifications criteria, Mirza (2003 and 2005) projected most of the mean flooded area will be in the 'deep flood' (F_4) category in future.

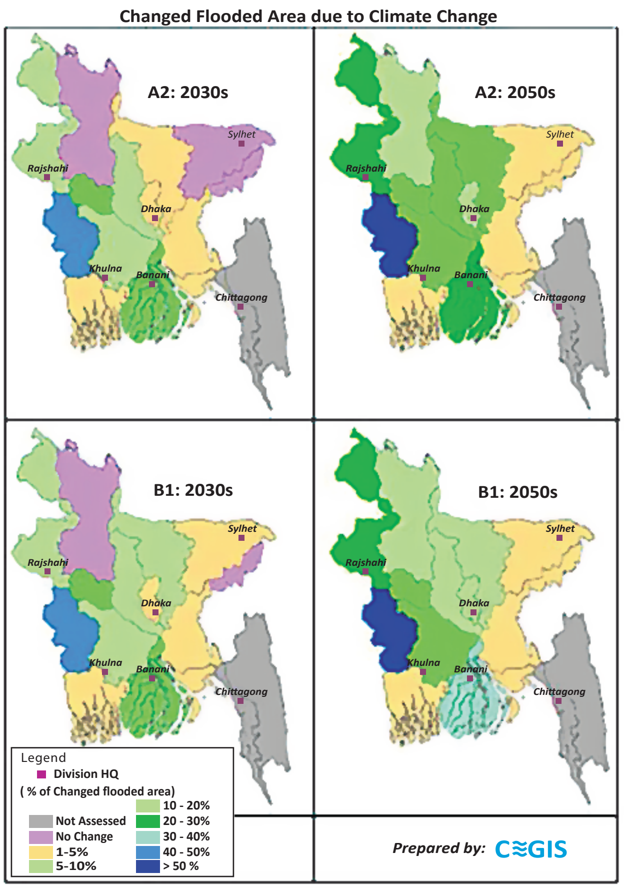


Figure 5.13: Changes in flooded area in 2030s and 2050s under SRES A2 and B1 scenarios.

The largest change in flooded area occurs between 0 and 2°C

Surprisingly, the model results indicate that most changes in the mean flooded areas occur between 0 and 2°C in relation to the increases in the peak discharges of the Ganges, Brahmaputra and Meghna rivers (Table 5.11 and Figure 5.13, 5.14) rather than at higher temperature increases. In the range of 0-2°C, 2-4°C and 4-6°C increases in temperature, increases in flooded area for per degree warming are 0.44-0.55 mha, 0.015-0.09 mha and 0.015-0.075 mha, respectively. In general, increases in peak discharge between 0-2°C will engulf most of the flood vulnerable areas. Therefore, at higher temperature increase, proportionate increases in discharge will not lead to further increase in the extent of flooding as it will possibly be limited by elevation of lands.

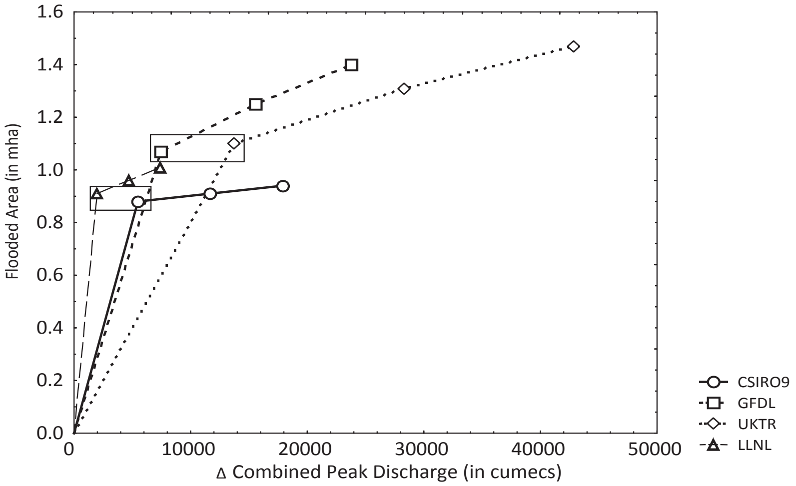


Figure 5.14: Changes in the combined mean discharges of the Ganges, Brahmaputra and Meghna rivers (under control and climate change scenarios) and the mean flooded areas. Values within boxes indicate changes for a 2°C rise in temperature (Mirza, 2003 and 2005).

The Brahmaputra and Meghna/Barak rivers will play a major role in future flooding.

Flood hazards are more prominent in the Brahmaputra and the Meghna basins and these two rivers play a major role in the flooding process in Bangladesh. The peak discharge of the Brahmaputra is the largest among the three major rivers. Although the peak discharge of the Meghna/Barak is much smaller than the other two, it drains out the smallest river basin. Therefore. the river causes significant flooding in the basin area especially in the greater Sylhet region.

Ground water recharging predicted to be on a decline

Farquharson et al. (2007 found large variations and conflicts in the projected changes in river flows. Note that across the GCMs, the projection of scenarios may vary due mainly to the detailing of physical processes incorporated in the models. However, ample indications of increases and decreases in the wet season and dry season flows, respectively, were found. The possibility of an early start of rising limb of the hydrograph as well as an early start of falling limb was also noticed. Increases in wet season flow would possibly increase flood hazard. At the same time, dry season water availability may be reduced due to a decline in the flow. The rate of evaporation from the soil, open water and plants would increase due to a rise in temperature. Therefore, soil storage would capture the larger amount of infiltrated water. This would result in a reduction in deep percolation to shallow aquifers as the upper limit of infiltration is limited by soil type. As a result, groundwater recharge would likely be reduced. In the dry season, groundwater storage is the source of the base flows in the rivers. Therefore, any reduction in groundwater storage would adversely affect dry season flows in the rivers.

Adaptation Options for Water Sector Investments in Bangladesh

As the water sector is one of the most vulnerable sectors to future climate change, implementation of large scale adaptation activities is required to make it climate proof now. Anticipatory and precautionary adaptation to the consequences of climate change is more effective and less costly than forced, last-minute emergency action. The aim of future investment to address the climate risk for the water sector is preservation of ground and surface fresh water resources, sustainable water management, sustaining human development and the protection of coastal and marine zones. Billions of dollars per year would be required to cover adaptation costs globally. The actual global cost could exceed $100 billion per year but would be dependent on many factors, for example, the policies and target to mitigate GHG emissions. The adaptation cost in the water sector has been estimated to be

$530 billion up to 2030 (Kirshen, 2007). Following a broad robust methodology, the UNFCCC (2009) estimated a $9-11 billion per year investment would be needed to meet the challenges to water supplies posed by climate change. This figure is perhaps an under-estimation of the adaptation cost as it did not take into account the residual impacts that include climate change lag-time, inadequate design for imperfect knowledge, costs of emergency actions, research and design, the implementation of policies and the transactional cost (Parry *et al.*, 2009).

Cost = cost of explicit adaptation measures

+ residual impacts of climate change

+ transaction costs of implementing adaptation measures

BCCSAP includes an implementation time-frame for the 44 identified programmes and estimated a requirement of $500 million in the first two years and about $5 billion in the first five years for full implementation (World Bank, 2010). An estimate for the entire water sector adaptation cost is not available for Bangladesh. The World Bank (2010) estimated that by 2050, total investments of $5.516 billion and $112 million in annual recurrent costs will be needed only for protection from the storm surge risks and risks from climate change.

The ADB (2012) suggested adaptation options for the water sector to be grouped into: engineering/structural, non-engineering/non-structural and bio-physical/ecosystem approaches. It further recommended to retain 'business as usual' (do nothing) options for policy level decision making.

Engineering Options

Construction materials and costs

Construction materials are usually climate sensitive. They are normally designed for the life of the structure or for a calculated period that keeps maintenance costs at a minimum level over the life span of the structure. Otherwise, maintenance cost of the infrastructure (storm-water pipes, irrigation structure, etc.) would increase. The strength of various construction materials needs to be enhanced in the context of: increased temperature and precipitation; high humidity; high salinity; possible increased wind speed; and increased solar radiation. Construction under flooding, coastal erosion, subsidence, and drainage congestion conditions requires new construction techniques. Poor weather conditions cause delays in construction which eventually increases the cost. For example, high temperatures delay the curing of concrete that lengthens construction schedules and adds to the cost. Photo-catalytic coating, shotcrete and concrete 'eco-columns' are presently becoming popular to adjust with changing climatic conditions. Climate change has opened up opportunities as new research on extreme climate proof materials would open up opportunities for industries and businesses.

Design Codes and Standards

The principal assumption made for all present infrastructure and codes and standards that have been designed using climatic design values, calculated from historical climate data (Auld, 2008) is that average and extreme climatic conditions of the past will remain stationary over the future lifespan of an infrastructure. The stationarity assumption is no longer valid because changing climate systems due to substantial human interventions are altering the means and extremes of precipitation, evapotranspiration, and rates of discharge of rivers (Milly *et al.*, 2008). When means and variances increase, the probability of higher extremes (e.g., flood discharge) also increases (Figure 5.15). For a 2°C global mean temperature rise, the probability of exceedance of a current 20-year flood of the Ganges River flood may change from 5% to 12%. In other words, magnitude of the flood would be about 2.5 times more likely to occur than at present (Mirza, 2003). For designing climate proof infrastructure, Auld (2008) suggested incorporating a 'climate change adaptation factor' in codes and standards. It is defined as an adjustment factor that could be applied to existing climatic design values, reflecting observed changes that have occurred recently and future expectations of changes in climatic design values. Such design values can be derived using scenarios from climate models. However, the issue of uncertainty (Figure 5.16) in terms of future socio-economic scenarios and temporal and spatial scales in the climate model derived future projection of scenarios, is a challenge to the engineers that needs to be addressed, especially for the extremes. It should be noted that the resolutions of the models are getting better and improved methodologies (e.g., downscaling) to address model biases are available. These are useful to address the issue of uncertainty for the climate model projections of future climate values for a particular scenario.

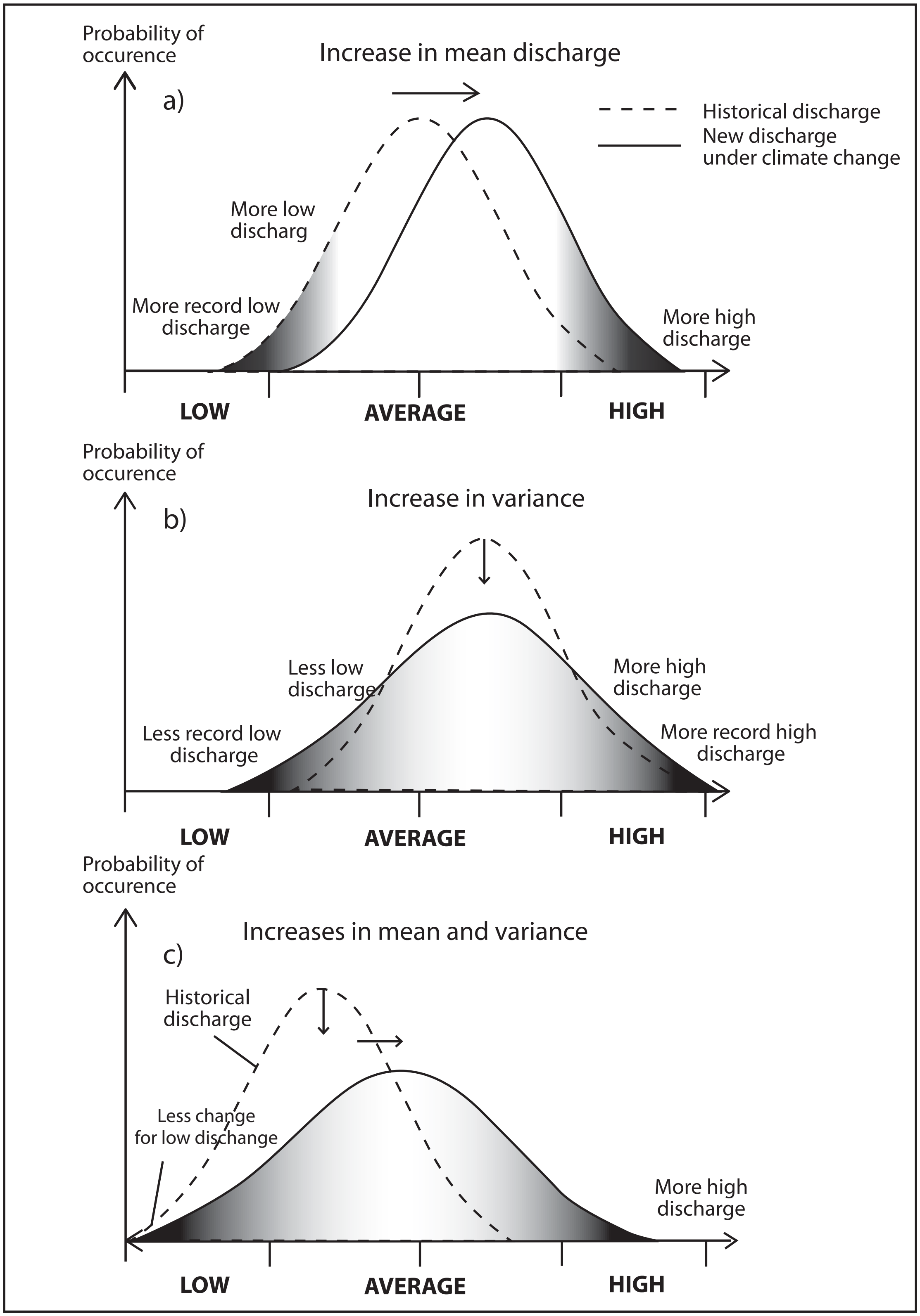


Figure 5.15: Schematic diagrams showing the effects on river discharges when: (a) the mean increases, leading to more record high discharge; (b) the variance increases; and (c) when both the mean and the variance increase, leading to much higher discharge

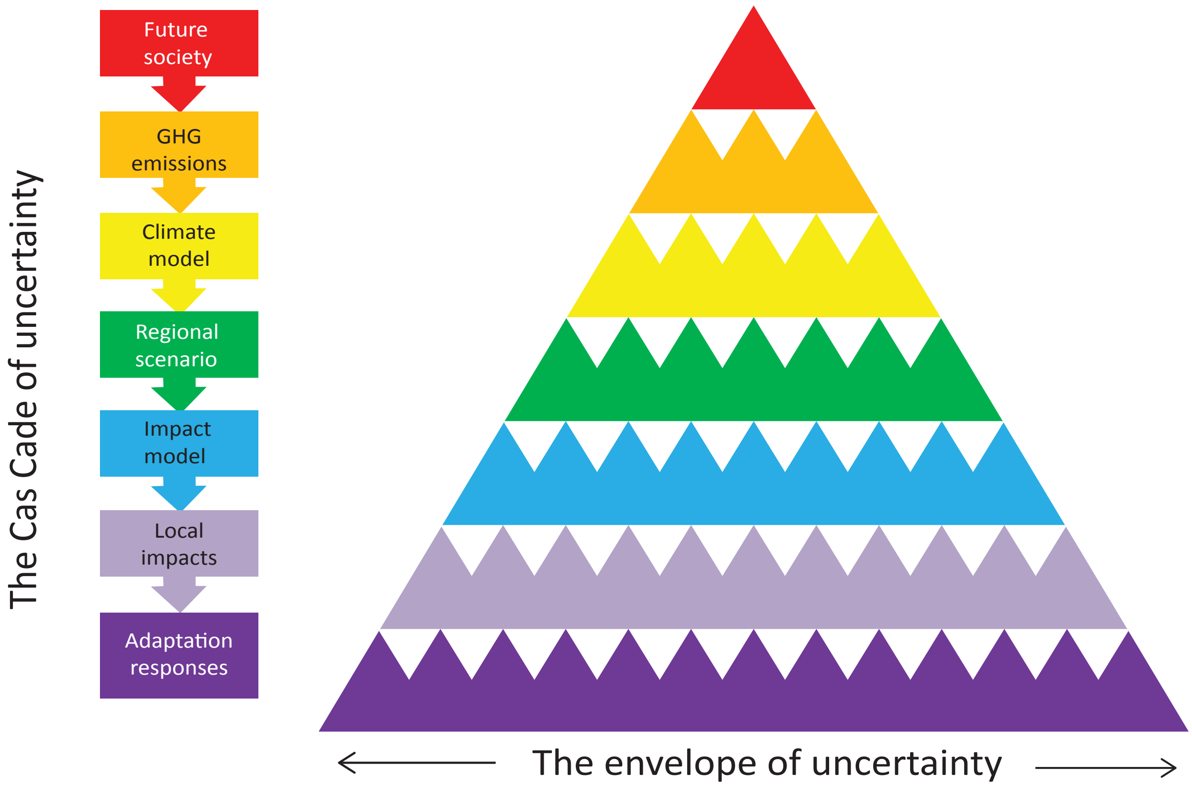


Figure 5.16: The uncertainty cascade (Wilby and Dessai, 2010).

Protective Embankments

Bangladesh has constructed thousands of kilometres of embankments for protection from tidal and inland flood inundations. Still currently some eight million people are vulnerable to inundation depths greater than three meters due to cyclonic storm surges in coastal areas where 28 percent of the country's population lives. This number will increase to 13.5 million by 2050 and an additional nine million is estimated to be vulnerable due to climate change (World Bank, 2014). Rising sea level, possible increases in extreme rainfall, stronger cyclonic storms and associated surges are projected for Bangladesh. Therefore, construction and strengthening of embankments is one of the adaptation options suggested for protection from increased flooding due to climate change. According to the World Bank (2014), rehabilitating and upgrading the height of the polders would increase the resilience of coastal areas to cyclones, tidal and flood inundations, and salinity intrusion in Bangladesh. However, the building of such infrastructure will face two major challenges. First, there is the challenge of meeting the data requirements. New embankments or strengthening of the existing embankments would require a number of data inputs (Kull *et al.*, 2008): past flood losses, maps of flooded areas, basin or sub-basin topography, hydro-meteorological time-series, embankment details including past performance, demographic information, ongoing flood risk reduction activities and climate change projections. Second, there is the challenge of determining and selecting the right flood volume and storm surge heights under different climate change scenarios. In Bangladesh, the current practice is to consider 10-year, 15-year and 50-year return period floods to design embankments for providing protection for agricultural land, major cities and small towns, respectively. For the embankments along the major rivers, the design period flood is 100-years. Such flood defences implemented in the past to provide these specific levels of design probabilities will no longer meet the future required design specifications.

Flood Proofing

In rural Bangladesh, raising homesteads above the highest flood level is a general norm. However, a larger flood will still often inundate them and the people adjust the level accordingly. The Bangladesh National Building Code (1993) defines the Flood Prone Area (FPA) to be any area that has the potential of being flooded by a metre of water. The code specifies that the lowest floor (including the basement) of any building located in the FPA should not be below the designated flood level.

Drainage infrastructure

Flooding situations are exacerbated by inadequate drainage. Drainage congestion occurs for various reasons: inadequate capacity of the drainage channels and urban storm water systems; filling up of the channels for commercial gains; inefficient drainage structures; and tidal inflow hampers drainage of flood waters. Drainage congestion in the coastal polders and major cities such as Dhaka and Chittagong needs to be given particular attention under future climate change. To protect low lying coastal areas from tidal floods and salinity intrusion, Bangladesh has built 123 coastal polders. Water regulating structures are used to prevent drainage congestion in the coastal polders. In future, higher rainfall during the monsoon and the rising sea level would increase drainage congestion in coastal polders in Bangladesh (Dasgupta *et al.,* 2010). Climate scenarios from multiple models can be used in the hydro-dynamic models for flood inundation calculation and mapping. In the past, such scenarios have been used for the estimation of flood damage and adaptation costs in Bangladesh (World Bank, 2010). However, new RCP scenarios are now available and it would be more prudent to use these scenarios for re-estimation.

Under future climate change, the number of short duration and heavy rainfall events could increase. This might result in increased water congestion especially in highly populated urban areas. The suggested adaptation measures are: improvement of urban drainage capacity including pumping provisions, detention storages and restoration of natural drainage canals; restoration of pervious surfaces for enhancing infiltration to ground water aquifers; and installation of new sewers, designed taking into account the climate impacts and retro-fitting of the sewers whenever possible. In designing the new sewers, one major challenge would be downscaling of sub-hourly extreme rainfall from the climate models at the climatic station level.

Irrigation Infrastructure

In Bangladesh surface irrigation is widely practiced. Surface irrigation is the easiest and least costly method of irrigation but is usually highly inefficient as large amounts of water are lost through the earthen irrigation channels. Rahman et al. (2011) found 41% water loss through the rectangular earthen channel in an experimental plot. Godagari, Rajshahi. Mondal *et al.* (1988) examined several options for reducing water loss in the irrigation channels. They found that brick lining, pre-cast sections, soil cement, asphalt mats and also clay lining can generate positive financial benefits in the sandy soils in Bangladesh but initial capital investment is high and large scale adoption by farmers is a formidable challenge. For fine textured soils, simple compaction of canals using proper engineering design specifications can save considerable amounts of water.

Rainwater Harvesting

Rain water harvesting, a low-cost system that is used to collect water throughout the year, is another option Bangladesh could explore comprehensively. This is a cost effective solution especially for the large cities where water demand often exceeds the supply. The systems' capacities vary from 500L to 3,200L and the costs are in the range of $50 to $150. One study shows that rainwater harvesting (RWH) systems could meet more than 15% of Dhaka's water requirements. It should be noted that the quality of water deteriorates with longer (>3 months) storage; in the study, the growth of coliform bacteria was detected. Islam *et al.* (undated) reported on the complete removal of contaminants and 60% removal of bacteria with the application of a traditional filtering system.

Non-Engineering/Soft Options

Water resources management

Given the seasonality of river flows, Bangladesh is a water scarce country. High river flows in the monsoon are actually wasted in the Bay of Bengal. The only major gains from the monsoon rain and surface runoff are recharged ground water aquifers and replenishment of soil moisture. Otherwise, due to the flatness of the country, the scope of water conservation is virtually none. A number of non-engineering options are available, and their implementation can bridge the gap between demand and supply and ensure regular functioning of the water dependent sectors. The major non-engineering options are: flood and drought forecasting and warning, disaster preparedness, insurance, demand management, participation of municipalities in water management, water use policy, pricing, environmental management, water trade and permits, and other institutional and governance measures. Table 5.12 provides a large range of non-engineering options (autonomous and planned) for the water sector.

Ecosystem Options

The 'ecosystems approach' of water management includes management of water quantity and quality in lakes/water bodies and river catchments, the sustainable exploitation of water resources, management of hazards and the maintenance of biodiversity within aquatic catchments. Ecosystems play a significant role in floods and storm surge impact mitigation. Ecosystems that regulate storm and flood impacts in the coastal areas include wave dissipation, absorption, reflection and resistance, barrier to flood surge, wind breaking, coastal accretion and stabilization (long-term), regulation of sediment transport, and linkage with coastal geomorphology. Forests have a significant role in water conservation and in controlling rainfall-runoff processes; tree roots stabilize soils and form channels for rapid stabilization and organic matter from roots and leaves improves soil structure and increases both infiltration rates and water holding capacity (Mirza *et al.,* 2006). Bangladesh wetlands also play an important role in flood control and storm surge protection (BCAS, undated). Shaw *et al.* (2013) suggested forming ecosystem based local flood management zones.

Table 5.12: Synthesis of non-engineering adaptation measures/coping mechanisms for water sector

Flood	Drought
Autonomous Relief operation and rescue Temporary rehabilitation Disease control measures Disaster preparedness Creation of institutions Migration Supply of basic necessities (food, energy, potable water, storage facilities, etc.)	***Autonomous*** Drought resistance agriculture Temporary employment creation Diarrhoeal/water borne disease control
Planned Legislation & policy formulation National land use and land cover plan Awareness raising at various levels Risk assessment and identification of risky locations Training and information systems Engaging NGOs, local communities, private sector in organized ways Promoting regional cooperation Flood forecasting and warning Diarrhoeal/water borne disease control Procuring food and creating a stock Capacity building of the poor with planned income and wealth generating activities/ programmes	***Planned*** Reservoir operating rules for drought situations Skimming wells (for root zone salinity management) and pressurized irrigation systems Drought forecasting and warning Training and information systems Water pricing and metering Participatory water management Regional cooperation for augmentation of flows Improved system of water management Water policy reform including pricing and irrigation policies Investment in water infrastructure to reduce leakages and unaccounted for water Policy for recycling and re-use of waste water

'Do Nothing' Option

The ADB (2012) included the 'do nothing' option to adjust to future climate change. It is similar to the 'bear the loss' option suggested by Burton (1996). However, there are strong arguments against this approach (Ackerman and Stanton, 2008; Richardson, 2009). The ADB's argument was that in some cases, an 'allowance' could be made in the design which would allow the project to adjust to future climate change. This may be true in some cases. for example, in the use of freeboard in the design of embankment to cover hydraulic and hydrologic uncertainty that might allow for the withstanding of a flood greater than the design flood. The magnitude of freeboard in the design values varies widely from country to country for floods of different return periods. In Bangladesh, the FCD/FCDI projects are normally designed to withstand the 20-year flood with a freeboard of 0.9 m (BWDB, 1996). The United States has adopted the 1 in 100-year event, plus 0.9 m (3 ft) of freeboard, which is equal to roughly an annual probability of 1/230 (National Research Council, 2000). The ADB (2012) further suggested letting a project deteriorate and be decommissioned in cases where uncertainty of climate change is too high or it is economically unjustifiable to factor climate change into the project design.

5.5.3 Health

Weather and climate have a significant influence on human health. A changing climate impacts our health and well-being, but it is difficult to determine the degree of complexity, scale and directness to which it does so. In the same way that the vulnerability of the local population varies according to their environment, the impacts of a changing climate also vary (Michael, 2003). Due to important interactions with ecological and social processes, it is difficult to determine the contribution of environmental and biological influences of climate change on health (Githeko and Woordward, 2003). The changes in exposure to heat waves, winter cold, increases in floods, cyclones, storm surges, droughts, increased productions of air pollutants and aeroallergens like spores and molds are all considered to have direct impacts on the health sector in Bangladesh in terms of lives lost, injuries, and disease outbreaks (Michael, 2003). More than 12.4% of the local heads of the Sundarbans community have suffered from illness and 28.5% of this group of have been in accidents due to natural calamities (Masum, 2012). The World Bank (2014) states that: *"According to data collected by the European Detailed Mortality Database, between 1980 and 2010, Bangladesh experienced 234 natural disasters, causing more than $17 billion in total damage. The total number of people killed as a result of natural disasters between 1980 and 2010 was about 191,836; on average, 6,188 people are killed each year."* (World Bank, 2014).

Table 5.13 lists the number of cases and deaths that occurred over a period of thirteen years (2000-2013) due to four different climate-sensitive diseases in Bangladesh. For all four diseases, malaria, dengue, kala-zar and diarrhea, the number of cases was found to fluctuate from year to year and no particular trend could be distinguished. At the same time, the numbers of deaths caused by these diseases were recorded to have suddenly increased from 2002-2004. The total number of deaths from the four diseases under consideration is seen to have substantially declined by 2012 compared to the number of deaths in 2000.

Table 5.13: Major Climate Sensitive Diseases in Bangladesh: Number of Cases and Deaths, by year (2000-2013)

Year	Malaria		Dengu		Kala-azar		Diarrhea	
	Cases	Deaths	Cases	Deaths	Cases	Death	Cases (thousands)	Deaths
2000	54,223	478	5,551	93	7,940	24	1,556	475
2001	54,216	490	2,430	44	4,283	6	1,866	521
2002	62,269	588	6,132	58	8,110	36	2,599	1,022
2003	54,654	577	486	10	6,113	27	2,287	1,282
2004	58,894	535	3,934	13	5,920	3	2,246	1,170
2005	48,121	501	1,048	4	6,892	16	2,152	929
2006	32,857	307	2,200	11	9,379	23	1,962	239
2007	59,857	228	466	0	4,932	17	2,335	537
2008	84,690	154	1,153	0	4,824	17	2,295	393
2009	63,873	47	474	0	4,301	14	2,619	360
2010	55,873	37	409	0	2,810	-	2,427	345
2011	51,773	36	1,362	6	2,534	2	2,268	70
2012	29,518	11	671	1	2060	-	-	-
2013	26,891	15	1,749	2	1428	2	2,641	13

Source: The Health Bulletin, DGHS, 2014; World Bank, 2014

Projected Trends of Diseases and their Health Burden

The IPCC Fifth Assessment (AR5) Report states that changes in temperature, variations in rainfall, heat waves, floods, and droughts will directly affect human health (Smith et al., 2014). In addition, people's health may be indirectly affected because of climate change impacts on crop production. IPCC AR5 also states that: *"until mid-century, climate change will act mainly by exacerbating health problems that already exist".* Climate change will adversely affect health through:

Greater risk of injury, disease, and death due to more intense heat waves and fires;

Increased risk of under nutrition resulting from diminished food production in poor regions;

Consequences for health of lost work capacity and reduced labour productivity in vulnerable populations;

Increased risks of food- and water-borne diseases (very high confidence) and vector-borne diseases;

Modest reductions in cold-related mortality and morbidity in some areas due to fewer cold extremes (low confidence), geographical shifts in food production, and reduced capacity of disease-carrying vectors due to exceedance of thermal thresholds (medium confidence). These positive effects will be increasingly outweighed, worldwide, by the magnitude and severity of the negative effects of climate change .(Smith *et al.*, 2014)

IPCC AR5 also identifies a number of vector-borne diseases, which are associated with different climate drivers including temperature, rainfall and humidity. The vector-borne diseases include malaria, dengue, tick-borne encephalitis, lyme, hemorrhagic fever with renal syndrome (HFRS) and plague. The water and food borne diseases mainly include cholera, diarrhea, skin diseases and malnutrition. Many scientists also anticipate that more frequent and more intense severe weather events will result in increased deaths, injuries and diseases in developed countries like Canada, but the biggest impact will be felt in low-lying, heavily populated areas such as Bangladesh, particularly when coupled with sea level rise (Canadian Association of Physicians for the Environment, 2004). According to IPCC (2001), global warming would enhance vector-borne and water-borne disease in the tropics. In addition, heat stress and heat waves would cause more health problems and morbidity and mortality would increase, especially in least developed countries like Bangladesh.

In terms of climate change impacts on human health in Bangladesh, the World Bank (2014) states that there are three areas of particular concern: *"First, the health impacts of increased climate variability and extreme weather events are projected to be significant by 2050, but well-targeted development investments can mitigate the excess health burden attributable to climate change. Second, rapid urbanization and a growing urban slum population are quickly changing the population dynamics in Bangladesh, and this has implications for climate-induced health risks. Third, given the seasonality effects and the role of confounding factors, the allocation of public resources to deal with climate health risks in the future should be spatially targeted to reach locations that are likely to be at high climate and health risk to ensure cost-effectiveness".*

Table 5.14 sums up the projection results of three childhood diseases and their health burden by 2050 (World Bank, 2014). With an increase in average temperature of 2°C and a 10% increase in the probability of flooding across regions in Bangladesh, the incidence of acute respiratory infection (ARI) is projected to increase by almost two-fold, and the incidence of fever is projected to increase by 10%. In addition, the incidence of diarrhea is projected to decrease by a mere 2%. Based on the United Nations population projections for Bangladesh for 2050, the future health burden of these three childhood illnesses is estimated to be about 14 million disability-adjusted life years (DALY). This burden is to account for about 3.4 percent of GDP by 2050.

Table 5.14: Projected Health Burden by 2050

Indicator	Estimation from DHS Data		Projection
	2004	2007	2050
Climate variable			
Average temperature (survey months) in °C	23.5	27.8	29.0
Probability of flooding (%)	22.6	30.6	40.0

Indicator	Estimation from DHS Data		Projection
	2004	2007	2050
Disease incidence			
ARI			
Incidence (%)	18.7	12.3	23.0
Cases (thousands)	9,009	5,734	14,220
Diarrhea			
Incidence (%)	7	9.2	7.3
Cases (thousands)	3,376	4,296	4,529
Fever			
Incidence (%)	39.2	36.1	46.3
Cases (thousands)	18,916	16,787	28,605
Population ages 0-14 (thousands)	48,222	46,541	61,833

Note: The average temperature refers to the survey months. Flooding is defined as monthly rainfall above one standard deviation for a particular location and month.

The transmission of many infectious water-, food- and vector-borne diseases and food productivity of Bangladesh would be affected by climate change. Change in physical factors like temperature, wind, precipitation, surface water and humidity and biotic factors like vegetation, parasites, etc. would affect the distribution of vector organisms and hosts and could cause immediate deaths and injuries. It was forecasted in various studies that there would be an increase in the geographical distribution of particular vector organisms i.e. malarial mosquitoes and childhood illness if there is a rise in ambient temperature. Water-borne epidemics and an increase in the number of vector-borne diseases may result due to large anomalies in temperature and rainfall in a particular season (Githeko and Woodward, 2003). Further changes in temperature and a longer monsoon season might lead to an increase in the potential transmission of vector-borne diseases such as dengue fever (mosquito), malaria (mosquito), kala-zar and others due to changes in the life-cycle dynamics of vector species and pathogenic organisms i.e. protozoa, bacteria, flukes which are projected to become more prevalent in Bangladesh in the coming decades..

Change in climate variables, living conditions and socio-economic factors can have a direct or indirect impact on childhood illness (World Bank, 2014; Githeko and Woodward, 2003) and most childhood deaths in Bangladesh are due to diarrhea, acute respiratory infection (ARI), which reduces a child's ability to absorb nutrients, and fever. Childhood illnesses such as diarrhea, malaria, pneumonia, measles as well as HIV-AIDS are the reasons behind the high child mortality rate and a higher risk to the climate may increase the numbers of such infections. While a lot of attention has recently been paid to vector-borne diseases, water-borne diseases, especially diarrhea, can be even more deadly. Reports of risk management and disaster management units identify outbreaks of infectious diseases as a result of overcrowding in temporary shelters where people have no access to potable water and live in poor sanitary conditions. In coastal regions, storm surges caused by cyclones, rising sea level and upstream withdrawal of fresh water causes potable water to become contaminated by saline intrusion.

Other health concerns include a possible increase in the number of cases of skin cancer in fair-skinned populations, increases in incidents of cataracts and suppression of immune activity, all caused by depletion in the stratospheric ozone due to global warming. In addition, hypertension, premature delivery and maternal deaths due to pre-eclampsia have been recorded among people who live in the coastal regions of Bangladesh (World Bank, 2014). Extremes of heat can lead to heat exhaustion and cardiovascular diseases to which increased rates of morbidity and mortality can be attributed. Extreme cold can lead to hypothermia. Incidences of food poisoning would increase due to noxious photochemical smog in urban areas and hotter summers.

The vulnerability of people's health is dependent on individuals' degree of sensitivity to climate change and his/her capacity to adapt. The availability of food, local environmental conditions, economic development level, income level and distribution, pre-existing health conditions and availability and quality of public health care are other factors upon which the vulnerability of the population depends. The poor, young and old are at the greatest health risks because of their inability to access resources. Their vulnerability may put the well-being of other members of the same population in danger. Health service interventions can often play a major role in containing the spread of diseases initiated by climate and environmental factors but in the rural areas of Bangladesh, it is often unclear whether intervention failure is responsible for outbreaks or not.

Control in terms of strategies - administrative, behavioural and engineering - may be able to protect the health of the population. Advocacy, education or financial incentives can be used to encourage adaptive actions on a voluntary basis at an individual level. In order to reduce the vulnerability of the population's health these strategies can either be reactive or proactive. With improved public health infrastructure, full employment, reallocation of income and better housing, a long-term reduction in health inequalities may be achieved. Maintaining personal hygiene and food safety may have some effect on mitigating health risks, but the results of research indicate that increased density of rainfall is one of the main reasons behind human infections such as giardiasis and cryptosporidiosis (Michael, 2003). Improved surveillance systems and monitoring can be an elementary approach to adapt to climate change. The sensitive index of impact by any specific disease can be found out from data provided by primary care facilities. However, the surveillance system of morbidity varies from locality to locality and for specific diseases. In order to understand the potential health penalties of climate change we need to have knowledge on population specific historical analogue studies to estimate and forecast the risks of diseases and potential health effects due to comparable exposures and to use existing theory to develop bio-physical models of future health outcomes.

Despite all of these uncertainties, the interest in developing responses to reduce unreceptive effects has grown in parallel to the growth in enhanced knowledge on climate change and health impacts. Earth's climate is expected to keep on changing regardless of heightened awareness and knowledge and increased reduction in greenhouse gas emissions. The IPCC believes that rebuilding public health infrastructure is the most important and urgently needed adaptation strategy. Public health training programmes, sustainable preventions and control programmes, emergency response systems and effective surveillance system are considered important measures. Mitigating disease or injury where possible, avoiding hazardous exposure, protecting people before any hazardous exposure or removing causative risk factors are referred to as primary prevention or anticipatory adaptation methods. For example, providing bed nets to the slums and rural areas of Bangladesh will help prevent dengue fever and malaria. Table 5.15 describes some of the current/potential adaptation options in the health sector.

If anticipatory adaptation fails to contain the outbreak, then secondary prevention or a reactive adaptation strategy needs be taken. The reactive adaptation strategy is implemented by early detection or before the disease becomes symptomatic and then subsequent treatments are given to avert a full progression of the disease. This approach is considered as most effective in fighting health risks due to climate change in Bangladesh because of the population's natural tendency to ignore symptoms and only take action when health starts to deteriorate. Climate related adaptation strategies are not the only options to be considered. Population growth, poverty, sanitation, nutrition, misuse of antibiotics, pesticide resistance, demographic change, availability of health care, public health infrastructure, environmental degradation should also come into consideration while seeking to reduce the negative impacts and minimise the vulnerability of the population.

Table 5.15: Climate Change Key Risks and Adaptation in Health Sector

<table>
<tr><th>Agent of climate change</th><th>Primary physical effect</th><th>Risk to human health</th><th>Adaptation</th></tr>
<tr><td>Temperature Rise</td><td>Heat stress</td><td rowspan="6">Increase in mortality and morbidity of the elderly and those with pre-existing illnesses
Malaria
Drowning and snake bites
Dengue epidemic
Diarrhea epidemics
Dysentery
Pneumonia
Eye Infections
Cholera epidemics
Physical injuries and infections
Direct loss of human lives
Malnutrition
Mental disorders</td><td rowspan="6">Water treatment facilities
Improved sanitation
Improved public health education
Improved disaster forecasting and warning systems
Initiation of training programmes on how to prevention from heat stress and environmental pollution
Improved drainage systems and sewerage lines
Protection of water supply system from heavy rainfall
Surveillance and monitoring
Installation of waste treatment plant to protect surface water
Mainstreaming climate change in national health programmes and policies</td></tr>
<tr><td>Sea level Rise</td><td>Inundation
Water logging</td></tr>
<tr><td>Flood</td><td>Inundation
Water logging
Drainage congestion</td></tr>
<tr><td>Cyclones and Storms</td><td>Extreme wind</td></tr>
<tr><td>Precipitation</td><td>Water logging</td></tr>
<tr><td>Droughts</td><td>Extreme dry weather</td></tr>
</table>

Source: Bangladesh Centre for Advanced Studies, 2008

5.5.4 Fisheries

Introduction

Climate change effects are likely to adversely affect fishery resources, fish production, biodiversity, fish habitats, fish physiology, reproduction systems, growth, migration, fishery and aquaculture related infrastructure, and the lives and livelihoods of the people dependent on them. Some effects may be beneficial to certain aspects of fishery; for example prolonged high floods may help fish production in inland open waters (particularly in floodplains) as they provide a greater area of water and a water depth with sufficient nutrient/feed which stimulates migration growth and breeding.

Fishery sector of Bangladesh

The fishery sector plays a vital role in the economy of Bangladesh. It contributes 3.7% to GDP (23.1% to agricultural GDP), 2.0% to export earning and more than 60% of the animal protein supply in people's diets. Fish is also an important source of different minerals, micronutrients and vitamins essential for the human body. It provides employment to 1.3 million fishermen and women meaning that about 10% of the population is directly or indirectly dependent on the fishery sector. Bangladesh is one of the major fish producing countries in the world. It is in fourth position in respect of inland capture fisheries production globally, and in fifth position in aquaculture production (FAO, 2010). In the overall world fish production Bangladesh occupies eleventh position in the world (FAO, 2010).

Bangladesh is rich in fish resources in its inland, coastal and marine waters with high potentials of further increasing fish production. Inland capture fish, estuarine fishery, marine fishery and aquaculture are the major sources of fish production. Bangladesh has about 3.9 million hectares of inland open waters in rivers, canals floodplains, beels (depressions), reservoirs (Kaptai Lake) and estuarine areas; 0.8 million hectares of closed/semi-closed and impounded water bodies *(Ponds, Dighis, Ghers, etc)* for aquaculture; and vast marine waters along the 710 km shore line in the Bay of Bengal measuring about 1,66,000 sq.km. In the period 2014 to 2015 Bangladesh was producing about 3.7 million metric tons (MT) of fish and shrimp, of which about 28% was from inland capture fishery, 56% by aquaculture and 16% by marine fishery. Inland capture fisheries were previously the major source of fish production in Bangladesh, but due to human interventions, over exploitation and habitat loss and degradation coupled with climate change impact, inland capture fishery has significantly declined. In the 1960s, inland capture fishery contributed to about 90% of the country's fish production. Aquaculture has since developed rapidly and its contribution now preponderates in more than 50% of the country's production. An account of different types of water bodies with annual fish production for the year 2014-15 is shown in Table 5.16. Both inland fisheries and aquaculture are threatened by climate change impact and vulnerability.

Table 5.16: Area and fish production in Bangladesh by different sources

Sl	Type of water bodies	Area of water bodies (ha)	Fish/Shrimp Production (Metric Ton)	% of production by type of water body
1	**Inland open water**			
	(1) River and Estuaries	853863	174878	8.75
	(2) Sundarbon	177700	17580	0.48
	(3) Beel	114161	92678	2.52
	(4) Kaptai lake	68800	8645	0.23
	(5) Seasonal Floodplain	2691910	730210	19.82
	Sub-Total Inland Open water	**3906434**	**1023991**	**27.79**
2	**Closed Water bodies**			
	(1) Pond	372397	1613240	43.79
	(2) Seasonal water	201280	5.46	1510
	(3) Baor/Oxbow lake	5488	7267	0.20
	(4) Shrimp farms	275583	223582	6.07
	(5) Pen culture	7553	13070	0.35
	(6) Cage culture	10	1969	0.05
	Sub-Total Closed Water	**794361**	**2060408**	**56.0%**
3	Marine Waters	166,000 sq.km		
	(1) Industrial fishing	-	84846	2.30
	(2) Artisanal fishing	-	515000	13.98
	Sub-Total Marine	166,000 sq.km	599846	16.28
	Grand Total Bangladesh	**-**	**3684245**	**100**

The inland water in Bangladesh is inhibited by 260 native and 14 exotic species of fish and 13 species of prawn. In marine and estuarine waters, there are about 475 species of fish, 36 species of shrimp, 6 species of lobster, 16 species of crab, 31 species of turtle and tortoise and 335 species of mussels and snails (DoF, 2016).

Fish are highly susceptible to climate change and the effects of climate change effects have, in some cases, already had an adverse impact on fish production, fish habitat/ecology and on the livelihoods of people dependent on fishing. The impact is likely to worsen in future unless appropriate mitigation and adaptation measures are taken to tackle climate change effects. A brief account of the climate change impacts on fishery is given below.

Projected Impact of Temperature Rise on Fisheries and Aquaculture

Temperature rise is a major climate change factor which is already being experienced in Bangladesh and temperatures are predicted to increase significantly by the end of the 21st century. As poikilothermic animals, fish cannot regulate their body temperature through a physiological process; their body temperature is regulated by environmental processes. Thus fish physiology i.e. growth, reproduction, and metabolism are directly influenced by changing temperatures (Chowdhury *et.al.* 2010). Extreme temperatures coupled with erratic rainfall patterns have a direct impact on fish physiology, growth, mortality, reproductive systems, feeding behaviours, production, and migration in inland and marine waters. High temperature may induce the growth of aquatic microphytes which can reduce the productivity of water, and cause habitat degradation and oxygen depletion. The indirect impacts of climate change on fish are the changes and effect on the fish habitat/ecology on which fishes depend for food and shelter (Mustafa, 2010). High or extreme temperature may affect the physical and chemical parameters of water which affects fish physiology, migration, growth, reproduction etc. Temperature rise may also affect the distribution patterns of some marine fish and they may migrate to higher latitudes in search of cooler water (Chowdhury, 2010). High temperatures and erratic or insufficient rainfall also means fish do not ovulate properly, eggs are not fertilized and there is a drop in the hatching rate.

Observed Impacts of Erratic Rainfall

High temperature with irregular or insufficient rainfall might affect the spawning activity of fin-fishes, particularly major carp, which needs very specific environmental, ecological and biological conditions for spawning. In 2009, due to high and fluctuating temperatures and late insufficient rainfall, aquaculture activity including fish hatchery performance and grow-out ponds was seriously affected in the Mymensingh region of Bangladesh, an important aquaculture area (Mustafa, 2009). Akhter, Z. Nasrin (National Fish Week, 2016, DoF) reported that erratic rainfall and temperature fluctuation have already had a negative impact on the spawning performance of major carp in the only natural spawning ground of major carp in the Halda river in Bangladesh. Spawning in the river usually occurs during April and May when favourable environmental conditions (rainfall, temperature, water flow, water quality etc) prevail. In 2004, due to late rainfall and higher temperatures, major carp suffered the lowest rates of spawning (20kg) on record). Table 5.17 shows that the spawning performance of major carp in the Halda river has drastically declined due to habitat degradation and change of climatic factors, mainly temperature and rainfall pattern. It has also been reported that there was no spawning in the Halda River in 2016 because of insufficient rainfall and other unfavorable climatic parameters. (Information provided by DoF officials).

Table 5.17: Spawning performance of major carp in the Halda River

Year	Date of spawning	Time of spawni ng (hrs)	Quantity of fertilized egg (kg)	Quantity of spawn produced (kg)	Rate of producing spawn compare to that of 1945
1945	30 April	18:00	50000	5000	-
1947	23 April	20:00	48800	4960	99.2
1948	25 April	04:00	50000	5000	100.0
1949	01 May	22:00	49800	4990	99.8
1997	29 May	22:00	11700	300	6.0
2003	03 June	16:00	8000	199	4.0
2004	21 June	03:00	780	20	0.4
2007	15 May	11:00	12700	307	6.1
2008	17 June	14:00	5000	120	2.8
2009	24 May	23:00	7500	180	3.6
2010	31 Marh	15:00	5700	138	2.8
2011	19 April 19 May 16 June	09:00 06:00 12:00	9700	235	4.7

Year	Date of spawning	Time of spawni ng (hrs)	Quantity of fertilized egg (kg)	Quantity of spawn produced (kg)	Rate of producing spawn compare to that of 1945
2012	8 April 01 June	11:00 06:00	70000	1559	31.2
2013	-	-	-	626	12.52
2014	-	-	-	508	10.16
2015	-	-	-	108	-

Extreme and prolonged cold weather may also affect fish and other aquatic animals. The metabolic function of fishes is reduced and the growth of fish is stunted in extreme cold weather which may also affect their physiological and reproductive systems. During continually overcast or foggy weather, photosynthesis ceases, leading to oxygen depletion in pond water and causing mortality in fish.

Observed Impacts of Drought

Drought associated with high temperatures and decreased rainfall is likely to cause adverse impacts on aquaculture and inland open water fisheries in the drought prone areas of Bangladesh. In the north and north-west regions of Bangladesh particularly in the Barind area, drought has been found to affect aquaculture due to the availability of sufficient water and drying up of bodies of water. Ponds, rivers, canals and beels dry up or retain insufficient water during dry periods or periods of drought and this affects fish production in aquaculture and in open waters in the north-east region (Haor area in Sylhet basin) as well as in the north and north-west drought prone area. Fish growth, reproductive systems, survivability and biodiversity are affected adversely by drought and and fish become vulnerable to diseases. Human interventions combined with climate change effects have adversely affected aquatic biodiversity. According to the IUCN, some 54 species of fishes are endangered, of which 12 are either critically endangered or have become extinct (IUCN, 2000). Connectivity of different water bodies particularly between rivers and floodplains/beels has been lost due to the drying up of various water bodies and connecting channels adversely affecting migration, breeding and growth of fishes and other aquatic animals.

As an adaptive measure, commercial fish farmers supply water in the fish pond from outside. Sometimes ponds, canals and beels are re-excavated to increase their water retention capacity for fish culture/production and re-excavated canals and beels may be declared fish sanctuaries for the protection and conservation of fish.

Projected Impacts of Sea Level Rise and Salinity Intrusion

With sea level rise, the intrusion of salinity will further reduce the area of water available for fresh water fish production. Increasing salinity levels have already adversely affected freshwater fish culture and are likely to continue to threaten aquaculture, species distribution and biodiversity in the coastal region. Farmers are now using saline tolerant species such as tilapia and parsa (Mugil). Fresh water giant prawn *(M. rosenbergii)* which can tolerate salinity up to 6 ppt are also being farmed in coastal areas. Sea level rise and salinity also threaten Bangladesh's mangrove forest, which is an important breeding and nursery ground of many species of fish and shrimp.

Sea level rise may affect oceanographic parameters that will have adverse consequences on fish. Atmospheric CO_2 concentration is likely to increase from 380ppm to 540 to 939 ppm by the end of the 21st century. Increased levels of CO_2 will reduce ocean pH by 0.4-0.5 which may disturb fish physiology (Royal Society, 2005). Fish embryo and larvae are very sensitive to pH change; eggs of pelagic fish are also susceptible to pH change and it may affect the physiology of marine fishes (H.O. Portner et al. 2004).

In low lying areas of the coastal region sea level rise will increase the water area available for farming fish and shrimp in the coastal belt. Increased salinity may create opportunities for brackish water or estuarine aquaculture and fisheries conducive to tiger shrimp (P.monodon) in coastal areas. The growth of tiger shrimp reaches its maximum at 2-25 ppt. of water salinity, beyond which growth may be affected.

Observed Impacts of Cyclone and Tidal Surge

Major impacts of global warming include increases in the occurrence of severe cyclone and tidal surges. Over the last few decades, the occurrence and intensity of tropical cyclones have increased in the Bay of Bengal region, particularly in Bangladesh (Chowdury et al., 2010) and have caused heavy loss of life, property, infrastructure, forest and aquatic resources. Cyclone Sidrs (November 2007) and Aila (May 2009) destroyed, among other things, coastal aquaculture, fishing equipment (boats and nets) and took the lives of many fishermen and women. More recently Cyclone Mahasen (May 2013) and Roanu (April 2016) adversely affected fishermen and women and their assets, aquaculture infrastructure, fish habitats and fish ecology.

More than 60% of fish ponds and shrimp enclosures in coastal areas of Bangladesh were totally damaged by Cyclone Sidr and the remaining ones were partially damaged causing an approximate loss of more than $200 million including $6.71 million damage to infrastructure (DoF, 2008; GoB, 2008). Table 5.18 shows these and other losses.

Table 5.18: Loss of fishery sector by cyclones

Cyclone/ Surge		Year	Wind speed (km/hr)	Surge height (m)	Total loss/damage (fish/shrimp and infrastructure damaged/lost) (Million USD)
1	Sidr	2007	260	5.5	300
2	Aila	2009	120	3.0	126
3	Mahasen	2013	120	1.1	1.0
4	Roanu	2016	54	1.0-1.5	20.1

Observed Impacts of Floods and River Erosion

Bangladesh consists mainly of plains. Mean elevation from sea level ranges from less than one metre in the tidal floodplain, to one to three metres in the main river and estuarine floodplain and up to six metres in the Sylhet basin in the north-west. The country is prone to floods. Almost annually 22-30% area of the country is flooded. Due to the climate change effect of erratic and excessive rainfall and run off from upper riparian countries, high floods occur frequently in Bangladesh, inundating vast areas and adversely affecting agriculture, fisheries, livestock, infrastructure and other property. River bank erosion, occurring mainly due to flood, contributes to river siltation reducing the water holding capacity of the rivers and degrading the fish habitat by reducing water availability in winter months for fish production and for the conservation of biodiversity. As floods inundate more areas in the floodplain however, the open water fishery/flood plain fisheries benefit as fish have increased feeding areas, more nutrients and sometimes a longer time to grow.

Flooding can, however also lead to loss for farmers when aquaculture ponds and enclosures are inundated and farmed fish escape. Predator fish may also find it easier to enter waters at periods of flooding and threaten aquaculture. Floods in 2015, while classified as low to medium, adversely affected aquaculture throughout Bangladesh; as per the estimate of DoF, about 140,000 fish ponds and shrimp ghers were inundated causing an estimated loss of 34,164 metric tons of fish and 2,926 metric tons of prawn and shrimp, valued at $92.6 million.

As an adaptation measure against the flooding of fish ponds, temporary fencing can be put on the pond dykes to protect the fish. Pond dykes may also be raised to protect the fish. Some farmers harvest fish at the beginning of a flood to avoid loss of fish. Once flooding subsides, work needs to be carried out on the affected ponds to remove predators and excessive silts and repair them before re-stocking the ponds with fish and shrimp for cultivation.

Adaptation to climate change on the fishing sector in Bangladesh

To cope with the adverse effect and vulnerability of the fishing sector caused by climate change, people take various measures. Scientists and the government also recommend strategies and actions to cope with the effects of climate change. A summary of these adaptation measures is given in in the following table.

Climate change effects	Impact & Vulnerability of climate change on aquaculture and fisheries	Adaptation measures
Flood & River Bank Erosion	High floods affect aquaculture – floods inundate and damage pond dikes and fish escape, causing loss to fish farmers. Floods pollute pond waters and cause disease in fish. Siltation also occurs at the pond bottom due to silt being carried out by flood waters. River bed siltation by river bank erosion affects fish migration, breeding ground, production and livelihoods of fishermen and women. Inland capture fisheries benefit from increased water.	Temporary fencing on embankment by nets to protect fish. Raising existing pond embankments. Development and supply of short cycle fish species for aquaculture. Increased water-holding capacity of the rivers by dredging. Construction and rehabilitation of flood free pond embankments Adjustment of aquaculture cycle with food period from July-September. Introduction of floodplain aquaculture. Storage of fry/fingerlings in flood free govt./private hatcheries for post flood stocking.
Drought	Water area and depth decreased/ dried up affecting fish stock, growth, breeding, production & biodiversity. Increased vulnerability to disease. Reduced fish production period. Decline in broods stock of natural SIS and other fish. Decrease in production. Decline in biodiversity.	Fish in pond harvested before drought and in commercial farming water. Regular re-excavation/dredging of water bodies. Construction of water reservoirs to supply water to aquaculture and river systems. Introduction of drought/heat tolerant resistant fish species for aquaculture. Introduction of first growing species for cultivation. Adoption of measures to control disease in pond aquaculture. Storage of rainwater and river waters by dams.
Cyclone and Storm Surge	Loss of coastal fishermen's and womens's lives and properties (net, boats) Damage to fish landing and marketing centres. Damage to aquaculture infrastructure (embankments, sluice gates), hatcheries and nurseries, and loss of shrimp and fish. Loss of coastal aquaculture production and damage to aquaculture infrastructure affecting the farmers' income and livelihood. Reduced employment opportunities and increased poverty.	Relief, rehabilitation and loans to adversely affected fishermen and women and fish farmers. Cyclone shelters. Timely warnings, awareness creation and precautions. Improvement of pond dykes and other infrastructures. Cyclone shelters and boat shelters for fishermen and women, multistoried dwelling houses. Rearing of shrimp/prawn PL/fry in other regions for post cyclone stocking.
Sea Level Rise (SLR)	Salinity intrusion and increase of saline water area facilitates brackish water aquaculture. Increase of saline water area by inundation of low-lying coastal area will increase brackish water fish/shrimp production. Change in oceanic water mass and oceanographic parameters affects marine fish stock, fish migration and biodiversity. Freshwater fish production area decrease affects freshwater fish production.	Construction of suitable coastal embankments and dams. Development of 1 km wide forest belt along the entire coast. Introduction of sea cage culture and sea fencing. Intensified coastal aquaculture with appropriate technology and infrastructure.

Salinity Intrusion	Inland open water fisheries area decreased affecting freshwater fish production and livelihood and income. Positive impact on coastal shrimp culture. Affects aquaculture pattern and fishing technology.	Enhance numbers of fish production through rehabilitation of fish habitats and establishment of fish sanctuary to compensate loss of freshwater fish production due to salinity intrusion. Saline resistant fish species be introduced in aquaculture. Introduction of brackish water finfish aquaculture.
Erratic Rainfall	Insufficient/irregular rainfall adversely affects the natural spawning of fish (including major carp spawning in Halda River and Kaptai lake) and ultimately fish production and fishermen and women.	Storage of excessive water by strong structures for dry season water supply for aquaculture.
Temperature rise and Variation	Affects breeding performance of fish and fish production in natural water bodies and fish/ shrimp hatcheries. Sudden or prolonged heat may affect fish breeding performance and aquaculture production. Affects fish biodiversity. Higher temperature increases metabolic function and growth of fish - if DO_2 and food supply are optimum, fish growth and production increase. Higher temperature may enhance primary productivity but reduces DO_2 affecting aquaculture.	Introduction of temperature tolerant species. Deepening of 10% to 15% of the pond area by 1-1.5 metre enabling fish to take shelter during extreme temperatures as deeper water is less affected by temperature change.
Heat Wave	High temperatures may affect fish breeding in hatcheries and natural water and may cause mortality in ponds/shallow waters.	Aquatic vegetation shelter in ponds. Ensure demand-based water supply for aquaculture. Introduction of heat resistant species for aquaculture.
Cold Wave	Retarded growth affecting breeding performance and fish production.	Introduction of cold tolerant species.
Fogginess/ Cloudy Weather.	Causes fish mortality in aquaculture ponds and small water bodies due to depletion of dissolved oxygen.	Agitation of Surface Water. Use of aerator to increase oxygen in water.

5.5.5 Livestock

Introduction

Livestock is under threat due to changes in climatic patterns. Climate change effects through flood/flash floods, river bank erosion, erratic rainfall, drought, seasonal variation, cold waves, rises in temperature, water logging, nor'westers, tornadoes and cyclones, thunder, hailstorm and salinity intrusion are likely to affect livestock in Bangladesh adversely.

Status of livestock in Bangladesh

Bangladesh's livestock is the second largest sector after the fishery sector to meet the national animal protein demand (BARC, 2011). Animal protein in the form of milk, meat and dairy products plays an important role in meeting people's dietary needs, and livestock, particularly cattle, are used in tilling land for agriculture. Livestock is an integral part of Bangladesh's agricultural economy and performs numerous economic, social and cultural functions – it is a source of nutrition, income, employment generation, foreign currency earnings (hides, skins, bones and other products are exported), draft power, manure, fuel and transport. Livestock and poultry production in Bangladesh is presented in Table 5.19 below.

Table 5.19: Livestock and Poultry production in Bangladesh (2014-15)

Sl. No.	Livestock /Poultry	Numbers (Million)
1.	Cattle	23.64
2.	Buffalos	1.46
3.	Goat	25.60
4.	Sheep	3.27
5.	Chicken	261.80
6.	Duck	50.52

Source: DLS Bangladesh

The country has increased its dairy production in recent years, but present production levels of both dairy and meat products remain far below the national demand. The status of the production of milk, meat and egg as of 2014-15 is presented in Table 5.20.

Table 5.20: Production of Milk, Meat and Eggs, 2014-15

Production	Unit	Amount/ Quantity
Milk	Million Tons	6.97
Meat	Million Tons	5.86
Egg	Million	10,995.20

The contribution of livestock and poultry to the national economy is presented in Table 5.21.

Table 5.21: Contribution of livestock and poultry to the national economy of Bangladesh.

1	Contribution of livestock in GDP (2014-15)	2.79%
2	Contribution of livestock sector to national economy (2011-12)	2.58%
3	GDP growth rate of livestock sector (2014-15)	5.85%
4	Share of livestock in agricultural GDP (2014-15)	17.15%
5	Employment (direct) out of total population	20%
6	Employment (indirect) out of total population	50%
7	GDP volume (current price) in million taka (2014-15)	2988.70 (appx)
8	Foreign exchange earnings only from hides and skins (2014-15)	4.31%
9	Cultivation of land	30%
10	Supply of animal protein for dietary purposes	44%
11	Production of organic fertilizer	125 MMT
12	Fuel Supply	25%

Source: Department of Livestock Service, GoB -2016 .Web: www.dls.gov.bd.

The livestock sector plays a vital role in the national economy, in employment generation and in reduction of poverty of marginal farmers and landless and destitute men and women of the country. About 17.15 % of agricultural GDP comes from the livestock sector and 20% of the people of the country are dependent on the livestock sector for their livelihoods. In the poverty reduction strategy of GoB, the livestock sector is considered to be one of the key players in overcoming the poverty of the rural households.

Impact of climate change on livestock

Climate change has both a direct and an indirect impact on livestock, and both pose a serious threat.

Effects from air temperature, humidity, rainfall, heat and cold waves, wind speeds and other climate factors have a direct influence on animal growth and reproduction and on milk and wool production (Hounghton *et al.*, 2001). Indirect effects of these same factors include climatic influences on the quantity and quality of animal feed in the form of pasture, forage and grains and on the severity and distribution of livestock diseases and parasites (Seo and Mendelsohn, 2006a).

The Intergovernmental Panel on Climate Change (IPCC, 2007) predicts that the global temperature will increase between 1.8 and 4.0°C by the end of the 21st century and as a result the sea level will rise by 0.18 to 0.79 meter. The sea level rise will inundate new coastal areas, which will affect livestock by reducing grazing areas and fodder productions. IPCC has indicated that the intensity of the drought will increase in the north and western parts of Bangladesh. While, compared to other sectors, few economic analyses have been carried out on climatic effects on the livestock sector worldwide, global climate change is expected to alter temperature, precipitation, atmospheric carbon dioxide levels and water availability in ways that will affect the productivity of crop and livestock systems (Hatfield et al., 2008). Like human beings, livestock and poultry may suffer due to natural disasters, higher temperatures, salinity intrusions and floods. The livestock sector of Bangladesh is characterized by homestead rearing and poor protection of homesteads often makes them the first victims of any natural disasters.

In 2007 Cyclone Sidr hit 17 districts in the coastal region of Bangladesh. The cyclone's surge was over 5 metres. According to official accounts, 3,447 people lost their lives during the cyclone, hundreds of thousands of people lost their homes, and there were enormous losses to livestock too. Livestock losses are presented in Table 5.22.

Table 5.22: Death of Livestock during SIDR 2007

Livestock/Poultry	Number of animal deaths
Cow	37,391
Buffalo	7,200
Goat	59,804
Sheep	3,517
Hen	22,19,328
Duck	3,53,691

Monetary loss in the livestock sector due to natural disasters including floods, surges, storm surges, salinity intrusions, epidemiological disasters (avian flu, ranikhet disease, foot and mouth disease, anthrax etc), flood, cold and heat waves is presented in Table 5.23 below.

Table 5.23: Loss of Livestock due to natural disasters in Bangladesh, 2005-2014

(In Million BDT)

Year	Amount
2005	2,540
2006	3,000
2007	10,000
2008	10,000
2009	10,000
2010	10,000

Year	Amount
2011	10,000
2012	10,000
2013	10,000
2014	5,000
Total	80,540

Source: DLS, 2015

This estimate does not include the damage to livestock sheds, houses and infrastructure.

It is clear that the monetary loss is substantial and damages occur annually.

In future, climate change could affect the costs and returns of livestock production by altering the thermal environment of the livestock and thereby affecting their health, reproduction and the efficiency by which livestock convert feed into retained product (especially meat and milk). Thermal stress for animals may reduce animal production and profitability by lowering feed efficiency, milk production and reproduction rates (Fuquay, 1981; Morrison, 1983; St-Pierre *et al.,* 2003).

Direct impact

The direct threat to livestock includes the death of animals and birds due to seasonal variations, nor'westers, tornadoes and cyclones, thunder, heat stroke and cold waves. Other direct impacts are as follows:

Impact on feed intake

Both high and low temperatures have a direct physiological impact on livestock. At temperatures below the thermo-neutral zone, livestock generally spend more energy and increase their voluntary feed intake in order to maintain their core temperature, resulting in lower feed efficiency. (NRC, 1981). Above the thermo-neutral zone, animals may experience heat stress and respond by reducing their voluntary feed intake, which reduces their weight gain and feed efficiency. (Hahn, 1999; NRC, 1981; Cooper and Washburn, 1998; Yalcin *et al.,* 2001). Heat stress can also reduce fertility, milk production and reproduction (Hansen *et al.,* 2001; Ranaudeau and Noblet, 2001). Extended periods of high temperature can be lethal for livestock and a particular risk for feedlot cattle in some regions (Hahn *et al.,* 1999; Hahn and Mader, 1997). Temperature can cause physiological stress in poultry. High temperature increase body metabolism rate of poultry which will result in a reduction in egg and meat production. In addition, disease may be more prevalent.

Impact on milk production

One of the direct impacts of climate change on livestock is on milk yield. An increase in the number of stressful days (Temperature Heat Index - THI more than 80) and their frequency will impact the yield and production of cattle and buffaloes (Upadhay *et al.,* 2007). Immediate impacts of climate change in the livestock sector are: reduced grazing areas; fodder crises; and reduced growth resulting in decreases in the production of milk, meat and eggs. Studies in India and Nepal which are relevant for Bangladesh provide strong evidence. In India, Maust *et al.,* (1972) reported the variation in milk yield (9%), milk fat (13%), feed intake (5%) and rectal temperature due to THI were attributable to prevailing weather conditions. This shows that an estimated annual loss due to direct thermal stress on livestock in India is about 1.8 million MT of milk which is nearly 2% of the total milk production in the country. Dhakal *et al.* (2013) observed that climate change had negative impacts on milk production and lactation length and infertility in Nepal.

Impact on livestock reproduction

Heat stress due to high temperatures accompanied with excess humidity during summer months causes infertility in most farm species and has an adverse effect on the reproductive performance of both male and female farm animals.

Impact on disease occurrence in livestock

A warmer and more humid climate has already caused increased prevalence of diseases and disease vectors to grow. Due to the synergistic effect of hot spells, and cold waves, emerging and re-emerging diseases like avian influenza, the poultry sector lost its upward trend in Bangladesh in 2007 and the sustainability of the sector is becoming fragile. As the livelihoods of small and marginal farmers face a critical environment, entrepreneurs are losing their confidence to invest more in the sector.

The impacts of changes in ecosystems on infectious diseases depend on the ecosystems affected, the type of land–use change, disease specific transmission dynamics and the susceptibility of the populations at risk. The changes brought about by climate change on infectious disease burdens may be extremely complex. Higher temperatures resulting from climate change may increase the rate of development of pathogens or parasites and shorten generation times leading to higher pathogen /parasite population size (Harvell *et al.,* 2002).

Impact on biodiversity

According to Watson (2002) climate will continue to change rapidly; cheap energy and other natural resources including freshwater will diminish and disappear at an accelerating rate. The socio-economic conditions of agricultural and farm communities will deteriorate further while genetic diversity among crops and farm animals is lost. Biodiversity will decline faster as terrestrial and aquatic ecosystems are damaged and harmful exotic species will become more numerous.

Indirect impact

In addition to the direct effects of climate change on animal production, there are profound indirect effects as well, which include climatic influences on quantity and quality of feed and fodder resources such as pastures, forages, grain and crop residues and the severity and distribution of livestock diseases and parasites.

Livestock is extremely vulnerable to the severe effects of natural disasters in the wake of climate change including floods, cyclones, storms and surges, heat- and cold waves. When livestock are threatend, so too are the livelihoods of those who dependent on livestock as a primary source of income. for Recently it has been noticed that irregular flooding is causing decimation of livestock and increased vulnerability among women, marginal farmers and poor people for whom livestock is their main source of livelihood. Frequent floods and tidal surges have created accommodation problems for birds and animals due to inundation. Irregular flooding causes problems for livestock in relation to feed and places where they are kept. In particular, water-logging and mudflat due to irregular flooding are the main cause of infections such as foot and mouth disease and bird flu which result in huge losses of livestock. The situation is more critical in the coastal regions where cyclones and floods often result in the deaths of animals, and where, in post flood situations the livestock become weak from lack of proper feed and water and more susceptible to diseases.

Salinity intrusion is an increasing threat in the coastal areas in Bangladesh. Climate change and its associated hazards like sea level rise, cyclone, storm and surge have all contributed to the increasing the salinity problem of salinity. Any increase in sea level may push saline water much further inland as the coastal zone in Bangladesh is relatively low-lying. As described in BCCSAP 2009, salinity intrusion is likely to seriously affect crops, livestock and fisheries. Grazing lands may no longer be productive due to rising salinity in coastal areas, which would limit the livestock population. The shortage of fodder is a common phenomenon after floods or tidal surges and livestock suffer when their feed is dimished. This creates a huge loss of productivity.

In addition to a decrease in productivity, fluctuations in temperature have resulted in large numbers of poultry deaths.

It is predicted that a 45 cm rise of sea level may inundate 10-15% of the land by 2050 resulting in over 35 million climate refuges from the coastal districts (DoE, 2007). Studies and assessments also indicate that the context of vulnerabilities and associated impacts vary by spatial and temporal scale and by the socio-economic conditions of communities. In Bangladesh, livestock, poverty and economic growth are interlinked. Therefore, a quick response is needed for the sustainable rehabilitation of livestock after any climate change event. Cyclone, storm surges and sea level rise are the most critical climatic factors responsible for severe effects on the livestock population.

Adaptation measures for livestock sector

In the decades to come, if livestock is to survive, action will need to be taken to alter distribution patterns, change behaviour patterns, and/or make adjustments in their physiology, either by short-term acclimation through phenotypic flexibility or by longer term evolutionary shifts in physiological phenotype by means of natural selection (Chown *et al.,* 2010). In this context, it is necessary to understand how individual animals will respond to higher air temperatures through phenotypic flexibility.

Livestock is sensitive to climate change and at the same time itself is a contributor to the phenomenon. Climate change has the potential to be an increasingly formidable challenge to the development of the livestock sector. As the number of farm animals reared for meat, egg and dairy production increases, so do emissions from those productions (FAO, 2006). Livestock waste for biogas production is an appropriate measure for development and management of livestock resource including GHG emission from livestock.

By 2050, global farm animal production is expected to double from its present levels. Impacts of climate change mean that present approaches and traditional methods of adapting to climate change need to be reassessed with more scientific information and technology. Applied research is urgently required to find ways to reduce the adverse effects of climate change on animals and birds, and DLS and BLRI should have separate cells to assess the issue of climate change in relation to livestock rearing, which are not addressed at present, and should undertake applied research in this regard in cooperation and consultation with relevant organizations such as BAU, Vet University, DoE and other relevant organizations such as the Palli Karma-Sahayak Foundation (PKSF) and BRAC.

Animal and bird houses have to be built using suitable roof materials with the provision for adjustment in response to high and low temperatures. Electricity and generators can be used to make the houses more comfortable and well ventilated for animals and birds. Hygienic conditions of livestock houses have to be improved to avoid the risk of infections. Basic animal husbandry services with primary animal health care services are required, and empowering women with adequate skills in rural areas may greatly boost livestock rearing, even in hazardous conditions. Efforts must be made to promote both service provisioning as well as reception of such services to maintain proper animal health during a climate driven stressful condition. At the same time, climate change adaptation-training programmes should be implemented for relevant stakeholders by government organizations. In this way, farmers can acquire knowledge on climate change in the context of livestock rearing from relevant government organizations and NGOs and be more responsive to the issues of animals and birds vis-a-vis climate change.

At present there are no safe shelters for livestock like the cyclone shelters that exist for humans which have been proved very effective. Safe shelters could save millions of livestock during natural disasters. Attention should therefore given to building more 'killas' (elevated high lands for livestock shelter) with adequate provisions for repairing them in the aftermath of a cyclone.

Based on studies and experience, some measures to cope with livestock sector climate change impacts and vulnerabilities are recommended as follows (Table 5.24)

Table 5.24: Potential adaptation measures on livestock sector

Strategy	Exposed to	Measures to reduce exposure
Reduction of exposure	Flood and flash flood	Construction of livestock shelters (*'killas'*); establishment of flood centres; ensure animal food supply; preventive measures during flood.
	Drought	Development of irrigation system for fodder production; feeds and fodder preservation for lean period.
	Erratic rainfall	Disease prevention and curative measures.
Reduction of sensitivity	Flood and flash flood	Awareness raising of and involvement of policy personnel and public at large. Development of feeding systems to reduce production of methane and carbon dioxide.

Strategy	Exposed to	Measures to reduce exposure
	Drought	Preservation of feeds and fodder; introduction of drought tolerant fodder species.
	Sea level rise	Protect fodder production area by embankment.
	Salinity intrusion	Introduction of salt tolerant fodder species.
	Temperature variation	Promotion of temperature tolerant livestock breeds.
	Heat wave	Development of special type of housing for animals and poultry; feeds and fodder preservation; introduction of heat tolerant fodder species.
Improvement of adaptive capacity of community	Cold wave	Establishment of veterinary centres at village level for animal health care during cold waves; management technology should be developed

Climate change damage is expected to get worse in the future and livestock may be affected even more than anticipated. Policymakers should therefore focus on applying effective adaptation measures to reduce vulnerabilities in the livestock sector. Given the country's dependence on agriculture, it is essential that advanced technology and knowledge is harnessed for the sustainable development of the livestock sector (Ahmed *et al.,* 2013).

5.5.6 Industries and Infrastructure Sector

Background

The impacts of climate change on activities are studied according to five focal areas, which are also five dimensions of vulnerability. The first focal area is the impact of climate change on the availability of resources and, by extension, on suppliers, in other words on the upstream production process. For example, for a water management activity, the potential reduction in the availability of water is a factor of vulnerability. The second area concerns the standards used in the design of infrastructure in terms of its robustness to adapt to climate change. Designers often use climate standards that are based on the past to determine the dimensions of infrastructure or production tools. The third focal area is the impact of climate change on the management of the industrial process. Are there certain elements or characteristics of this process that are sensitive to the climate in general and to climate change? The fourth area is that of demand and its climate sensitivity. This is the case, for example, of demand for heating or air conditioning and its impact on electricity generation or the design of district heating networks. The fifth and final area of concern is the occurrence of industrial climate incidents, in other words climate disasters (violent storms, gales, floods, droughts and cold waves) that cause direct or indirect damages to the industrial base.

Practically speaking, these five focal areas can structure the development of potential vulnerability indicators. In Bangladesh, these indicators should be developed in consultation with climate scientists and industries both in the private and in the public sectors .The need to think now about the impacts of climate change has not yet been proven for all industrial sectors, but neither has it been established that not doing so is risk free. Some industries already take climate change into account in their investment decisions, but in others, a number of obstacles make it difficult even to establish a dialogue. Although the reality of the phenomenon is not questioned, the question of the impact of climate change on industrial activity is rarely posed. At the same time, it cannot be ignored. Appropriate adaptation measures should be identified through analyses of the realities and assessment of risks and action taken accordingly.

Climate change risks and adaptation in industry

Climate change risks and adaptation can be discussed in the context of a number of major industrial categories.

The Textile Sector

In Bangladesh industrial growth has been significant over the last few decades. The most significant growth has been in the export textile sector. Factories were set up mostly in and around big cities like Dhaka and Chittagong where infrastructure – roads and access to natural gas and electricity, for example - is better than in rural areas. This resulted in the formation of clusters of the factories, which has created stresses on the resources required for running them. Almost all the factories located in these clusters use ground water for required washing, dyeing and finishing, processes which require large volumes of water. Aquifer levels in these areas are falling, which may create water shortages in the future. The problem may be exasperated by climate change which will adversely impact recharging of ground water. Adaptation measures are needed such as a reduction in water consumption and conservation implementing recycling, reusing and Zero Liquid Discharge (ZLD) technology which is being made mandatory by the Department of Environment (DoE). The other alternative is to switch to using surface water. This will require large surface water treatment plants, involving large investments. More than 90% of the textile industries are privately owned and for them to make these investments all by themselves is virtually impossible unless a private public partnership approach is set up.

The Power Sector

Bangladesh plans to establish a number of power plants to meet the growing electricity demand for domestic, commercial and industrial use. In order to achieve socio-economic growth to become a middle-income country in line with Bangladesh Vision 2021, the country would require generator capacity of around 20,000 MW. The target can be achieved through building large base-load power plants, primarily based on coal and gas. For coal and gas-based power plants, ultra super critical technology and combined cycle technology need to be used to achieve higher efficiency and lower emissions. For power plants, the impacts of global climate change will be serious and power plant cooling using river water is an example of a process that is sensitive to climate change. The requirement of cooling water is high when it is drawn from rivers; if water temperature rises with global warming, the efficiency of cooling systems will decrease which will make it difficult to operate the power plants. If the temperature of the water rises beyond a certain level, it can no longer be cooled enough for use. Therefore, provisions for adapting to such a situation must be considered by the sector. The required steps will involve high investment. As for turbines, which are designed for specific ambient conditions, their efficiency will decrease if the ambient temperature increases. This will increase the cost of electricity. It should be noted that the southern region of Bangladesh especially the coastal belt has already been affected by salinity intrusion. It is expected that after the completion of the Padma Bridge there will be increased investment in industries in the region. The quality of water will become a barrier to the industrialization process, especially for industries and power plants that require high volumes of good quality water. Therefore, desalination of surface water in the coastal zone will have to be undertaken for which technology like reverse osmosis is available but will require large investment.

The Air conditioning and Cooling Sector

With the emergence of a more affluent middle class in Bangladesh and a steady growth in industry, there has been an increase in demand for air conditioners for domestic use and cooling equipment for industries and large buildings. The equipment is designed to perform at maximum efficiency taking account of the current ambient temperature. In case of increases in the ambient temperature, the efficiency of this equipment will decrease and it will consume more electricity. The most effective way of adapting to this vulnerability is to ensure higher energy efficiency of the equipment.

The following table shows the short-term impacts of different climate parameters on different types of industries and related infrastructure.

Table 5.25: The interaction matrix for short-term effect on major industries

Short Term Effect									
Type of Industry & Infra-structure	Location/ Feature	Causal Factors							
		Sea Level Rise	Temp. Change	Rainfall Change	Flood/ Flash Flood	Cyclone/ Tornadoes	Water Logging	Drought	Salinity
EPZs	Dhaka	N	M	M	S	M	S	S	N
	Chittagong	M	M	M	S	S	M	M	S
	Khulna	M	M	M	S	S	M	M	S
	Comilla	N	M	M	S	M	S	S	N

Short Term Effect									
Type of Industry & Infra-structure	Location/ Feature	Causal Factors							
		Sea Level Rise	Temp. Change	Rainfall Change	Flood/Flash Flood	Cyclone/ Tornadoes	Water Logging	Drought	Salinity
Fertilizer	Jamalpur	N	M	M	S	M	M	N	N
	Narshingdi	N	M	M	S	M	M	M	N
	Sylhet	N	M	M	S	M	M	M	N
	Chittagong	M	M	M	S	S	M	N	S
Textile	Dhaka,	N	M	M	S	M	S	S	N
	Chittagong	M	M	M	S	S	M	M	S
	Rajshahi	N	M	M	S	M	M	S	N
	Comilla	N	M	M	S	M	M	S	N
Dying, Bleaching & Finishing	Dhaka	N	M	M	S	M	S	S	N
	Narayanganj	N	M	M	S	M	S	S	N
	Gazipur	N	M	M	S	M	S	S	N
	Chittagong	M	M	M	S	S	M	M	S
Chemical Products	Dhaka	N	M	M	S	M	S	S	N
	Chittagong	M	M	M	S	S	M	M	S
	Khulna	M	M	M	S	S	M	M	S
	Narayanganj	N	M	M	S	M	S	S	N
Pharma-ceuticals	Dhaka	N	M	M	S	M	S	S	N
	Chittagong	M	M	M	S	S	M	M	S
	Gazipur	N	M	M	S	M	S	S	N
Cement	Dhaka	N	M	M	S	M	S	S	N
	Chittagong	M	M	M	S	S	M	M	S
	Sylhet	N	M	M	S	M	M	M	N
	Khulna	M	M	M	S	S	M	M	S
Power Plant	Hydro	N	S	S	M	M	N	S	N
	Gas/ Gasoline	N	M	M	S	M	M	S	S

Source: NAPA, 2005 Study Note;

Note: N- No Effect, M- Moderate Effect and S-Severe Effect

Industries and power plants in Bangladesh need to be climate proof against climate related events. When construction for an industry begins, the highest historical flood levels in the area need to be taken into consideration and the area required by the industry should be raised one to two meters above that flood level. Provisions need to be made for the drainage of storm water in case of heavy precipitation.

It is essential that regulatory standards be fixed for the industrial sector. The industries must carry out a Quantitative Risk Assessment on the impacts of climate change on the industry and identify the adaptation measures that need to be taken. The adaptation measures will have to be internalized in the project design.

Regional level consultations with relevant stakeholders provided different types of risks and adaptation measures in the industry sector are shown in Table 5.26.

Table 5.26: Different types of risks and adaptation measures in the industry sector for some specific regions in the country

Region	Major Problems associated with Climate Change	Affected Industry and Infrastructure	Adaptation Strategies
Chittagong	Increased flood frequency particularly flash flood Increased flood level Increase of frequency and extent of storm surges, increased intensity and frequency of cyclone Water logging Salt water intrusion Sedimentation	Ship building industry is severely affected by cyclone – increased navigational and environmental hazard Damages to machinery equipment, stopping power generator, and loss of production in industrial areas such as EPZ Inundation and lack of communication hamper flow of input and output Shortage of raw material supplies for a certain period Fish production is severely affected by cyclone and storm surge	Set up industry and power plants at elevated places Facilitate the use of alterative emergency power and water supply Develop emergency repository for valuable equipment Develop safe dumping place of the pollutants Forecast cyclones & flash floods in due time and forecast the flood level Set up power plant and gas installations considering historical flood level
Khulna	Increased flood frequency Increased flood level Intensity of high-tide rise Water logging Salt water intrusion SLR Cyclone and Storm surge Variation in temperature and rainfall	Damages to machinery equipment, stop power generator, loss of production Stoppage of production for a certain period Shortage of supplies and raw materials for a certain period Destruction of road and embankment affects industrial operation and distribution Disruption of communication during flood, industrial waste mix- up with water	Set up power plants at elevated places Set up new industry considering flood level history Improve flood forecasting for industrial stakeholders Set up fuel bank for critical areas Construction and reconstruction of road and embankments for smooth distribution and communication
Rajshahi	Increased flood frequency Increased flood level Water logging River erosion Drought	Damage to machinery equipment, stop power generator, loss of production. Loss of telecommunications system at certain period Stopping production of various affected industries like silk industry, husking and hand loom industry for a certain period Shortage of supplies of raw materials for affected industries for a certain period Stoppage affected cold storages, dairy firms, poultry firms for a certain period Loss of production of sericulture raw material	To set up power plants at high places Use of generators and kerosene lamps Set up new industries considering flood level Move husking industry to elevated places Move hand loom machinery equipment to elevated land Measures for protecting handloom, poultry industry at certain periods

5.5.7. Education

Bangladesh is recognized as a role model for its disaster management initiatives as well as for its role in climate change adaptation and mitigation. Several of its policies and legal frameworks concerning disaster and climate change have been the first initiatives of their kind within South Asia. However, all sectors have not been given equal attention, and while budgetary allocations for education have been increased, a dedicated budget for children affected by climate change or living in disaster prone areas has not been prioritized. Although Bangladesh has been committed to Education for All (EFA) goals since the World Conference on Education for All in 1990, providing education to children living in hazardous locations has always remained a challenge.

Natural disasters disproportionately affect women, girls and children, especially those who are living in hazardous areas. The children of the river islands, coastal and haor areas are extremely vulnerable and their basic needs and livelihoods are far from secure (Nasreen and Tate, 2007) Although the enrolment rate of children in primary schools in these areas at the time of research was 75 per cent, their attendance rate was low and the dropout rate was as high as 65 per cent. When flooding occurs many schools remain closed for several months, during which time they are used as shelters and relief camps. This, despite the fact that the Shelter Policy of the Ministry of Disaster Management and Relief has stated that all shelters in disaster prone areas will be used as multipurpose shelters where children's education will be continued.

Hossain (2013)[31] reported that natural hazards like the floods of 2004 and 2007 and Cyclones Sidr of 2007 and Aila of 2009 draw attention to Bangladesh's need to protect children and to ensure sustainable environmental protection from the perspective of climate change. The vulnerability of this sector of the population needs to be addressed in government policy and country-wide programmes.

Islam (2015)[32] indicates that designing effective interventions in the education sector is a challenge due to a lack of information. In an attempt to close the information gap, the Climate Change Education for Sustainable Development in Bangladesh (CCESD) Study collected data from 12 disaster clusters. This revealed that structures of institutions are fragile (57% are non-concrete); nearly half (47%) of the classrooms are not-usable; coastal area institutions are more likely to be used as disaster shelters, and are thus more prone to lost days of schooling and damage of their assets by the shelter users (the case for 53% of central coast primary schools, 41% of offshore island primary schools and 71% of south-western coast primary schools); one third of educational institutions (28.88% for primary schools) have no water supply systems; only about half (47.78%) of the educational institutions in disaster hotspots have good sanitation facilities; recreational facilities are poor (only 50% of educational institutions have usable playground facilities); and support services are severely limited in their scope; 40% of institutions are two kilometers or further from the nearest health care centres; and more than 50% of institutions lack even a basic first aid box, and of those that do have one, 70% do not have training on its use. Based on the findings the study recommended the adaptation measures detailed below.

Adaptation to Climate Change

The CCESD highlighted the need for educational institutions to have: resilient building structures; disaster contingency funds for sustainable education; flexible class routines; special allocations for schools used as shelters; secured WaSH facilities for education; usable playgrounds; health care facilities; first aid boxes and related training; adequate numbers of teaching staff; repairs following damage; for students to have better access to educational institutions; and for unique and permanent registration numbers for all students. Broader recommendations included the creation of partnerships with community and of a disaster education directorate (DED); the construction of movable structures in river bank erosion areas; disaster preparedness, skills and management training; and the adoption of a schools disaster management plan (SDMP).

The framework for Disaster Risk Reduction (DRR) in Education and Education in Emergencies (Directorate of Secondary and Higher Education, MoE) has developed a Comprehensive School Safety Framework[33] to support climate-smart disaster risk reduction and to bridge development and humanitarian action in the education sector. Comprehensive school safety is addressed by education sector policies and plans aligned with disaster management at national, regional, district and local school site levels. It rests on three pillars:

Pillar 1 - Safe Learning Facilities
Pillar 2 - School Disaster Management
Pillar 3 - Risk Reduction and Resilience Education

31 Hossain , Khondokar Mokaddem, 2013, 'Sustainable Environment and Convention on the Rights of the Child (CRC) in Post MDG-2015 Context: Case of Bangladesh', paper presented at the 'Convention on the Rights of the Child (CRC) in Post MDG-2015 context' on 16 February (Saturday), 2013 organized by Institute of Disaster Management and Vulnerability studies (IDMVS), University of Dhaka in collaboration with World Vision and Plan Bangladesh.

32 Islam, Sheikh Tawhidul, 2015, 'Climate Change Education for Sustainable Development in Bangladesh', BANBEIS, Ministry of Education

33 'Framework for Disaster Risk Reduction (DRR) in Education and Education in Emergencies', Directorate of Secondary and Higher Education, MoE, CDMP, Education Cluster, DeSHARI, NAARI, CARITas and ECHO.

Under the Comprehensive Disaster Management Programme (CDMP-II) Directorate of Secondary and Higher Education, the MoE has also provided training for 10,000 teachers in colleges and teacher training colleges with dedicated modules developed by the Institute of Disaster Management and Vulnerability Studies (IDMVS), University of Dhaka in 2015. IDMVS has also provided capacity building training to 300 master trainers (college, TTC and HSTTI teachers) who are providing training to the 10,000 teachers around the country.

Nasreen *et al.* (2014)[34] attempted to identify the best practices related to strengthening the resilience of schools and communities in the different disaster-prone areas of Bangladesh. The first best practice identified by the study was highlighted in the *'Participation of Women, Children and Persons with Disabilities in Community Risk Assessment (CRA) and Risk Reduction Action Plan (RRAP) Process'* in Moharajpur Union of Koyra Upazila under the Khulna district. Activities were conducted based on the guidelines of the Comprehensive Disaster Management Programme (CDMP-II) with the technical support of Save the Children. Another milestone in the education sector was to replicate the disaster-resilient school level

improvement plan (SLIP) in Non-DIPECHO schools. As per the guidelines of DPE and the direction of the upazila education office, the school managing committee, with the cooperation and collaboration of teachers and parents/guardians of the students, formed a school level improvement plan (SLIP) committee at the Modinabad Model Primary School of the Koyra Upazila, Khulna. Another initiative was the *'Transition School Makes Safer Learning Environment'* at Gourakhalikanda Government Primary School of Durgapur Upazila under the Netrokona district with the support of Dan Church Aid (DCA). The school managing committee (SMC), with the support of the DIPECHO VII project, constructed an accessible transition semi-permanent (tin roof) school building. The school has now been transformed into a multi-purpose building that can be used as a flood shelter without disrupting academic activity.

A second case study focused on *'SMC Involvement in Inclusive Risk Mitigation: a story of Badurtoli-1 Primary Government School'.* The SMC, with the support of Muslim Aid, designed a school based disaster preparedness plan. Another best practice developed a disaster resilient school level improvement plan (SLIP) based on a case study taken from the Sultangonj Governament Primary School, Kolpara Upazila, Patuakhali. Developing disaster resilient school level improvement plans (SLIP) has been found to be an effective way of reducing vulnerability and mitigating the risk of disaster at school level. The researchers identified another good practice in the *'UDMC and SMC Flood Response'* at the Chatanpara Model Government Primary School, Taltoli, Borobagi, Borguna. The model schools of SBDP, designed by ACF, draw a path-breaking success stories in the coastal district Borguna. The major objectives of such initiatives were to support the model schools and communities to complete the number of SSM, paying attention to the protection of education materials, education investments, accessibility of shelters, and inclusiveness for disaster risk reduction (DRR) and education in emergency (EiE). *'Students' communication and transportation'* was another example; with the support of DIPECHO-VII through CCDB the School Managing Committee (SMC) along with other stakeholders such as school age students, members of SMC and teachers introduced a transportation system in Atulia Union for the students of Sofirunnesa Secondary Girls School. With this transportation the students do not need to wait at the ferry terminal (ghat) for a boat as boatmen are assigned for their transportation. The examination schedule is submitted to the authority at the ferry terminal and high priority is assigned to transporting students so that they are not late for their exams.

Initiatives taken

The government has formulated various policies and national laws since 2009 on protecting the rights of children, including the rights of children to education.

The National Curriculum and Text Book Board included climate change and disaster management issues in both the Primary and Secondary Education Curricula in 2013.

Disaster management and climate change issues have been included in higher education activities with the support and initiatives of CDMP. Nasreen (2014) highlights the fact that an independent department in the Patuakhali Science and Technology University was launched in 2009. The University of Dhaka introduced

34 BEST PRACTICES OF STRENGTHENING RESILIENCE AND SAFETY IN SCHOOLS AND COMMUNITIES IN BANGLADESH, Nasreen, *et al,* 2014, DeSHARI Consortium Bangladesh: 7th DIPECHO Action Plan

professional degree courses on disaster management through establishing the Centre for Disaster and Vulnerability Studies (CDVS) within the Department of Sociology in 2009. In 2012, the CDVS was transformed into the independent Institute of Disaster Management and Vulnerability Studies (IDMVS). It offers certificate courses, bachelor and master's degrees on disaster management and postgraduate diploma courses. Gender and disaster risk reduction has been one of the central themes of courses offered since the institute's inception. The University of Dhaka's Department of Geography and Environment houses the Centre for Disaster Research, Training and Management which began offering courses on disaster management under a master's programme in 2010. In addition, the Dhaka School of Economics (DScE), established as a constituent institution of the University of Dhaka, teaches courses on environmental and research economics, which include climate change and disaster risk reduction at both the bachelor and master's levels. BRAC University is the only private university offering a postgraduate course on disaster management. CDMP has been involved in sponsoring professional training programme on disaster management to both the public and private universities in Bangladesh since 2008. Under the CDMP I initiatives, three universities, namely the University of Dhaka, Khulna University and the Patuakhali Science and Technology University offer diploma courses and a total of 13 universities (eight during CDMP I and five during CDMP II) have been getting Professional Training Courses on disaster management. All of the programmes feature courses on gender and disaster management.[35]

The Palli Karma-Sahayak Foundation (PKSF) has implemented adaptation actions in highly climate vulnerable areas of the country particularly in coastal, flood–prone and drought-prone areas. It has an environment and climate change unit and has also established a Disaster Management Fund which currently has Tk 3000 million (or approximately $38 million) earmarked for disaster management and disaster reduction activities focused on development activities around the country.

The Campaign for Popular Education (CAMPE) interventions focus primarily on policy advocacy, networking, campaigning, research, documentation and capacity building of its members and partner organizations. CAMPE attempts to facilitate the process for sustainable development and pro-poor policy frameworks which will enable the achievement of the SDGs which target education. The Education Watch Report has been significantly contributing to identifying children located in vulnerable areas and recommending policy advocacies in this regard.

The government has been implementing various programmes and projects through different ministries and departments to reduce poverty and provide child care services and facilities to vulnerable children and address the plight of child victims of violence.

The Ministry ofWomen's and Children's Affairs (MWoCA) has formed the CRC Focal Person Committee under the Chairmanship of the Honorable State Minister for Women's and Children's Affairs with representatives from the relevant ministries, from civil society and from national and international NGOs. The members of this committee regularly contribute to the planning and undertaking of research, policy formulation, monitoring and evaluation. District child rights monitoring committees (DCRMC) have been formed across the country.

The Sixth Five Year Plan, 2011-15 and the Seventh Five Year Plan, 2016-2020 recognize the importance of children's advancement and rights and each includes a separate chapter with a specific vision and actions, which include protecting children from all forms of abuse, exploitation and violence. In addition, a Child Protection Policy has been drafted by the Ministry of Social Welfare.

The National Human Rights Commission (NHRC) formed under the National Human Rights Act 2009 works to promote and monitor human rights, including those of children.[36].

The Ministry of Disaster Management and Relief (MoDMR) and Department of Disaster Management (DDM) have initiated several policies of which the most significant is the school based disaster risk reduction policy under which school drills are compulsory. Other initiatives in collaboration with the MoDMR and organizations such as

35 Bangladesh Climate Change and Gender Action Plan (ccGAP), Ministry of Environment and Forests, GoB & IUCN, 2013

36 Save the Children and Breaking the Silence carried out a World Day actions for the first time in 2012. The World Day theme of protection of children from violence aligned well with the ongoing work and priorities of both organizations. Engaging children and communities in the observance of symbolically significant ('Success Story: Mobilizing a Community to end Sexual Violence against Children' Breaking the Silence, 2012).

the Bangladesh Red Crescent Society, the Fire Brigade Civil Defence and other government and non-government actors, academia, development partners, and civil society organizations have been introduced.

Inclusive disaster and climate change related education requires dedicated budgetary allocations and capacity building of the various actors concerned.

5.5.8 Livelihood

Livelihood is a multidimensional issue combining multiple resources. The issue of livelihood is one of sustainability; a livelihood is sustainable when it is adequately robust for people to recover from stresses and shocks and also maintain or enhance their capabilities or assets while not undermining the natural resource base (CIRDAP, 2009). Livelihood assets/capitals are often grouped into five categories: human, natural, financial, social and physical and all five contribute to sustainable livelihood.

The majority of the population of Bangladesh has traditionally been dependent on natural resources and activities for their livelihoods and food security. Agriculture, still largely dependent on nature despite a growing trend of mechanization in the sector over the past few decades, plays a gradually reduced role in terms of its contribution to providing employment and growing the economy. As a result, the economy has been undergoing a structural change with the non-farm sector playing an increasingly greater role. The contribution of agriculture to GDP fell from 33.07% in 1980-81 to 16.33% in 2013-14. (Bangladesh Economic Review, 2014). This fall in the share of agriculture has been matched by a concomitant rise in the shares of the industrial and service sectors. The contribution of industry to GDP increased from 17.31% in 1980-81 to 29.61% in 2013-14 and that of the service sector increased from 49.62% to 54. 65% during the same period. Despite a gradual reduction in its contribution to GDP, agriculture still plays a vital role in providing employment, livelihoods and food security. The agriculture sector accounted for 47.33% of total national employment in 2010 compared to 48.10% in 2005 (Labour Force Survey, 2010). While agriculture is highly susceptible to change and variability in climate, non-farm sectors may also be seriously affected by climatic factors and impacts.

Agriculture and non-farm sectors are strongly interlinked and mutually dependent. Agriculture provides food for people and raw materials for the non-farm sectors. Non-farm-agricultural sectors support agriculture by supplying inputs (fertilizers, insecticides, irrigation structures, infrastructure and market for farm produce (CIRDAP, 2009). Deficiency in the production of one sector becomes a constraint for the growth of other sectors.

Due to its geographic location, geomorphological conditions, and demographic and socio-economic features, Bangladesh is highly vulnerable to climate change. Both rapid onset and slow onset climatic hazards and disasters cause serious havoc to the socio-economic fabric of the country. Climate induced vulnerabilities are likely to exacerbate further in the future with projected changes in the climate. Climatic events are likely to be more frequent, and more severe in the future. These will jeopardize livelihoods, especially those of the poor who are mostly dependent on natural resources. They may also threaten the achievements Bangladesh has gained in terms of poverty reduction and improvements in living standards.

Expected Impacts on Agriculture

The agriculture sector in Bangladesh includes crops, horticulture, fisheries and livestock. Floods, erratic rains, drought, storm surges, and salinity intrusion cause significant losses and damages to crops. Salinity intrusion may affect up to 2.5 million hectares of arable land in the coastal belt and an increase in the frequency of flash floods may affect 2.8 million hectares of land (CDMP-II, 2013). Rises in temperature will reduce rice production by 16%, lead to a decrease in land productivity of approximately 3.4 million ha of arable land and cause a significant decrease in wheat and potato production. Changes in temperature, humidity and radiation have a great effect on the incidence of insects and pests, diseases and microorganisms, all of which have direct bearing on crop yield. All these adverse effects of climate change will adversely affect employment income and food security. A shortfall in rice production due to climatic events often causes the price of rice to rise. Those with low income cannot afford to buy the rice they need at higher prices. The hardship of the poor intensifies and many of them suffer from hunger and starvation. The incidence of transitory poverty rises, forcing many non-poor to live below the poverty line. In 2007, the high price of rice due to 1.2 million tons in production loss caused by flooding led to many hardships and social problems.

Expected impact on Fishery

Fisheries, both in open waters and aquaculture, will be severely affected due to climate change impacts on the water regime. Fish shelter and fish migration will be affected which will reduce fish production and growth. Rougher seas will also affect the ability of coastal fishing communities to fish and they will suffer economic losses.

Expected impacts on Livestock/Poultry

Although the livestock subsector accounts for only 1.78% of GDP, it makes a significant contribution towards meeting the requirements of animal protein (Bangladesh Economic Review 2014). Many rural poor, especially women, depend on livestock/poultry rearing for their livelihoods; the subsector plays a vital role in poverty alleviation and income generation for the poor including women.

The livestock/poultry subsector is likely to be seriously affected by climate change. Livestock productivity is directly affected due to temperature rise arising from global warming which is likely to lead to outbreaks of new diseases. In addition, pasture land is declining as rising sea level causes scarcity of green grasses used as fodder. (Bangladesh Economic Review, 2014)

Expected impacts on Water Sector

Climate change impacts are likely to result in an excess of water in the wet season and less water in the dry season. There is likely to be more floods, droughts, water logging, drainage congestion, storm surges, salinity intrusion and river bank erosion. Shortages of fresh water are likely to be more pronounced in the coastal areas and in drought prone areas. Rising salinity in the coastal belt and droughts in the north-western region will reduce crop yields and crop production. A lack of fresh drinking water will bring hardship to women and children, who are responsible for collecting drinking water for their families. Drinking salinity-contaminated water may result in health hazards, especially for pregnant women (CDMP II, 2013). Increased river bank erosion and salinity intrusion in coastal areas are likely to displace thousands of people from their existing habitats and force them to migrate to slums of big cities or elsewhere. If sea level continues to rise leading to the failure of the polder-embankments, six to eight million people could be displaced by 2050 and would have to be resettled (CDMP-II, 2013). All these water related climate change impacts will threaten food security, livelihoods and health, especially of the poor.

Expected impacts on Infrastructure

Climatic disasters such as cyclones and floods of increasing frequency and intensity would weaken or damage partially or fully the existing infrastructure including roads, highways, railways, ports, embankments, polders, warehouses, silos, cyclone shelters, electricity and telecommunication networks. Damages to infrastructure could disrupt transport and communication systems with a chain effect on the overall economic activity and livelihood of the population at large. People could lose employment. Prices of food items and other essential goods and services will rise due to a scarcity of supplies arising from the failure of the transport and communication systems. In addition to chronic poverty, transient poverty would significantly increase, forcing many non-poor to become poor and poor to become extreme poor. The impacts of climate change are likely to be widespread across all sectors of the economy and all sections of the population, with the poor and marginalized communities being the worst victims.

Current Non-Farm Livelihoods

Non-farm livelihoods are affected adversely to various extents due to climate change impacts. The impacts are more widespread in the salinity affected coastal areas and flood prone areas. Among different non-farm activities, transport activity is usually worst affected followed by agri-based enterprises (CDMP-II, 2013). Employment in cottage and micro industries is also adversely affected. Floods, and even relatively low water logging cause serious disruption to non-farm activities. Non-farm activities in drought prone areas are less affected than those in flood, flash flood and cyclone prone areas.

Current impacts on Livelihood Assets

All five categories of livelihood assets/capitals - natural, physical, financial, human and social - are adversely affected by different climatic events. Floods, cyclones, and river erosion cause damages to land, crop, forest, fresh water (natural capital); to infrastructure and housing (physical capital); to wages and income (financial capital); an increase in rates of sickness and school dropout (human capital); and forced migration and disintegration of families (social capital).

5.5.9 Forest, Biodiversity and Ecosystems

Forests

Bangladesh is relatively rich with flora and fauna. The following table sets out forest land resources in different districts of the country.

Forest Types	Legal status	Location (District)	Area (1000 ha)
Tropical Evergreen and Semi-evergreen Forest (Hill Forest)	Majority areas are Reserved Forest[1] with smaller areas of Protected[2], Acquired and Vested forest[3]	Rangamati, Khagrachari ,Bandarban, Chittagong, Cox's Bazar, Sylhet, Moulavibazar, Hobigong and Sunamgonj	638.06
	Un-classed State Forest (USF)	Rangamati, Khagrachari and Bandarban,	17.35
Tropical Moist Deciduous Forest (Sal Forest)	Forests of different districts have different status, some areas are Reserved Forest, Some are Protected Forest and some are Acquired and Vested Forest	Mymensing, Tangail, Gajipur, Dhaka, Tangail, Rangpur, Pacnchagar, Dinazpur, Thakurgaon, Naogaon, Nilphamari and Comilla	120.69
Mangrove Forest (Natural - Sundarban)	Reserved Forest	Khulna, Satkhira, Bagerhat and Patuakhali	607.7
Mangrove Forest (Plantation)	A part of the mangrove plantations in the coastal belt and off-shore islands has been classified as reserved forest and the rest is under the process of reservation.	Noakhali, Feni, Bhola, Lakshmipur, Patuakhali , Barguna, Pirozpur, Chittagong and Cox's Bazar	130
Wet Land Forest (Swamp Forest)	Reserved Forest or under process of reservation	Sylhet and Sunamganj	23.59

Source: DOF website

[1] Any land declared as forest under the purview of the Forest Act by the government or the competent authority of a country; many restricitons on what is and is not allowed.

[2] Fewer restrictions than [1].

[3] Forest development officers are vested wth the authority to prohibit certain activities within privately owned lands or other lands for the protection of publicly owned forest or for the protection of property and the environment.

Projected climate change risks on forests

Climate related events will create negative impacts on the forests and the IPCC has projected a worsening in the state of tropical forest ecosystems as a result of climate change. (MoEF, 2016; IPCC, 2001). Non-stop deforestation is reducing natural forest stocks, threatening valuable wildlife and degrading the micro-climate in both forests and adjacent regions (Baten, 2008). The best method to increase carbon credits in forest biomass is reforestation. In order to respond to global warming, forest management is considered more beneficial in the short-term, but reforestation provides a long-term solution and can be a strong weapon against climate change in Bangladesh.

Water runoff rates have increased due to an increase in monsoon rainfall and consequently, rapid soil erosion has also increased. Thus, nutrient leaching and destruction of micro-organisms have reduced soil quality, adversely affecting forest growth in the previously dense hill forests of Chittagong, the Chittagong Hill Tracts, Sylhet and Cox's Bazar. Studies show that the number of Garjan or Dipterocarpus Spp in Chittagong and Chittagong Hill Tracts has declined *considerably due* to a decrease in regeneration rate.

According to one projection, the Sundarbans will be permanently inundated by 2050 due to rise in sea level. As a result, swamped vegetation will gradually die and the rotting vegetation will give rise to the release of more detritus, which will primarily boost the aquatic population. Terrestrial fauna in this mangrove forest will possibly move towards the north before finally disappearing and the composition of aquatic fauna is likely to be altered. Inundation is one of the resultant effects of the rise in sea level, which will lead to death of species that do not thrive under higher inundation. Inundation results in the loss of habitat of fauna and in the elimination of water holes which supply water for wildlife of this forest. This may result in a decline in the number of tigers, as they face shortages of prey in the jungle.

Higher inundation boosts volumes of water flow during a given time period, which adversely affects creepers and softer vegetation. Additionally, water turbidity may increase due to more movement of soft clayey particles, which will change the soil texture at some locations and create a negative impact on aquatic populations and their composition. This mangrove ecosystem is likely to experience higher salinity due to sea water flow inside the forest and the low salinity zone or fresh water zone of the northern part of the Sundarbans could be decimated and the whole ecosystem under threat. The decrease in the number of sundri trees *(heritiera fomes)* is one of the consequences of the presence of saline water in the mangrove forest. Scientists have also implied that the tropical cyclones have destroyed a significant portion of this mangrove forest.

Adaptation and mitigation in the forest sector

The current climate change trend leaves us no option but to adapt and mitigate (Kibria, 2015). Afforestation or reforestation (World Bank, 2010), construction of green buildings and low carbon homes with energy and water efficient appliances and investment in renewable energy are all necessary to mitigate GHGs. Additionally, introduction of programmes to change people's behaviour and an imposition of carbon pollution tax may be of advantage. Conservation of mangrove habitats and of species with higher genetic diversity, elimination of barriers to assist in the migration of species and seed banking are options. (Sovacool *et al.,* 2012; Staudinger *et al.,* 2012). Shifts in planting and harvesting dates, cropping patterns, using clean energy in irrigation pumping, promoting agroforestry and triple F models (forestry, food and fish production) are likely to provide positive results. Emphasis should be placed on improving early warning systems, building cyclone shelters and designing new storm-proof or wind resistant huts. Kibria, G. (2015) recommends, *"Capacity building of communities (women & men); disaster preparedness/disaster risk management; social protection; climate resilience funds/insurance; awareness, education and research on climate change"*

Biodiversity

The IUCN Bangladesh Red Data Book lists 266 species of inland fish, 442 of marine fish, 22 amphibians, 109 inland reptiles, 17 marine reptiles, 388 resident birds, 240 migratory birds, and 110 inland mammals, as well as 3 species of marine mammals in Bangladesh. The Department of Forests administers 38 protected areas in the country. These protected areas, including 17 national parks and 21 wildlife sanctuaries, are the habitat for huge biodiversity conservation. In total, the protected area is about 0.3 million hectares or about 11 percent of the total forest area of the country.

Projected climate change risks on biodiversity

Ecosystems with more diversified species, functions and structures tend to provide more ways for transferring nutrients and energy among their network and have greater resilience to shocks such as storms, floods, droughts and other climate change impacts compared to systems with weaker biodiversity. However, inevitably, climate change leads to: migration and extinction of some species, including the inability of many species to cope and adapt to change; an increase in the populations of alien invasive species; and major loss of biodiversity through changes in the community. Scientists have warned that a rapid change in average temperature will impact many species and may result in decreased fertility of mammals. A rise in temperature may reduce the genetic diversity of individual species and jeopardize forest succession process. *"Resident and migratory terrestrial birds of the Sundarbans and coastal areas will create excess pressure and ecological problems on the existing fauna and flora where they will fly." (Faruk, 2015).* Rapid climate chage could bring about severe cyclone sweeps over the coastal belt from the Bay of Bengal, extending into the northern part of the Indian Ocean. There will be a sharp decline in river flow due to a rise in drought intensity, which is the result of temperature rise during winter and pre-monsoon and low rainfall during the dry season. As a result, high or moderate level water demanding plants and organisms will become extinct locally and most preferred crops will not grow inland due to penetration of saline water.

Baten (2008) states: *"Recent studies show that massive afforestation with exotic species wouldn't be a pragmatic solution for the adaptation to the climate change. Rather, it is suggested that as implications of response, diversity and functional diversity-biodiversity should be conserved in their natural habitat by protecting existing natural forests, minimising soil disturbances, reducing carbon loss from soil, preventing potential loss of mycorrhizae and increasing freshwater inflow in the saline affected mangrove regions".*

Ecosystem

Each of the coral reefs, wetlands, forests, oceans, mountains and other ecosystems has its own specific biotic and abiotic factors such as plants, animals, microbial communities and non-living environments interacting among them as a functional unit. This dynamic complex unit is referred to as a natural ecosystem, providing multiple services for the livelihoods of the community and environmental integrity as a multiple-resource system. The Millennium Ecosystems Assessment (MEA, 2005) lists four functions that ecosystems fulfill: providing services (food, fuel, fruits, freshwater supplies, genetic resources etc.); regulating services (biodiversity regulation, water

and air quality regulation, water flow regulation, pollution control, flood control, pollination etc.); providing cultural services (education and research, ecotourism and recreation, cultural heritage, religious values etc.) and supporting services (photosynthesis, soil formation, nutrient cycling, etc.) (Rahman, 2014). Climate change threatens all of these services and harms the function of the natural ecosystem (Siddiqui, 2014).

Projected climate change risks on ecosystems

The IPCC predicts that droughts and floods will worsen to the point of eventually submerging the Sundarbans. It also believes that 75% of the Sundarbans mangroves will be destroyed due to a rise in sea level combined with the other forms of anthropogenic stress. Supporting services i.e. as a habitat for plants, fish and wildlife ,will be greatly affected (Shamsuddin *et al.*, 2013). Changes in the supporting services will have tangible effects on what the Sundarbans provide in terms of trees and fisheries. Shamsuddin *et al.*, 2013 reported that the available area of sundri *(herittiera fomes)* trees and gewa *(excoecaria agallocha)* trees will decrease by 45% and 7% respectively by 2100 due to rise in sea level.

Adaptation through conservation of ecosystems

In order to reduce the population's vulnerability to climate change and build resilient ecosystems ecosystem-based adaptation aims to promote social resilience through management and conservation of ecosystems. This adaptation is essentially about ensuring the management of the ecosystem's components within a larger landscape of which human activities are part, and the capacity to generate essential services needed for climate change adaptation of socio-ecological systems (Devischer, 2010). The Convention on Biological Diversity (SCBD, 2009) highlights the role of ecosystem and biodiversity in adaptation action: *"Ecosystem-based adaptation integrates the use of biodiversity and ecosystem services in an overall adaptation strategy that includes the sustainable management, conservation and restoration of ecosystems to provide services that help people adapt to the adverse effects of climate change."* Shereen (2013) emphasises the resilience of ecosystems and the services they provide to society and explains that ecosystem-based adaptation (EbA) should, *"where relevant, take into account strategies to increase ecosystem resilience and protect critical ecosystem services on which humans depend to reduce the vulnerability of human and natural systems to climate change."*

The EbA approach benefits local communities by recognizing the inter-connectivity between ecological, social-cultural, economic and institutional structures and processes. Midgley *et al.* (2012) shows that three inter-related development components (viz. community-based natural resource management, climate change integrated conservation strategies, and community-based adaptation) ensure sustainable development and build resilience collectively in the face of a changing global climate. Munang et al. (2013) argue that EbA approaches safeguard people and ecosystems against the negative impacts of climate change and climate variability and ensure healthy ecosystems and their flow of services, thereby providing opportunities for sustainable ecological and economic outcomes (Midgley *et al.*,2012).

The following table includes a short inventory of adaptation practices used to tackle the impacts of climate change. The adaptations are of two types: anticipatory and reactive, where anticipatory means the measure is taken to reduce future impacts of climate change, and reactive signifies that the measure is taken in order to reduce present climate change effects. The numbers in the table signify how many sector-wise adaptations have been recorded in a specific geographic location.

***Coastal District = Bagerhat, Barguna, Barisal, Bhola, Chandpur, Chittagong, Cox's Bazar, Feni, Gopalganj, Jessore, Jhalokati, Khulna, Lakshmipur, Narail, Noakhali, Patuakhali, Pirojpur, Satkhira and Shariatpur (PDO-ICZMP, 2005)

***Flash flood = Sylhet, Moulvibazar, Sunamganj, Habiganj, Kishoreganj, Netrokona, Rangamati, Bandarban and Khagrachari (MoDMR, 2014)

*** River and Rainfed Flood = Lalmonirhat, Kurigram,Bagura, Sirajganj, Natore, Pabna, Manikganj, Tangail, Jamalpur, Sylhet, Moulavibazar, Sunamganj, Comilla, Madaripur, Faridpur, Rajbari (BARC 2000)

***Drought prone = Rajshahi, Chapai Nababganj, Joypurhat, natore, Noagoan, jessore, Chuadanga, Jhenaidah (BARC 2000)

Sectors	Geographic location			Timing of the adaptation			
	Coastal districts	Drought Prone districts	Flood Prone districts	Anticipatory	Reactive	Stress	Adaptation measures
Agriculture and Food Security	51	23	32	34	50	Irrigation water scarcity, flood, salinity, waterlogging, climate change	Stress tolerant crops (salinity, drought, submergence), non-rice crop cultivation, floating gardens, rainwater harvesting for surface irrigation, drip irrigation, homestead gardening
Water Resources Management	82	18	37	49	83	Climate change, salinity, arsenic, water logging, water scarcity	Submersible embankment, drainage infrastructure, pond sand filter, rainwater harvesting
Health	4	3	3	3	0	Climate change, poor sanitation	Sanitation technology, establish surveillance system on climate change related diseases
Fisheries	6	3	5	5	3	Climate change, salinity, flood	Sanctuary establishment, cage culture, fish-rice culture
Livestock	3	1	3	0	4	Drought, salinity, water-logging	Duck rearing, fodder cultivation
Infrastructure	124	3	40	69	113	Flood, erosion, water-logging, climate change, cyclone	Embankments, cyclone shelters, climate proof infrastructure, bank protection works
Education			1			Flood	Floating schools
Livelihood	24	16	13	9	33	Climate change, flood, salinity, water-logging	Mat weaving, charu making, crab cultivation
Forest, Biodiversity and Ecosystem	19	1	2	12	6	Climate change	Afforestation, canal re-excavation

Source: IWFM (DECMA project), 2016

5.6 DRR-CCA Linkages

Climate change affects the development process and potential in Bangladesh. It undermines all key development sectors including agriculture and food security, water, health, and economic development and people's livelihoods. Conventional disaster preparedness approaches (relief and rehabilitation) are becoming ineffective in the context of rapid climate change and its forceful impacts. Efforts have been made to find linkages between climate change adaptation (CCA) and disaster risk reduction (DRR), but there is a further need for integration of the two approaches at the local/community level, at the regional level among climate affected zones and at the national level in policy, strategies and programmes.

The government revised its CCA and DRR plans and strategies in the light of the HFA-1 (2005-2015), Sendai Framework for 2015-2030 and SREX report (Special Report on the Extreme Events) of the IPCC. After the World Conference on Disaster Risk Reduction held in Sendai, Japan in March, 2015, the government committed to the implementation of the priority areas of the Sendai Framework of Action for the integration of DRR in development.There is a pressing need to assess the cumulative impacts of climate disasters on the key development sectors and livelihoods, as well as to find integrated responses of CCA and DRR to address the impacts and to reverse the negative linkages to transformative adaptation and sustainable development.

Synergies between Climate Change and DRR for Transformative Adaptation and Sustainable Development

Awareness has been raised at different levels to integrate CCA and DRR for climate resilient and sustainable development and to protect the livelihoods of millions of poverty-stricken and marginalized people in Bangladesh. There is political commitment at the highest level of the government to address disaster and climate change simultaneously and collectively. But the country needs an integrated and feasible framework on DRR and CCA in the light of the Sendai Framework and Paris Climate Agreement and this should be reflected in macro-economic development and sectoral policies. Some progress has already been made in integrating CCA and DRR in the Seventh Five Year Plan, addressing poverty alleviation and economic growth strategy, as well as in some sectoral policies; agriculture, water and health policies have included climate change and DRR issues. Furthermore, national disaster management policy, plan and strategies have considered the importance of CCA and resilience to climate change and at the same time, BCCSAP, NAPA, NAP and INDC processes are considering DRR in their approaches and activities in Bangladesh.

The country has experienced a huge transformation in policy and strategies towards integration of CCA and DRR in recent years. With the vision of a nation capable of ensuring safe lives and the livelihoods of its people, Bangladeh has been able to move from a culture of relief and response to a more disaster risk reduction comprehensive one. In the vigorous pursuit for resilience, disaster risk reduction and climate change adaptation have become an integral part of the country's poverty reduction strategy and its attempt to achieve the Sustainable Development Goals. The country has incorporated disaster risk reduction into its social safety net programme and put in place food security measures to protect millions of the most vulnerable women, children, and men. Political commitment and long term strategic planning have moved the nation towards sustainable development by reducing risks to households and communities. However, the challenges in disaster risk reduction and climate change adaptation remain formidable and are increasing in intensity and complexity, some persistent and recurring and others emerging. Overcoming these challenges will require scaling up our efforts through cooperation and collaboration among nations and communities, exchanging knowledge, information and technology for a common vision of a resilient future. Upholding the spirit and vision for disaster risk reduction and climate change adaptation, Bangladesh has embraced a holistic process to integrate disaster and climate change issues into development planning and processes. Many aspects of climate change and variability are already having a profound effect on the livelihoods of poor rural communities and much is known about the future impacts of climate change for action to be taken (CDMP and MoDMR, 2012). Disaster risk reduction and climate change adaptation both focus on increasing resilience to hazards and disasters. However, there are policy related differences. While DRR focuses on short- and medium-term measures related to hazards, CCA targets resilience building over the long-term to tackle changes in average climate and associated extremes. Bangladesh has already developed disaster risk management systems pertaining to the current climate. The country is also a front-runner in climate change adaptation related policy and action plans among developing and least developed countries.

Research results show that investing in DRR pays high dividends and the many synergies between DRR and CCA allow them to be integrated, meaning Bangladesh can greatly benefit in terms of climate resilience (AFC, BCAS and SSIL, 2015).

New legal and institutional frameworks for disaster risk reduction and climate change adaptation have been established. Disaster and climate change sensitive sectoral development strategies, norms and standards (e.g. urban development, water management, natural resource management, and infrastructure) have also been adopted. Social safety net programmes have been strengthened to cope with disasters and anticipated climate impacts in Bangladesh. Cooperation and collaboration in DRR and CCA have been strengthened among government and non-government actors in the areas of land-use planning, city emergency management, early warning message dissemination and community-based disaster preparedness. Post-disaster needs assessments are undertaken in the aftermath of a disaster to accelerate resilient recovery (CDMP, 2013). The MoFDM, as the ministry primarily responsible for addressing disaster risk reduction, has adopted the Comprehensive Disaster Management Programme (CDMP) to address capacity building and mainstreaming as key areas of support toward making the country and its development resilient. In line with this, an initiative has been taken to develop mechanisms to mainstream DRR and CCA into development planning and processes. As part of this, a guide to practice was drafted to facilitate the operation of the integration process into ministries, agencies and departments (MoFDM, 2009). The following activities were identified as immediate actions:

- Understanding disaster and climate risks;
- Contextualizing risks in relation to sectors and concerned agencies/departments;
- Exploring a range of disaster and climate risk reduction options in relation to mandated goals, targets;
- Identifying priorities, needs, gaps, cross- and inter-sectoral linkages;
- Planning to address priorities, needs, gaps, cross- and inter-sectoral concerns;
- Mobilizing resources, both internal and external;
- Implementing priority risk reduction activities as anticipatory interventions, addressing needs, filling gaps; and
- Reviewing and monitoring disaster and climate resilient activities, programmes, projects and feedback to mainstream processes.

5.7. Impacts, Vulnerability and Adaptation Measures in Coastal Bangladesh

The Coast of Bangladesh

Nearly one-third of the total population of Bangladesh lives in coastal districts. The coastal population increased from 35.1 million in 2001 to about 50 million in 2011 (Islam, 2004; BBS, 2011). The coastal area, which comprises 19 out of 64 districts, boasts many advantages but is exposed to multiple vulnerabilities (Islam, 2004). 1.95 million ha (41% of the total area) is given over to agricultural cultivation which is rich with natural and mineral resources, including gas and oil. However, the coastal zone is prone to cyclones, storm surges, tidal floods, coastal erosion, water logging, variations in temperature and rainfall, salinity intrusion and is threatened by sea level rise. People living in these coastal low-lying areas often suffer from the impacts of climate change and natural disasters and the poverty rate in the coastal zone is higher than the national average (World Bank, 2014).

Major Climate Change Induced Sudden and Slow Onset of Hazards and Associated Impacts on Coastal Bangladesh

Cyclone and Storm Surges

IPCC (2007) reports that an increase of 2°C and 4.5°C of SST would cause an increase of 10% and 25% wind speed of cyclones, respectively (IPCC, 2007). In general terms, this means that the intensity of cyclones will increase with an increase in temperature. Bangladesh's coast was struck by 149 cyclones between 1891 and 1998 (Karim and Mimura, 2008) and it appears that 38 cyclonic events affected the south-western coast between 1877 and 2010 (Islam and Peterson, 2008). Only three major cyclones hit the coast of the country in the first and second fifty year periods (1795-1845 and 1846-1896) while 13 and 51 major cyclones affected the coast in the third (1897-1945) and fourth fifty year (1948-1998) period respectively (BBS, 1993; BBS, 2002d). According to the 2010 World Bank Report, Bangladesh is at the receiving end of at least 40% of the impacts of total storm surges in the world because of a number of geographical factors including its funnel shaped structure, shallow continental shelf, character of recurvature of tropical cyclone in the Bay of Bengal, high tidal zone and low elevation land. The 1991 cyclone killed about 140,000 people, mostly from the Chittagong, Noakhali and Cox's Bazar districts. 1.75 million houses were destroyed and 6,500 schools and embankments of about 470 km damaged. Salt water intrusion occupied rice crops of about 72,000 ha. Cyclone Sidr (2007) and Cyclone Aila (2009) were characterized by 3-5.5 metre levels of storm surge, which brought saline water into agricultural lands and flooded the homes of many coastal communities. Cyclone induced saline intrusion in surface water and soil resources become a serious challenge and a significant limitation of adaptation practices for the local farmers. Local livelihoods and incomes related to agriculture, fisheries, forestry and livestock remain extremely vulnerable to cyclonic events. The World Bank estimates that the adaptation deficit of Bangladesh in relation to cyclones is $25 billion (World Bank, 2011; IPCC AR5, 2014).

Sea Level Rise (SLR): State, trend and associated impacts

According to the Fifth Assessment Report (AR5) of the IPCC, sea level, ocean temperature and ocean acidity due to climate change will make the coastal ecosystems extremely vulnerable (Wong *et al.,* 2014). IPCC (AR5) also estimates that the global mean sea level rose by 1.7 mm/year from 1900 to 2010 (WGI AR5 Section 13.2.2). The mean sea level was observed to be 3.2 mm/year between 1993 and 2010. This might be further increased from 8mm/year to 16mm/year between 2081 to 2100 with the high emission scenario (Church *et al.,* 2013). According to Stern (2007, p.16), if the ice sheets in Greenland and the West Antarctic *'began to melt irreversibly, the world would be committed to substantial increases in sea level in the range 4-12m over a timescale of centuries to millennia'.* Sea level rise as a result of climate change poses a threat of displacement and even threatens the very existence of some small island developing states (SIDS) (Pelling and Uitto, 2001; Otzelberger, 2014; Dossa *et al.,* 2016).

According to the World Bank, Bangladesh faces an expected 30cm and 50cm SLR in 2030 and 2050 respectively (World Bank, 2000). A recent report shows a trend of increasing SLR at Hiron Point near Sundarbans by 7 mm/year, at Cox's Bazar by 13 mm/year from 1981 to 2013, at Khal No 10 in Chittagong by 20 mm/year from1983 to 2012 (CEGIS, 2015 and Table 5.27). Other stations along the Bangladesh coastline also show an increasing trend of SLR.

Table 5.27: Significant trends derived from select water level stations (near the coastline) in the coastal region of Bangladesh based on the data of last 30 years

Location	Subzone	Analysis Period	Trend based on Regression Slope (mm/year)	Trend based on Sen's Slope (mm/year)	Significance level
Hiron Point*	Ganges tidal floodplain (saline)	1981-2013	8	7	significant at 95%
Char Chenga	Meghna estuarine floodplain (charland)	1980-2012	6.3	6	significant at 99%
Sandwip	Meghna estuarine floodplain (charland)	1977-2012	9	9	significant at 99%
Khal No. 10	Chittagong coastal plain	1983-2012	15	20	significant at 99%
Cox's Bazar	Chittagong coastal plain	1980-2012	11	13	significant at 99%

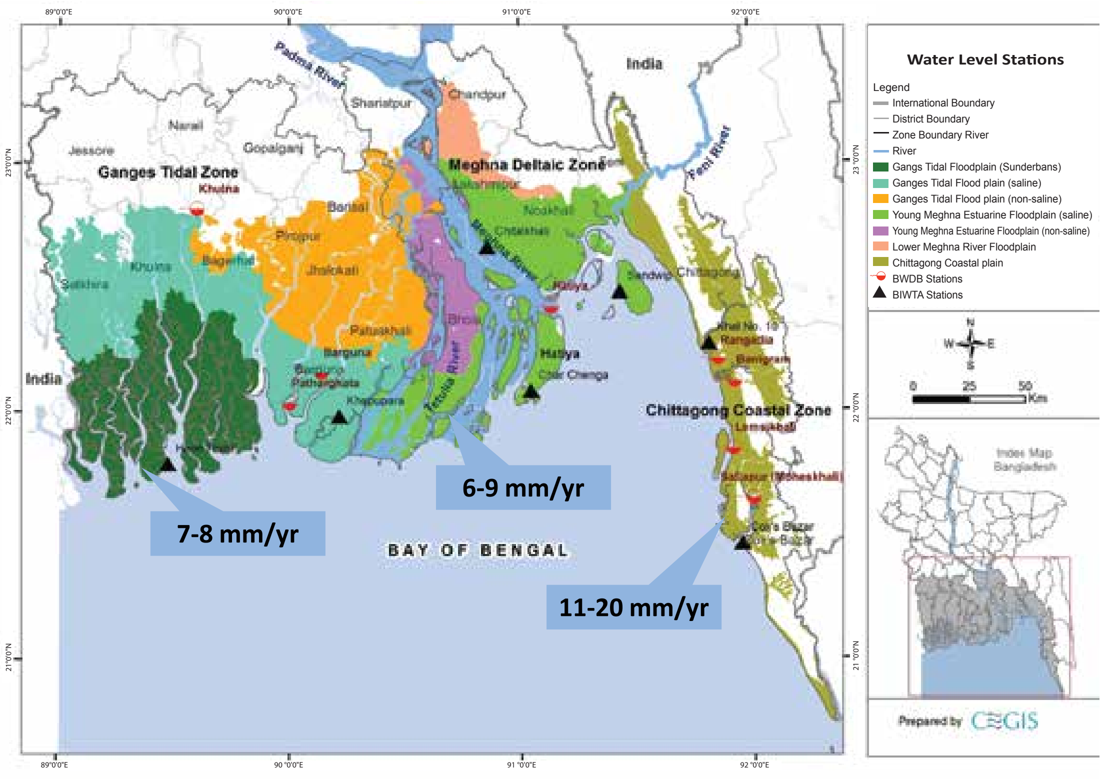


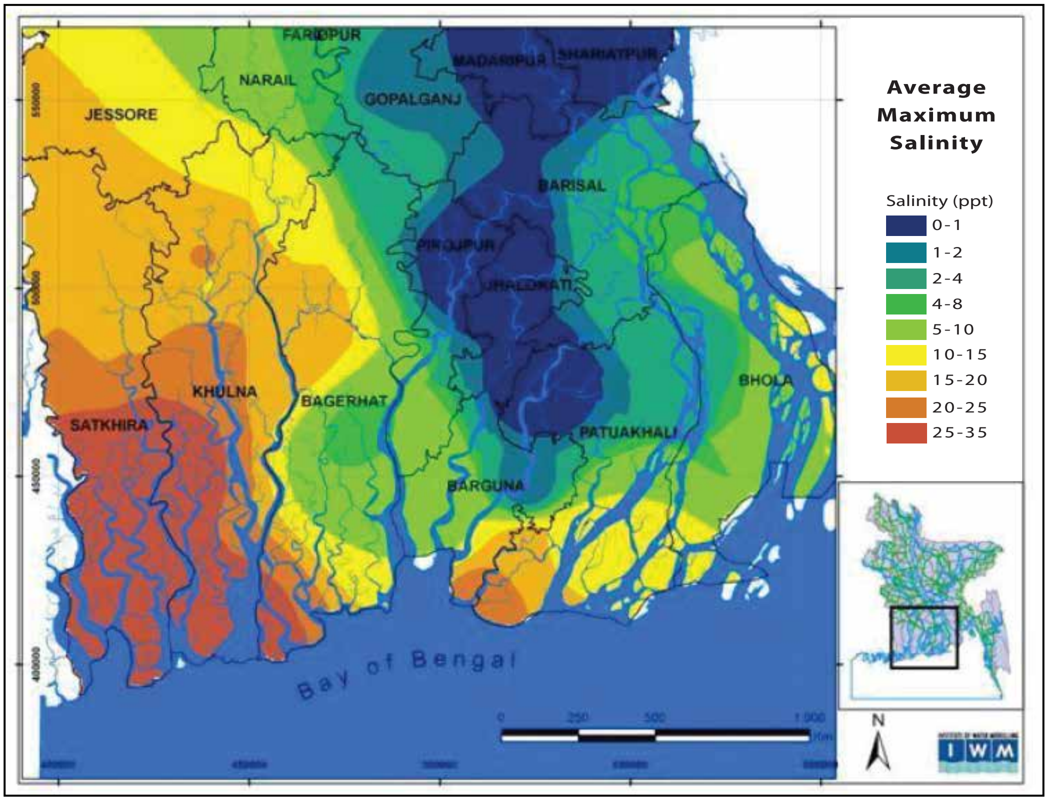
Figure 5.17: Water level trends for the Ganges, Meghna and Chittagong coastal sub-zone of Bangladesh based on data from last 30 years. Source: CEGIS, 2015.

SLR would exacerbate the impacts of cyclones and storm surges on the quality of water in Bangladesh, as such events have the potential to spread pollution from contaminated sources. For example, Cyclone Sidr in 2007 spread saline water to more than 6,000 ponds in the affected coastal districts of Bangladesh (Rabbani *et al.,* 2010). This kind of pollution will, in the future, increase the prevalence of waterborne diseases such as cholera and diarrhea. SLR in Bangladesh could displace millions of people from the coastal areas (Rahman et al., 2007; Rabbani *et al.,* 2010). Estimates show that SLR would affect at least 1 million people in the Bangladesh part of the GBM basin, by 2050 (Ericson *et al.,* 2006; Cruz *et al.,* 2007 in Rabbani *et al.,* 2015). The people of the exposed coast especially in Satkhira, Khulna, Bagerhat, Barguna, Patuakhali, Jhalkhati, Pirojpur, Barisal and Bhola are very vulnerable to SLR and surge flooding. It is estimated that nearly 7 million and 13 million of people will be at risk in coastal zones alone (25,504 km^2) by 2025 and 2050, respectively if the population growth continues at a rate of 1.4% and climate remains unchanged (Karim and Mimura, 2008). Due to high population and poverty levels, coupled with inadequate infrastructure and services, such low-lying areas struggle to cope with the impacts of flooding, storm surges, erosion and salinization, and SLR will only make this situation worse (Huq and Rabbani, 2015). The low lying coastal lands might be gradually inundated affecting all agricultural activities, water supply and sanitation system, infrastructure, etc. unless these are protected from SLR.

Salinity intrusion

Saline intrusion in water and soil will be triggered by the climate change and variability. The level of salinity is already increasing in many rivers including the Garai, Baleswar, Pussur, Rupsa, Kobadak, Shibsha, and Ichamoti rivers (World Bank, 2014). Studies indicate that people of some districts including Patuakhali, Pirojpur, Satkhira, Bhola, Khulna, Feni and Noakhali are suffering from salinitiy in both their water and their soil (Islam, 2004). According to a 2014 report of the World Bank, a number of factors will exacerbate the salinity level in the water streams, among them rainfall patterns, freshwater flows in the rivers, cyclone induced surges and SLR. Bagerhut, Barguna, Bhola, Jessore, Khulna, Satkhira, Patuakhali, and Pirojpur will be extremely vulnerable with > 5ppt salinity level in the rivers under A2 emission scenario with 67 RMSLR (Table 5.29), (World Bank, 2014). The study reveals that the fresh water river area (salinity level 0 to 1 ppt) will be reduced to 59% by 2050 in thirteen coastal districts.

It also indicates that the total salinity intrusion affected area (from 5ppt to 10 ppt) will be increased to 68% by 2050 (Figure 5.18). Over 10 ppt salinity levels will also affect huge areas. Bagerhut, Khulna and Satkhira will be the worst hit by salinity intrusion by 2050 (Figure 5.18 and Table 5.28). Increases in salinity levels in river waters have devastating effects on agriculture, water resources/supply, sanitation, river ecosystems, biodiversity and so on. Freshwater fish species and giant prawn *(golda)* will be adversely affected. The income and the livelihoods of the local fishing communities will also be affected and poor local populations may suffer from malnutrition.



(Source: IWM in World Bank, 2014)

Figure 5.18: Map of average maximum salinity in the south-west region of Bangladesh

Table 5.28: Baseline of river salinity by district (March 2012)

SL	District	Baseline of river salinity by district (March 2012)								
		0-1ppt	1-2ppt	2-4ppt	4-5ppt	5-10ppt	10-15ppt	15-20ppt	20-25ppt	Over 25ppt
1	BAGERHAT	455	303	478	14	816	975	659	216	0
2	BARGUNA	737	123	138	52	325	72	73	0	0
3	BARISAL	2113	429	0	0	0	0	0	0	0
4	BHOLA	0	747	2045	43	0	0	0	0	0
5	GOPALGANJ	1456	0	0	0	0	0	0	0	0
6	JESSORE	2054	167	108	34	78	0	0	0	0
7	JHALOKATI	742	0	0	0	0	0	0	0	0
8	KHULNA	96	49	241	82	383	1136	1737	419	51
9	NARAIL	930	48	0	0	0	0	0	0	0
10	PATUAKHALI	1113	833	218	76	266	171	408	3	0
11	PIROJPUR	960	179	85	28	12	0	0	0	0
12	SATKHIRA	353	88	101	60	436	473	848	359	1006
13	SHARIATPUR	1233	0	0	0	0	0	0	0	0

Source: World Bank, 2014

Table 5.29: Worst Future Scenario (2050): A2 emission scenario and 67 RMSLR

SL	District	Worst Future Scenario (2025): A2 emission scenario and 67 RMSLR								
		0-1ppt	1-2ppt	2-4ppt	4-5ppt	5-10ppt	10-15ppt	15-20ppt	20-25ppt	Over 25ppt
1	BAGERHAT	34	143	353	227	964	1216	857	212	33
2	BARGUNA	0	0	863	81	357	126	80	13	0
3	BARISAL	188	134	1970	249	0	0	0	0	0
4	BHOLA	19	0	8	1963	845	0	0	0	0
5	GOPALGANJ	1438	18	0	0	0	0	0	0	0
6	JESSORE	1864	169	171	85	144	8	0	0	0
7	JHALOKATI	0	0	742	0	0	0	0	0	0
8	KHULNA	0	0	12	42	659	891	1838	669	83
9	NARAIL	509	207	179	69	15	0	0	0	0
10	PATUAKHALI	0	0	1663	519	333	150	275	149	0
11	PIROJPUR	3	200	943	53	64	0	0	0	0
12	SATKHIRA	161	92	149	49	500	535	718	391	1130
13	SHARIATPUR	847	177	210	0	0	0	0	0	0

Source: World Bank, 2014

Coastal Floods and Water logging

Coastal floods and water logging due to excessive rainfall often affect the coastal ecosystem. Floods in 1998, 2004 and 2007 affected most of the coastal districts. In future, the increased snow melt from the Himalayan permafrost, due to increasing temperature, may force more water to flow through the Ganges, Meghna, and Brahmaputra river systems and their river networks resulting in additional flooding extending over the central flood plains of Bangladesh (Rahman *et al.,* 2007). Moreover, increased floods due to climate change may affect large areas with high incidences and casualties in the coastal zone of the country.

Erosion and accretion in coastal Bangladesh

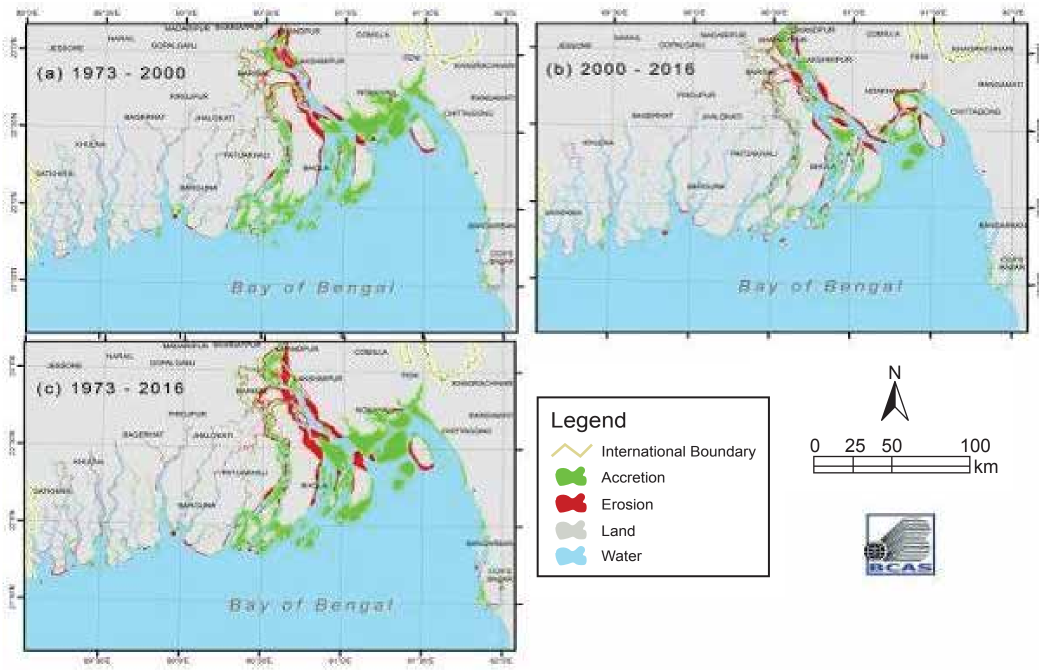
Table 5.30 shows the natural erosion and accretion statistics in the period 1973-2016 for the whole coastal region of Bangladesh. A higher rate of land aquisition ~47 km2/year during the first 27 years assessment period (1973-2000) than that of the later 16 years assessment period (2000-2016) can be observed. This may be attributed to a large dune suddenly reclaimed at the south of Noakhali. After that period, during the last 16 years of the study (2000-2016) the trend of the rate of net gain was 6 km2/year, which actually reduced the overall trend of rate of net gain of land during the whole assessment period (1973 – 2016) to 30 km2/year. The trend of erosion and accretion points to the highly unstable coastal areas especially the Meghna estuary through where the combined water and sediment flows from the Ganges, Brahmaputra and Meghna rivers.

Table 5.30: Erosion and accretion in the coastal zone

Duration	Erosion (km^2)	Accretion (km^2)	Net gain (km^2)	Rate of gain (km^2/year)
1973 – 2000	1105.5	2362.2	1256.7	46.5
2000 – 2016	1085.4	1174.6	89.2	5.6
1973 – 2016	1464.5	2749.1	1284.6	29.9

Figure 5.19 shows the spatial distribution of erosion and accretion areas in the whole coastal area of Bangladesh. Huge erosion and accretion is seen in the Meghna estuary area i.e., Bhola, south of Noakhali and south of Patuakhali is highly unstable during the assessment period, unlike the western (Ganges estuary) and eastern coasts (Karnaphuli) which are relatively stable. In the western coast, some erosion can be seen over the last 43 years. This may be attributed to the erosion caused by mainly wave action during high tide and low tide because of high clay

content in the upper soil layer. A number of storm surges during cyclones in pre-monsoon and post-monsoon period also can be a cause of this erosion.



5.19: Erosion and accretion of whole coastal Bangladesh 1973 – 2016

Temperature and rainfall variation

In Bangladesh, the temperature is predicted to increase by 0.7ºC in monsoon and by 1.3ºC in winter (World Bank, 2000). A recent report indicates that the average temperature increased from 1978 to 2007 in all four seasons in Bangladesh (Syed and Amin, 2016). It states: *"in pre-Monsoon (March–May), the average maximum and minimum temperatures were found to be increasing at a rate of 0.016ºC and 0.015ºC per year, respectively. Similarly, the rate of increase in the average maximum and minimum was found to be 0.034ºC and 0.014ºC for monsoon (June–August), 0.018ºC and 0.010ºC for post-monsoon (September–November) and 0.015ºC and 0.009ºC for winter (December–February)".* In the Chittagong coastal region, the average maximum and minimum temperature increased by 0.067ºC /year and 0.031ºC /year respectively (Syed and Amin, 2016). Similarly, both maximum and minimum temperature shows an increasing trend in the Barisal region. Regarding rainfall, it indicates that the total rainfall is decreasing in pre-monsoon (3.978 mm/year), monsoon (7.0049 mm/year) and in winter (0.3519 mm/year) in the Barisal coastal region while the Chittagong region is experiencing an increasing trend in total rainfall with the exception of during the monsoon season.

Drought

The coastal districts of the country usually face some extent of drought almost every year in the period from March to May. Drought in the coastal districts affects the overall agricultural production.

Adaptation technologies and practices in the coastal zone and other vulnerable eco-zones of Bangladesh

Government organizations, INGO/NGOs, CBOs and farmers have introduced different adaptation technologies/options in different sectors in the coastal region. The 'Deltas, Vulnerability and Climate Change: Migration and Adaptation (DECCMA)' project under the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA) programme identified 85 different current adaptations measures for crop agriculture in the coast (Mondal *et al.,* 2016). Of the total, 53 adaptation options relate to infrastructure and 31 options are socio-economical. The infrastructural adaptations mainly include polders/embankment, cyclone shelters, irrigation channels and drainage infrastructure. The infrastructural adaptation in the coast actually addresses both water and agriculture sector/sub-sectors. In addition, stress (salinity, flood, drought and cold) tolerant varieties, changes in cropping patterns, integrated farming practices, access to information, early warning system and innovative technologies, such as floating and hanging gardens, are being out into practice in the coastal region. The following table provides a list of climate related stress tolerant rice varieties being grown in Bangladesh. However, all saline tolerant rice varieties and some flood and drought tolerant varieties may be grown in the coastal zone (Table 5.31).

Table 5.31: Climate related stress tolerant rice varieties developed for Bangladesh by the BRRI and BINA

Climate Related Stress	Climate Tolerant Rice Varity	Growth Duration (days)	Average Yield (Ton/Ha)
Flood (submergence)	BRRI dhan 51	142-154	4
	BRRI dhan 52	145-155	4.5
Salinity in soil, surface and ground water	BRRI dhan 40	145	4.5
	BRRI dhan 41	148	4.5
	BRRI dhan 47	152	6.0
	BINA-8	130-135	5.0
	BRRI dhan 53	140	5.0
	BRRI dhan 54	140	5.0
	BRRI dhan 61	150	6.3
	BRRI dhan 67	143	6.0
	BRRI dhan		
	BRRI dhan 73	120-125	6.1
Drought	BRRI dhan 42	100	3.5
	BRRI dhan 43	100	3.5
	BRRI dhan 55 (also saline and cold tolerant)	145	7.0
	BRRI dhan 56	110	4.5
	BRRI dhan 57	100	4.0
	BRRI dhan 65	99	3.5
	BRRI dhan 66	113	4.5
	BRRI dhan 71	115	5.5
	BRRI dhan 76	153	4.5
Cold/low temperature	BRRI 36	140	5.0

Source: BRRI, 2016; updated from Huq and Rabbani, 2015

Some other large, medium and small-scale adaptation technologies/options being practiced in the coastal areas can be seen in Table 5.32.

Table 5.32: Adaptation options for agriculture/water supply due to different vulnerability of climate change (modified from Sikder, 2010).

Challenges	Existing Coping Strategies
High water level, riverbank erosion or breaching of the embankment.	Plant timber trees Fast growing and early growing crop varieties Kitchen gardening Tree plantation on both sides of the embankment
Salinity	Cultivate paddy in shrimp *gher*/farms in rainy season Cultivate saline tolerant rice and fish varieties Grow vegetables in raised beds Cultivate paddy and shrimp alternatively Shrimp cultivation at distances far from homestead Cultivate the land by re-excavation of canals and ponds
Cyclone and tidal surge	Coastal Afforestation or green belt to protect from cyclones and storm surge damage Plant timber trees Fast growing and early growing crop varieties

Challenges	Existing Coping Strategies
Floods and water logging	Water drainage and re-excavation of canal Submergence -tolerant varieties of crops Rural to urban migration for job search/employment Embankment/polders to avoid flood damage Raising plinth height of infrastructure e.g. latrine, tube wells etc.
Lack of drinking water	Rain water harvesting Pond protection/conservation Pond Sand Filter (PSF)
Drought	Excavate and re-excavate ponds

Strengthening individual and institutional capacity through training, networking and knowledge management in agriculture and water sector is also being practiced. For example, the Disaster and Climate Risk Management (DCRM) Project under the Comprehensive Disaster Management Programme (CDMP) of the Government of Bangladesh established 156 Farmers Field Schools (FFS) in flood, drought, flash flood and coastal zones. Of these, 48 schools were in the coastal region. This project organized a series of training workshops for the farmers of each FFS. The project also identified and supported the implementation of at least 27 adaptation options including the cultivation of saline tolerant varieties, the conservation of freshwater in mini ponds, drip irrigation, and homestead gardening.

5.8 Impacts and Vulnerability in Flood-prone and Drought-prone areas in Bangladesh

Flood is one of the major disasters that adversely affect the people of Bangladesh. Of a total number of 310 rivers, the Ganges, Brahmaputra and Meghna (GBM) are the major rivers (MoDMR, 2013). The country is flooded almost every year. Inundation of less than 25% is considered a 'normal' flood. Figure 5.22 shows the flood vulnerable areas in the country. The severe riverine flood areas are mainly located along the GBM basin especially in the north-west and central part of the country. The north-east part is an area that is prone to flash floods while the entire southern region is exposed to severe and moderate tidal surge. The floods of 1987, 1988 1998, 2004 and 2007 were highly catastrophic and caused huge damages in all sectors including agriculture, water, infrastructure, fisheries, livestock, forestry and health. As shown in Figure 5.20, over 30 % of the country was inundated at least seven times by flood in the period 1954-2013. The most catastrophic of these floods was that of 1998 which inundated about 70% of the country. Table 5.33 gives an overview of the loss and damages caused by the four major floods in the last three decades. Climate change will intensify the level of inundation across the country, especially in the coastal region. The southern and the central parts may face additional inundation due to climate change by 2080 (Figure 5.22). This would cause livelihood crises and influence migration of the local communities.

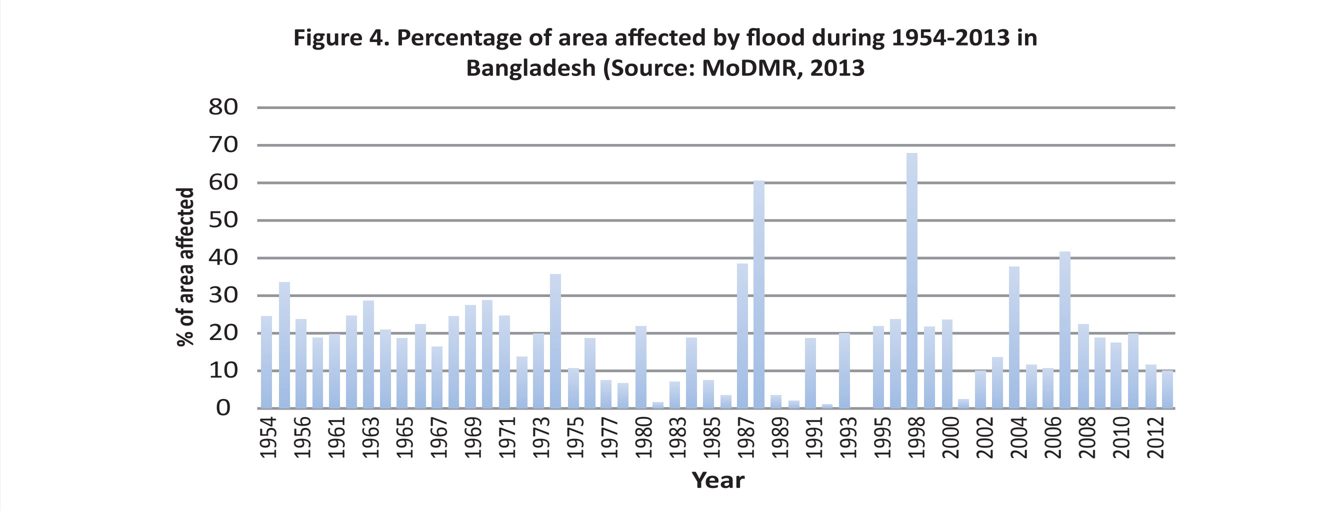


Figure 5.20: Percentage of area affected by flood in Bangladesh, 1954-2013

Table 5.33: Loss and damages caused by the major floods in different years in Bangladesh (Source World Bank in Kausher, AHM. 2010; Rabbani and Huq, 2013)

Item	1988	1998	2004	2007
Inundated area of Bangladesh (%)	60	68	38	42
People affected (millions)	45	31	36	14
Total Deaths	2300	1100	750	1110
Livestock killed (numbers)	172,000	26,564	8,318	40,700
Crops damaged (fully/partially in million ha)	2.12	1.7	1.3	2.1
Loss of rice production (million tons)	1.65	2.06	1.00	1.2
Road damaged (km)	13,000	15,927	27,970	31,533
No of houses partially/fully damaged (millions)	7.2	0.98	4.00	1.1
Total loss in USD (billions)	1.4	2.0	2.3	1.1

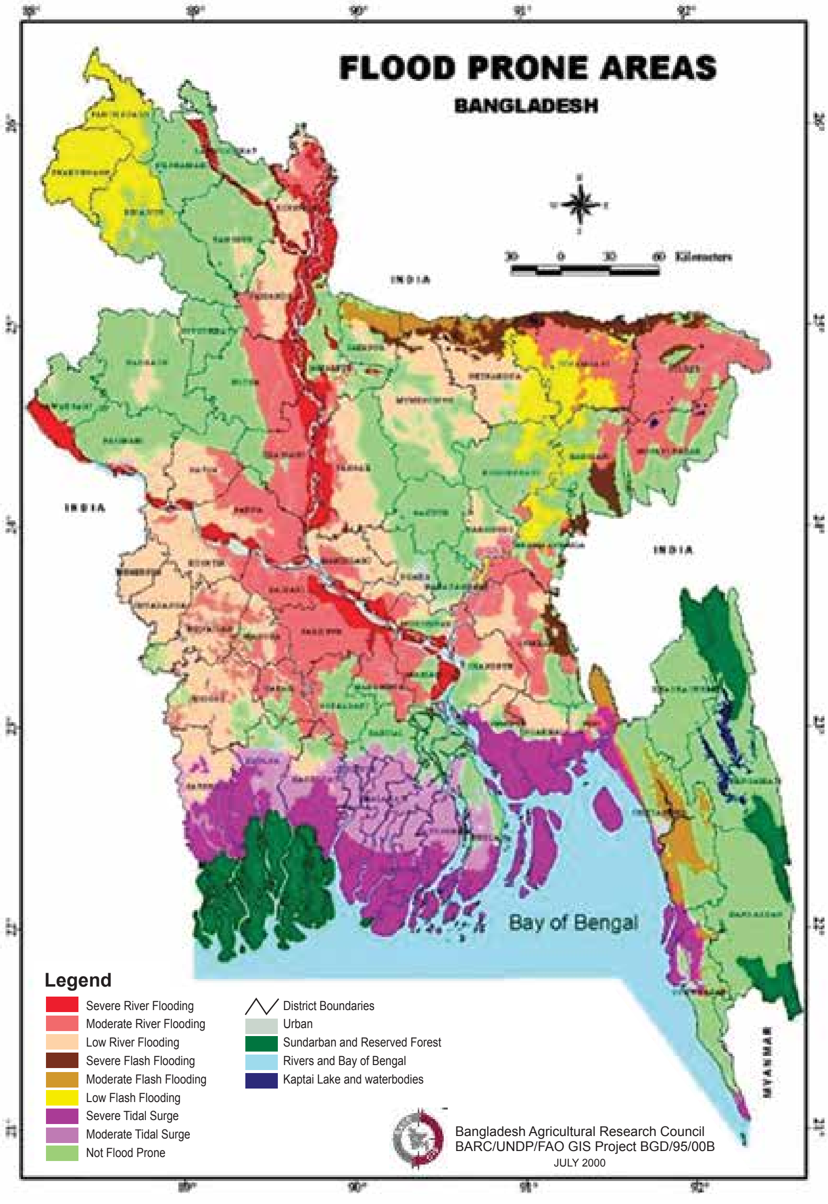


Figure 5.21: Flood prone areas in Bangladesh (Source: BUET)

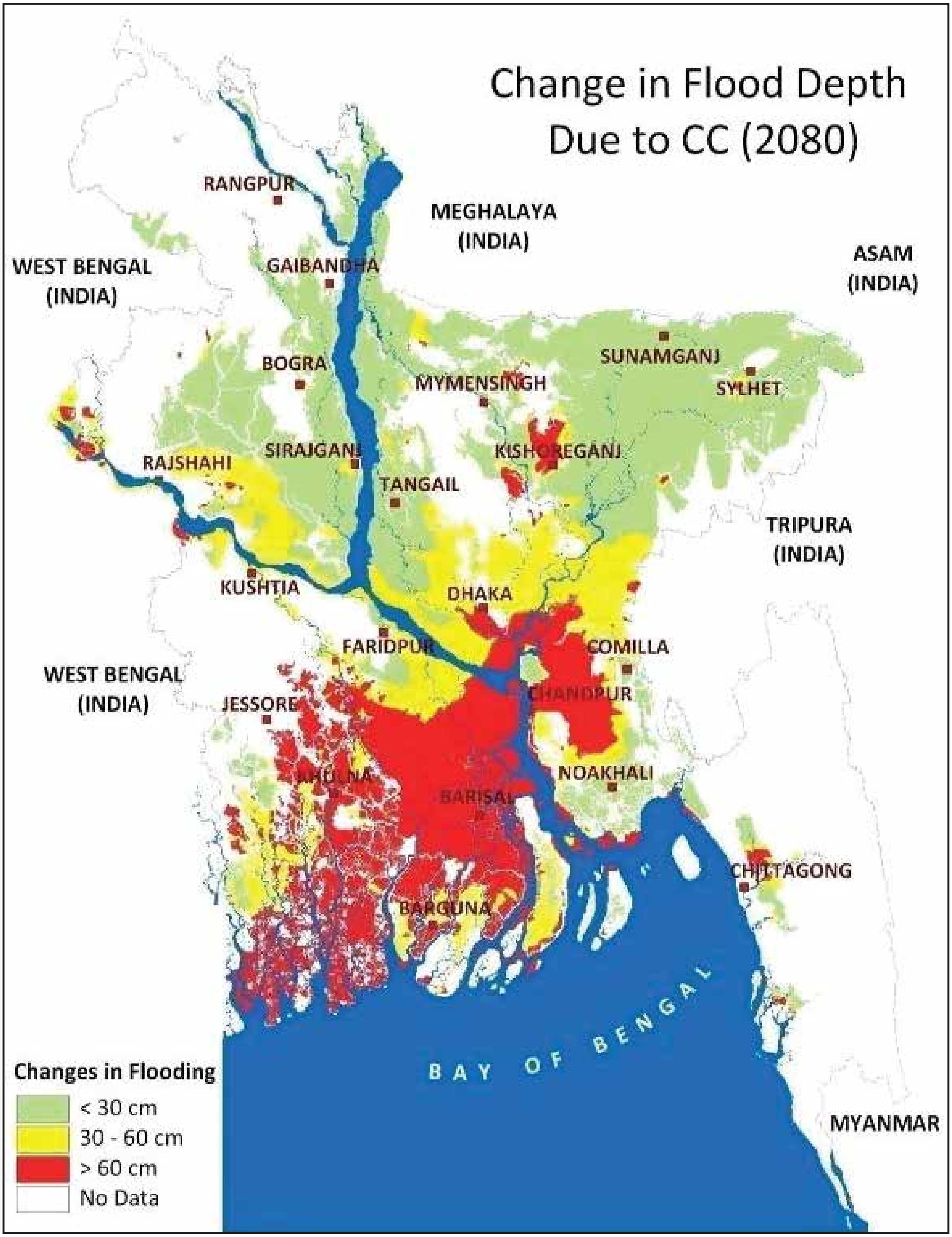


Figure 5.22: Changes in floods due to climate change by 2080 (Source: Kausher, 2010)

Drought is defined as the condition when the moisture availability at the root zone of plants is less than the required amount (SNC, 2012; BBS, 2010). It is a recurrent slow onset event which mainly impacts the north-west part of the country. Drought affects 3 to 4 million ha of land every year. People in Bangladesh were affected by nine major droughts affected between 1971 and 2007 (Shahid, 2007). Climate change may aggravate drought conditions and there will be a direct impact on agriculture production, water supply, health, life and livelihoods. Ahmed et al., (2015) states that: *"the potential bimodal distribution of monsoon rainfall might aggravate drought conditions so much that rain fed aman cultivation might no longer be a viable practice".* Figure 5.23 shows that an area of over 40 % of the country was affected by drought in 1957, 1972 and 1979. Table 5.34 shows the brief impacts of drought in different vulnerable areas in the country (GED, 2009).

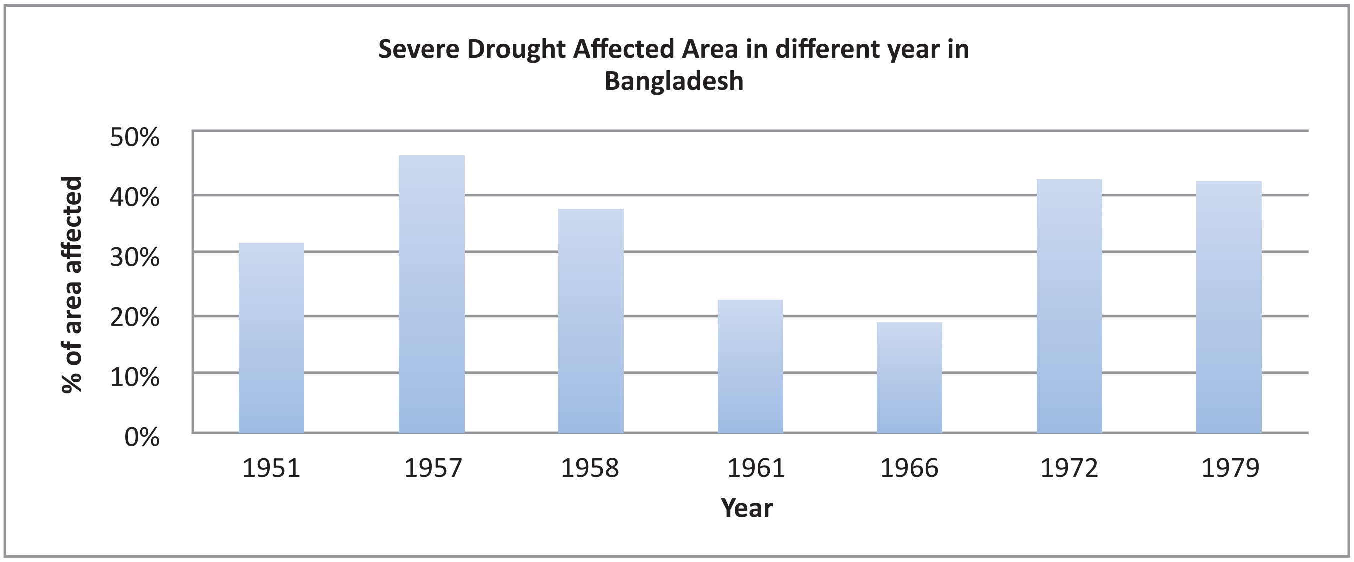


Figure 5.23: Severe Drought Affected Areas in different years in Bangladesh

Table 5.34: Impacts of drought in different vulnerable areas (GED, 2009)

1791	Drought affected Jessore district. Prices rose to twice and three times their usual levels.
1865	Drought preceded by famine occurred in Dhaka.
1866	Severe drought in Bogra. Rice production of the district was hit hard and the price went up three times its normal level.
1872	Drought in Sundarbans. The rainfall was deficient and in several plots the crops suffered to a great extent.
1874	Bogra was affected and the crop failure was much greater. The rainfall was extremely low.
1951	Severe drought in north-west Bangladesh and substantially reduced rice production.
1973	One of the most severe droughts of the 20th century responsible for the 1974 famine in northern Bangladesh.
1975	This drought affected 47% of the entire country and caused suffering to about 53% of the total population.
1978 -79	Severe drought causing widespread damage to crops. Reduced 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 severest in recent times.
1981	Severe drought adversely affected crop production.
1982	Caused a total loss of rice production amounting to about 53,000 tons. In the same year, flood damaged about 36,000 tons of rice.
1989	Most of the rivers in NW Bangladesh dried up and in several districts, such as Naogaon, Nawabganj, Nilpahamari and Thakurgaon, dust syndrome occurred for a prolonged period due to drying up the topsoil.
1994 -95	This drought was followed by that of 1995-96, and caused immense damage to crops, especially rice and jute - the main crops of NW Bangladesh. The most persistent drought in Bangladesh in recent memory.

FAO (2007) assessed the drought potential in Bangladesh and impacts on the agriculture sector (Table 5.35 and Table 5.36). The study focused in particular on the Barind Tract in the north-western region of the country. The region is potentially more vulnerable to dry periods during both the monsoon and dry season. Some climate sensitive crops may not be suitable to the altered climate. Small-scale farmers are likely to suffer the most because of increased pressure on natural resources and higher demand of crops due to an increasing population (FAO, 2007).

Table 5.35: Climate change scenarios and drought

Scenario	Drought
Current	Severe drought can affect yield in 30% of the country, reducing national production by 10%.
2030	Temperature increase of 0.5°C and annual rainfall reduction by 5% could reduce runoff into the Ganges, Brahmaputra and Meghna rivers by 14%, 11% and 8%, respectively. With 12% reduction of runoff, the population living in the severe drought prone areas increases from 4% to 9% under moderate climate change due to expansion of areas.
2050	Future droughts may increase the probability of a dry year (i.e. a year with certain percentage of below-average rainfall), by 4.4 times. A rise in temperature by 1.3°C and fall in precipitation levels by 9% would reduce runoff into the Ganges, Brahmaputra and Meghna rivers by 27%, 21% and 15%, respectively. If runoff drops to 22% in the *kharif* season, drought-prone areas would expand to include north-western to central, western and south-western regions.

Source: FAO, 2007

Table 5.36: Examples of climate variability, extremes and their impacts on crops, water and energy

Projection of changes in extremes in the IPCC AR5	Examples of projected impacts in the drought prone area in Bangladesh
Warmer and/or more frequent hot days, warm spells/heat waves (*virtually certain*)	Increased risk of damage to both monsoon and dry season crops Increased crop pest and diseases Increased irrigation water requirements Increased energy demand for irrigation Reduced energy supply reliability
Warmer and/or fewer cold days and nights (*virtually certain*)	Decreased risk of damage to some crops Increased risk to crops such as wheat and chickpea Increased activity of some pest and diseases vectors
Heavy precipitation events; increase of frequency, intensity, and/or amount of heavy precipitation (*very likely*)	Increased chances of flooding Increased soil erosion Increased loss of topsoil and nutrients Increased loss of soil fertility
Increases in in tensity and/or duration of droughts (*likely*)	Decreased crop yields Decreased water resources (quantity and quality) Pressure on surface and ground water resources Increased prices of crops and food insecurity Increased migration of labours

Source: Left column from IPCC AR5 WGI and right column modified from FAO (2007). Virtually certain: 99-100% probability; Very likely: 90-100% probability; and Likely: 66-100% probability.

5.9 Impacts and Vulnerability in Urban Areas

Introduction

The urban population of Bangladesh will exceed 50% of its projected total population by 2050 (Revi et al., 2014, Islam, 2015). The annual growth rate of urban population in Bangladesh during the last decade of population census (2001-2011) was 3.5%, while for Dhaka mega city it was 4.7% (BBS, 2014). Rapid population growth and mass urbanization are pushing agricultural lands, water bodies, forest, wetlands and urban utility services (drinking water and sanitation facilities, drainage etc.) beyond their provisional capacities. These pressures are higher in larger cities because of their appeal as employment hubs. As demand for land has increased, large scale encroachment and conversion of land usage have been rampant. This is mostly attributable to weak enforcement of government regulations. However, both public and private sectors have contributed to an unplanned urbanization process which is being exacerbated by climate change, rapid and unplanned industrialization, unplanned settlement formations like slums, piecemeal forms of transport, and infrastructural development all of which pose tremendous challenges in developing and implementing an approach to planned urban development (Rahman et al., 2016).

The potential impacts of climate change on urban cities and their populations are identified in a wide range of pathways considering cities' adaptation capacity, sensitivity and exposure layers. City dwellers have faced high levels of risk regarding damage and loss of property and health. Climate change has substantial potential to modify the urban micro-climate with increasing extreme heat events, extreme hot days and nights, consecutive dry and wet days, increasing energy consumption, etc. Climate change may affect human health of city dwellers in many ways, through, for instance, floods, droughts, vector borne diseases and malnutrition. Many urban cities in Bangladesh located along the coast and mouths of rivers, are facing climate related hazards with their rapid growing populations. Disasters in urban centres will lead to damages in infrastructure, and threats to biodiversity and to ecological sustainability. Heavy rainfall and storm surges would affect urban centres through flooding which in turn damages infrastructure and livelihoods, and increases the rate of water-borne diseases. Coastal floods, sea level rise, and storm surges contribute to negative economic impacts that lead to displacement and declining living standards in the cities as well as in rural areas. Cities are particularly vulnerable because they were developed without due consideration for climate change and with little or no regard for climate resilient infrastructure.

Nature and characteristics of urbanization in Bangladesh

The definition of urban areas used in different censuses has not been uniform. The definition of urban area of the 1981, 1991, and 2001 censuses included growth centres (GC) and urban agglomerations adjacent to large cities, i.e., city corporations termed as statistical metropolitan areas (SMA). Since 2011, the concept of SMA has been abandoned and only city corporation areas are treated as urban areas (BBS, 2014). This definitional change makes it difficult to compare urban growth or patterns between censuses e.g., the proportion of urban population declined to 23.3% in 2011 in contrast to 23.5% in 2001. In fact, if the former SMA, GCs and other urban areas are taken into account, the percentage of urban population would rise to 27.7%. Moreover, the post enumeration check adjustment factor further adjusted the urban population of 2011 to 28.0%. The urbanization of Bangladesh in different census years in a comparable format is summarized in Table 5.37.

Table 5.37: Time series of volume of urban population in Bangladesh, 1901-2011 (BBS, 2014)

Census year	Population (million)	Percentage of national
1901	0.7	2.4
1911	0.8	2.6
1921	0.9	2.6
1931	1.1	3.7
1941	1.5	3.6
1951	1.8	4.3
1961	2.6	5.2
1974	6.3	8.8
1981	13.5	15.5
1991	22.5	20.2
2001	31.1	23.8
2011	42.0	28.0

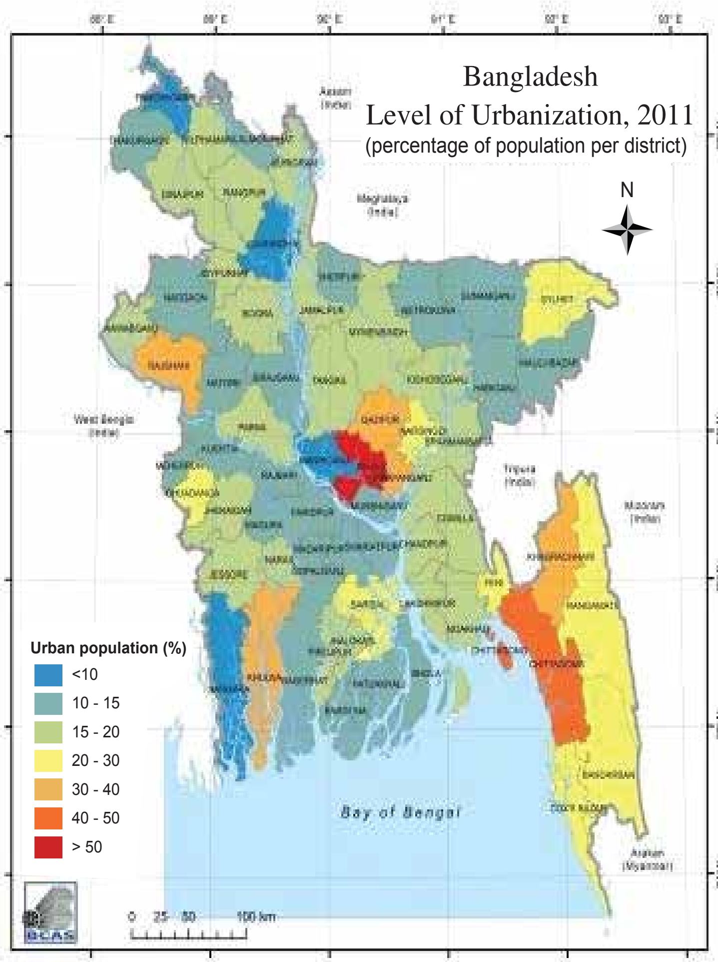


Figure 5.24: Level of urbanization (percentage of urban population in each district) in Bangladesh in 2011 (data taken from BBS, 2014)

Urbanization levels in Bangladesh, in terms of the proportion of urban population by districts, vary quite substantially. In fact, according to the 2011 census, it varies from as low as 9% in the Gaibandha district to more than 77% in the Dhaka district (Figure 5.24). After Dhaka, the other most urbanized districts (>30%) are Chittagong (41%), Khagrachhari (35%), Narayanganj (34%), Khulna (34%), Rajshahi (33%), and Gazipur (31%). Most of the districts, 49 out of 64, have low levels of urbanization (<20%). There are four districts namely Satkhira, Panchagarh, Manikganj, and Gaibandha, where the urban population is less than 10%.

Risks, vulnerabilities and adaptations in urban areas

This section summarises the risks, vulnerabilities and direct and indirect impacts of changes of climatic variables on urban populations and urban systems of Bangladesh as well as the present adaptation practices and future adaptation measures that can be implemented. Due to diversified urban systems, it is critical to understand the distribution of climate induced risks and vulnerabilities and corresponding impacts on different urban systems. According to the Fifth Assessment Report of IPCC (2014a), the key risks of major urban centres identified on a global scale, with high confidence are: (a) water supply systems; (b) waste water systems; (c) energy systems; (d) food systems and security; (e) risks associated with housing; (f) human health; and (g) poverty and access to basic services. Other key risks identified with medium confidence are: (h) coastal zone systems; (i) terrestrial ecosystems and ecological infrastructure; (j) green belt infrastructure; (k) transportation systems; (l) communication systems; (m) human security and emergency response; (n) key economic sectors and services; and (o) livelihoods. In Bangladesh, urban areas especially large and coastal cities, are at high risks as per IPCC (2014a).

The geographical shape of the country possibly makes it more vulnerable to recurrent cyclones and storm surges that have hit the coastal areas twice as super cyclones (>220 km/h) and 19 times as very severe cyclones (119-220 km/h) in the last 40 years, and now it is evident that both frequency and intensity of cyclones along the Bay of Bengal is an increasing trend (Huq and Rabbani, 2011). The key climatic induced hazards of urban areas in Bangladesh are identified as floods and drainage congestion, salinity, sea level rise, cyclones and storm surges (in coastal cities like Chittagong, Khulna, Barisal, Cox's bazar), cold waves, drought, and heat stress. Climate change will affect Dhaka primarily in two ways: through floods / drainage congestion and through heat stress (Alam and Rabbani, 2007). The causes of waterlogging are mainly river floods, excessive rainfall, low capacity of drainage systems and poor urban planning and management. The causes of 'heat islands' are mainly increasing vehicle exhaust emissions, industrial activity, increasing use of air conditioners, and lack of green space (Alam and Rabbani, 2007). During the last five years (2010-2015), Dhaka's registered vehicles have doubled in number (BRTA, 2016).

Urban development needs to planned, taking into account the risks, vulnerabilities and adverse impacts of climate change, along with the following measures. First, attempts need to be taken to understand the complex and adverse impact of climate change on different sectors in urban areas. The knowledge gathered needs to be incorporated in the planning and development processes emphasising the most vulnerable group i.e., the urban poor. Second, the agglomeration of urban centres should be decentralised i.e., the development of urban centres, especially the divisional and district headquarters, should be enhanced simultaneously along with the capital, Dhaka. Third, economic activities and public amenities should be developed in a holistic manner so that people are encouraged to stay in urban centres other than Dhaka or Chittagong. Fourth, infrastructural development, mainly transport and communication, should be easy with different alternative options. Fifth, enforcement of existing regulations and coordination among government agencies responsible for monitoring unplanned expansion or encroachment should be expedited. A recent initiative by the government to establish special economic zones (SEZs) may make urbanisation more manageable than at present. Despite this initiative, the number of vulnerable in the urban population may increase because many of the SEZs planned are in the coastal islands or near the coastline which is more exposed to climate induced hazards than inland regions.

In Dhaka, non-climatic factors such as population density and poverty along with climatic factors may affect the lives and livelihoods of the city dwellers adversely. Socio-economic uncertainties in slums are also expected to produce a multiplier effect, resulting in an increase in morbidity and mortality for future generations (Rabbani *et al.,* 2011). Responding to these risks and vulnerabilities requires immediate action from city authorities. Government plans and policies require ensuring the wise utilisation of available resources combined with the efforts of NGOs and research institutions to address climate change through a holistic approach in both rural and urban contexts.

With the increase of climate risks and vulnerabilities, increasing urban population is also a burden for the existing urban centres, especially for large cities. Priority should be given to providing urban facilities and services simultaneously in large cities e.g., employment opportunities, safe water supply, housing and good living environment, mass transport, and other infrastructure. A comprehensive climate action plan for urban centres should be taken into consideration with high priority; successful and sustainable implementation can only be ensured by better addressing the issues and reducing climate impacts and vulnerabilities.

5.10 Adaptation Initiatives to Address Impacts and Vulnerability to Climate Change

5.10.1 Policies, Strategies and Institutions

The Ministry of Environment, Forest and Climate Change (MoEFCC) of the Government of Bangladesh takes the lead on the policy and institutional arrangements on climate change issues in Bangladesh. Over the last one and half decades, MoEFCC made a set of critical policy decisions to address climate change in the country. It led the preparations for national adaptation programmes of action (NAPA), national communications, for the Bangladesh Climate Change Strategy and Action Plan (BCCSAP), intended national determined contribution (INDC) and NAP process. It also provides approval of CDM projects, leads international negotiations, and facilitates mainstreaming climate change at sectoral level.

The MoEF in association with relevant line agencies, e.g. Department of Environment (DoE), Bangladesh Agriculture Research Council (BARC) and leading civil society organisations e.g. Bangladesh Centre for Advanced Studies (BCAS), formulated the national adaptation programmes of actions (NAPA) in response to the decision of the Seventh Session of the Conference of the Parties (COP 7) of the UNFCCC. NAPA identified fifteen immediate actions to adapt with floods, salinity intrusion, and droughts as the most damaging effects of climate change (Huq and Rabbani, 2012). It also determined the coastal population to be at the highest risk of climate change and suggested a number of measures to avoid risks and vulnerabilities. NAPA was revised in 2009 with more specific and elaborated action programmes.

The Bangladesh Climate Change Strategy and Action Plan (BCCSAP) was developed in 2009 to reduce the risks of climate change. The BCCSAP proposes a ten year plan of action to tackle climate challenges. It emphasises major climate induced hazards including flood, drought, SLR, salinity intrusion, cyclone and storm surge, variations in temperature and rainfall and their associated impacts on different sectors. BCCSAP placed 144 activities/measures under six major themes (Figure 5.25).

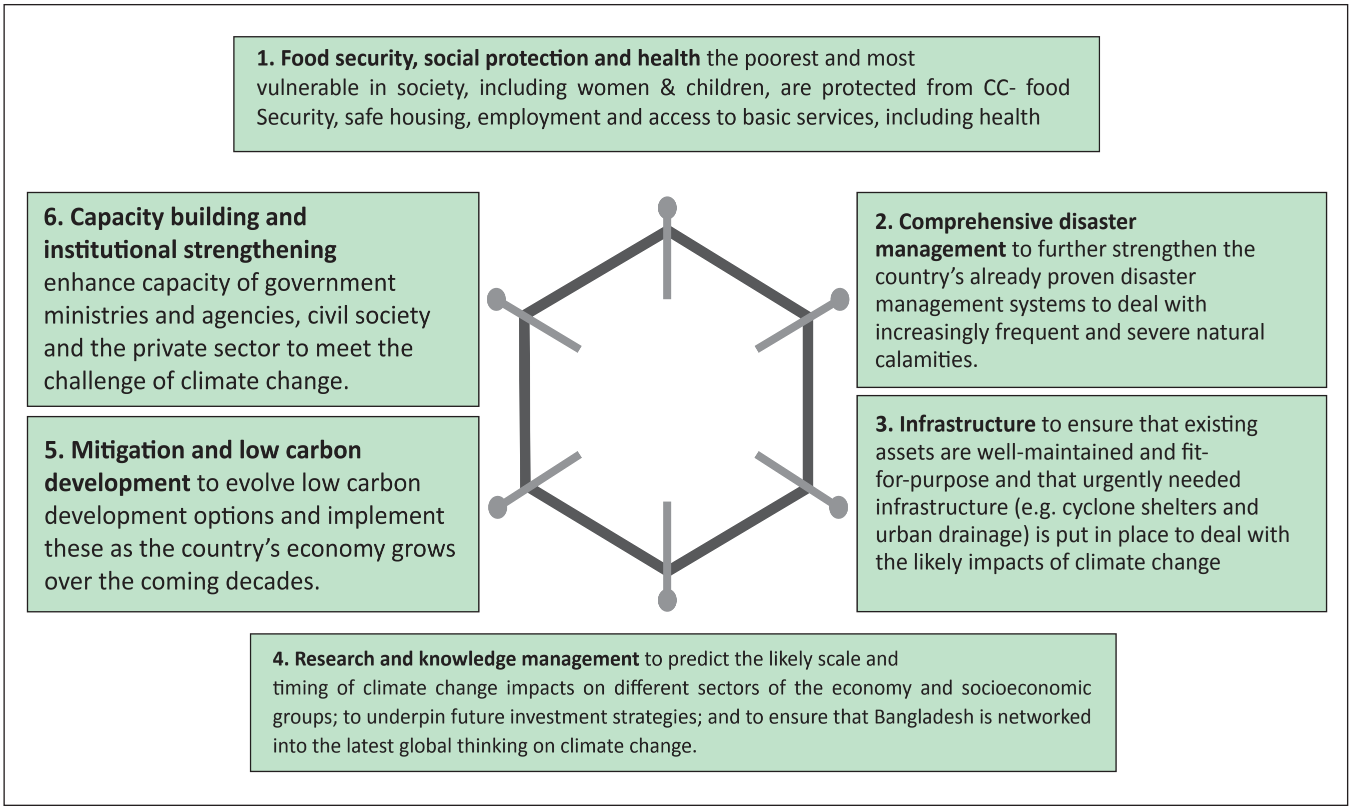
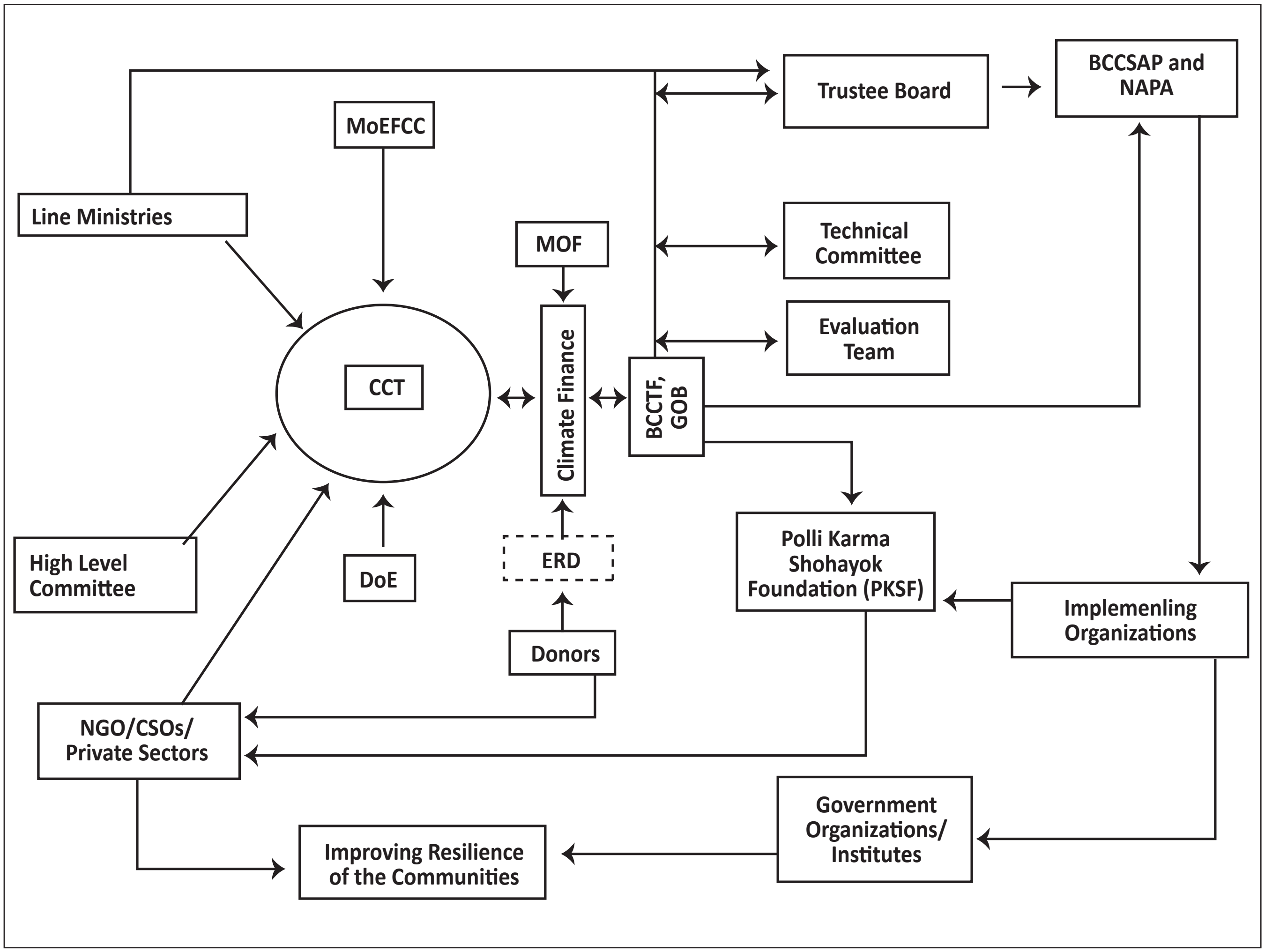


Figure 5.25: The six pillars of the BCCSAP (Source: Das, 2010).

BCCSAP is currently being implemented by relevant government agencies and civil society organizations with support from BCCTF under MoEFCC.

The MoEFCC played a vital role in establishing both the Climate Change Unit (CCU) and Bangladesh Climate Change Trust Fund (BCCTF) in 2010. The CCU was later renamed as the Climate Change Trust (CCT). The major functions of the CCT include: providing administrative and organizational support to the trustee board and the technical committee formed under the Climate Change Trust Act, 2010; receiving and analysing project proposals from different ministries and divisions; implementing the decisions of the trustee board; managing the Climate Change Trust Fund (CCTF); releasing funds for the projects approved by the trustee board; coordinating with the climate change focal points of different ministries or divisions; communicating with different stakeholders related to climate change including civil society, NGOs, the private sector and international agencies; and monitoring and evaluating the projects approved under CCTF.

Figure 5.26 below illustrates how the MoEFCC and other stakeholders are engaged in the implementation of the Bangladesh Climate Change Strategy and Action Plan (BCCSAP). MoEF, line ministries and NGOs/CSOs play crucial roles to advance the functions of the CCT. The CCT under MoEFCC takes the lead on the implementation of BCCSAP with the overall guidance of the trustee board, technical committee and an evaluation team. The trustee board and the technical committee is headed by the MoEFCC. The government has also engaged PKSF to take a lead on the implementation of small-scale adaptation and mitigation actions through NGOs/CSOs. The donors/development partners also provide financial support to both government and non-government organizations to improve the resilience of the vulnerable communities.



Source: Revised from Huq and Rabbani, 2012

Figure 5.26: Conceptual framework on institutional arrangement to address climate change in Bangladesh

5.10.2 Climate Change and Financing Adaptation

As mentioned above, the Government of Bangladesh established the Bangladesh Climate Change Trust Fund (BCCTF) to address climate change threats in the country. In the last seven years, between 2009-2010 and 2015-2016, the BCCTF received about 3000 crore BDT or over $384 million from the Ministry of Finance (MoF) of the Government of Bangladesh to implement adaptation and mitigation actions identified by BCCSAP (Table 5.38).$300 million was allocated between 2009-2010 and 2011-2012. The government also spent large amounts of money from the development and non-development budgets on climate sensitive activities. The Planning Commission (2012) estimates that this total amount stands at about $1 Billion (at the 2012 exchange rate). Estimates also show that 77% of the total budget for climate sensitive activities between 2009/10 and 2011/12 came from domestic resources and the rest, 23%, from foreign donor resources. The BCCTF is still active with own contribution to the government.

Table 5.38: Bangladesh Climate Change Trust Fund Allocation in Different Years

SL	Financial Year	Allocation (in core BD Taka)	Allocation (In Million USD)
1	2009-10	700.00	89.74
2	2010-11	700.00	89.74
3	2011-12	700.00	89.74
4	2012-13	400.00	51.28
5	2013-14	200.00	25.6
6	2014-15	200.00	25.6
7	2015-16	100.00	12.8
8	2016-17 (Proposed)	100.00	12.8

Bangladesh also established the Bangladesh Climate Change Resilience Fund (BCCRF) with contributions from development partners/donor countries to implement BCCSAP. The BCCRF is managed and implemented by the government with technical and secretariat support from the World Bank. The BCCRF also invested over $190 million to address climate change in the country. Other major climate change funds that have contributed to adaptation actions in Bangladesh include the Pilot Programme on Climate Resilience (PPCR) and the Least Developed Countries Fund (LDCF) under GEF. In addition, many development partners/donor countries, international organizations, multi-national banks/finance institutions have supported adaptation actions on the ground.

5.10.3 Projects and Programmes

The CCT under MoEFCC has undertaken 441 adaptation and mitigation projects with support from the BCCTF. Of these, 378 projects were/are being implemented by government organizations and the remaining 63 were/are being implemented by NGOs/CSOs through PKSF. Over the last seven years, there have been major adaptation investments on infrastructure development: construction/reconstruction of polders/embankments; afforestation; river dredging to ensure water flow in the rivers; drainage infrastructure in urban areas; climate resilient housing for vulnerable communities; water supply and sanitation; and climate resilient agriculture and mitigation actions. The Bangladesh Water Development Board (BWDB) under the Ministry of Water Resources (MoWR) received the highest resources from BCCTF for construction and reconstruction of embankments/polders and water infrastructure under the Comprehensive Disaster Management and Infrastructure thematic pillar of the BCCSAP. The Local Government and Engineering Department (LGED) and Department of Public Health and Engineering (DPHE) has implemented a number of adaptation projects related to drainage systems and water supply and sanitation services. The Department of Environment (DoE) took the lead on mitigation and on some adaptation projects. The Department of Forests (DoF) took the lead on the afforestation/reforestation projects besides the coast, in urban areas and in other places e.g. parks. The Department of Agriculture Extension (DAE), Bangladesh Agriculture Development Corporation (BADC), Bangladesh Rice Research Institute (BRRI) and Bangladesh Institute of Nuclear Agriculture (BINA) implemented projects on agriculture related issues. The Bangladesh Rice Research Institute (BRRI) and Bangladesh Institute of Nuclear Agriculture (BINA) initiated research on climate resilient varieties. Many other government and non-government organizations were on the ground with adaptation and mitigation projects supported by BCCTF.

5.10.4 Potential adaptation actions

Potential adaptation measures (Table 5.39 and Table 5.40), regarding different sectors that affect human lives and livelihoods, such as water, agriculture, health, and transport, have been formulated. These adaptation measures are further classified into engineering or non-engineering based. In the water sector, adaptations approached from an engineering perspective involve maintaining variations in temperature and precipitation and preventing contamination. Non-engineering based approaches to tackle concerns in the water sector include using the ecosystem and preserving floodplains as measures for adaptation. In the agriculture sector, engineering and non-engineering based approaches involve constructing storage structures and irrigation facilities, in addition to crop insurance and training for farmers respectively. Engineering and non-engineering approaches in the health sector encompass building hazard resilient infrastructure and incorporating better monitoring systems and training for the employees. To develop the country's transport system, both non-engineering and engineering approaches involve improving the roads so as to allow for the drainage of flood water and improve evacuation when it is necessary.

Table 5.39: Potential engineering and non-engineering adaptation options for different sectors

Sector	Engineering	Non-Engineering
Water	Modified codes and standards for tackling future changes in temperature and precipitation Flood protection infrastructures to prevent contamination of water supply	Reduce volume of storm water with ecosystem measures Preserve floodplains Disaster preparedness to tackle disruptions to water supply and sanitation services
Agriculture	Flood control structures and water storages Expansion of irrigation facilities Seed and agriculture input storages at high grounds	Crop insurance and other insurance schemes to protect and restore assets and productivity after a disaster or extreme climate event Improve access to timely weather forecasts and response options Training of farmers and extension workers on extreme climate induced crop diseases and their management
Health	Construction of healthcare infrastructure Adjust infrastructure design standards for healthcare facilities to tackle increased future hazards	Incorporation of early warning systems for disease surveillance and response systems Training of manpower to tackle increased health hazards and onset of new diseases
Transport	Redesign or relocate road facilities Increase drainage for road facilities against projected increases in rainfall and erosion Increase access to hospitals and evacuation centers and distribution of relief where road infrastructure may be damaged during extreme events	Advanced warning and communication system for evacuation of affected people and transportation of goods

Source: modified from ADPC (2013).

Table 5.40: Potential adaptation options for different sectors

Sectors	Potential Adaptation Action
Agriculture	Development, dissemination and extension of flood, drought, salinity and disease tolerant crop varieties should be ensured on a priority basis Adjusted cropping variety and pattern Early warning system should be developed and strengthened Information based on agro-metrology and agro-climatic data and forecast of planting and harvesting time with possible yield of crops Enhance irrigation and water use efficiency by introducing crops requiring less water and technologies that ensure efficient use of irrigation water in the cultivation practices Coordinated efforts are very much needed to address and take adapting measures for probable climate change effects Replication of adaptation options (validated) of LACC-I and LACC-II/from other on-going projects in vulnerable areas of Bangladesh through DAE Develop AEZ based suitable cropping pattern Providing agriculture risk insurance Share information on management of climate change and related science, data, tools and methodologies in South Asia Restoration of wetland and increasing water storage capacity and connectivity of river systems Regional co-operation on climate change adaptation primarily in water and agriculture sector Construction/reconstruction of strong water infrastructure Strengthening and capacity building of DAE personnel and other stakeholders on climate change issues and management.
Water	Revisiting and appropriate strengthening of embankment systems along the coastal zones based on future vulnerability Implementation of proper tidal river management in the long-run to avoid water logging Excavation (removal of siltation) of river systems to allow greater passage for drainage during peak flood periods Maintenance and construction of cyclone shelters as well as more climate proof housing Strengthening local disaster committees and using indigenous knowledge and practices to solve water related problems Strengthening local disaster committees - local efforts to be given due support, both knowledge-wise and financially, so that local water related problems may be solved locally Promotion of research on water related hazards Promotion of early warning and preparedness for all hazards (flood, cyclone, river erosion, drought)
Fisheries	Protection and improvement of floodplain capture fisheries habitat through excavation of silt from beel, river and canal beds, sanctuary establishment, and connectivity improvement Enhancement of culture fisheries by retaining water for longer periods through pond deepening, removal of sludge, pond dyke tree plantation and floating macrophytes, pumping facilities and harvesting of run-off water Additional raising of dyke height to reduce pond overtopping during floods Screening for and development of shallow water and temperature tolerant fish species Screening for, and development and culture of salt tolerant species in the coastal area Encourage paddy cum fish polyculture Encourage alternative livelihoods during fish breeding

Sectors	Potential Adaptation Action
Forestry	Develop a national strategy for integrated ecosystem-based water resources management to protect aquatic plants and animals Develop adequate technical, institutional resources and mobilize financial resources to adapt to climate change impacts on ecosystem and forest sector Maintain and manage protected areas and ecologically critical zones to conserve threatened species Create buffer zones or migration corridors for ecosystems. Protective corridors can allow the migration of plants and animals following pole-ward shifts in habitat distributions due to changes in temperature and precipitation. Mitigate drainage congestion in the coastal areas through increasing infrastructure drainage capacity Protect areas (providing shelter to already threatened populations of plants and animals) that would be particularly threatened by the effects of climate change Augment swamp forests in the wetland (haor, beel) to conserve aquatic animals. Implement afforestation and reforestation programmes and increase area coverage to reduce dependency on primary forests. Enhance afforestation programmes in the reserve forest areas Promote natural regeneration in degraded forest lands and develop the social forestry sector by selecting appropriate species and by selecting proper placement from a safe environment perspective Afforestation including expansion of coastal greenbelt to protect the mangroves and coastal wetlands Conservation of threatened species Protect corridors to allow the migration of plants and animals following pole-ward shifts in habitat distributions due to changes in temperature and precipitation Conserve and protect the habitat of plants and animals
Livestock	Use feeding and water drinking management practices to minimise the effects of heat stress Improvement of housing facilities such as shade, cooling and ventilation to reduce the impact of heat stress on livestock Raising platform/plinth level of housing/*killa* for livestock in coastal and flood prone areas Initiation of training for capacity development to veterinary services and awareness raising of farmers of enhanced climatic disasters
Infrastructure	Redesigning and improvement of roads, rail lines, embankments, and other infrastructures to keep them functional during floods Increase number of openings (bridge, culvert) to improve drainage congestion Maintenance and improvement of existing shelters and construction of additional shelters Climate smart and cheap housing design research and implementation Dredging of navigation routes and canals
Health	Enhancing the capacity of existing health infrastructures and construction of new ones Increase manpower to ensure health services during climate change adversity Strengthening capacity of health professionals including doctors and nurses to deal with future climate change related adversity Raising awareness to reduce diseases related with floods, cyclones, heat wave, cold spells etc Raising levels of hand tube wells and sanitary latrines to reduce the threat of water contamination Research on vectors, parasites and virus mutation and adaptation to changing climate for future health support system strategies

Sectors	Potential Adaptation Action
Urban Areas	Properly implement existing policies and plans for development of built-up areas and redesign urban planning keeping climate change impacts in mind with attention to elevations, drainage congestion etc. in parts of the city
	Mainstreaming adaptation to climate change into urban development policies and programmes (disaster management, water, health and industry)
	Ensure that the city authority properly monitors, guides and controls the city's development activities as per the existing planning guidelines
	Revision and implementation of building codes with due consideration to climate change
	Urban greening programme including roof top gardening
	Preservation, maintenance and improvement of drainage areas
	Improvement of water use efficiency and designing alternative water sources like rainwater harvesting
	Ensure adequate financial and human public health resources, including training, surveillance and emergency response as well as prevention and control programmes
	Initiate awareness building programmes at community level to disseminate knowledge and information on climate change and its impacts
	Strengthening capacity building of concerned ministries and agencies through training programmes, seminars and workshops.

Source: extracted from SNC, 2012; DAE, 2015; BCAS, 2013

5.11 Loss and damage

Introduction

Major sectors, such as water, agriculture, health, infrastructure, fisheries and forestry, all of which contribute to global livelihood, suffer the devastating effects of climate change; in 2011 the IPCC estimated a global increase to $200 billion in annual economic loss due to climatic disasters in 2010 from a few billion dollars in 1980. Due to poor resilience to climatic disasters, the least developed countries will be more prone to damage and suffer greater losses than nations with middle or higher incomes. Before COP 15, loss and damage were merely informal discussion topics. In Cancun, Mexico at COP 16, UNFCCC made loss and damage an official discussion. This led to the Cancun Agreement of the Sixteenth Conference of Parties being the first official document of UNFCCC that recognized the importance of loss and damage and other relevant adverse impacts of extreme weather impacts and slow onset impacts.

The coastal zone of Bangladesh is particularly vulnerable to loss and damage from climate induced disasters. Bangladesh and neighbouring Myanmar suffered huge damages at the time of Cyclone Sidr in 2007, of Cyclones Nargis and Reshmi the following year 2008, and of Cyclone Aila in 2009. The government of Bangladesh put the damages from Cyclone Sidr at $1.6 billion (DMB 2010). More than 3,000 lives were lost, and crops from approximately 0.7 million hectares damaged (Rabbani et al., 2010; DMB, 2010). In Khulna, more than 0.1 million tons of rice crops were damaged (BBS, 2009). Other climate change-induced disasters, such as riverine floods, flash floods, drought, river bank erosion, and water logging, have caused major losses in most of the employment sectors, adversely affecting people's livelihoood and sources of income.

Evidence of loss and damage in Bangladesh

Loss and damage has been identified as a crucial concern for both communities as well as policy-makers. Communities are victims of the limitations in the community level adaptations. As part of the loss and damage in vulnerable countries initiative supported by CDKN, research was conducted to investigate how climate change impact leads to loss and damage among vulnerable households. This research was conducted in five countries (Bang¬ladesh, Bhutan, Gambia, Kenya and Micronesia) across three major regions.

In coastal Bangladesh, regardless of the increasing salinity levels, farmers are able to continue producing rice thanks to saline tolerant varieties of rice crops. However, Cyclone Aila, that struck Bangladesh in May 2009, left the salinity content of the soils in the areas of research at such high levels that even the selectively bred saline tolerant varieties could not adapt to their soil environment. The cyclone not only resulted in an immediate loss of harvest, it also reduced the rice harvest in the following years due to the higher salinity concentration in the soil. It was estimated that between 2009 and 2011, Aila totalled a loss of $1.9 million in the four villages surveyed. Table 5.41 shows the loss of various agricultural products in millions of dollars between 2009 and 2014, with the most damage being almost $660 million worth of rice paddies and total damage in agricultural products worth more than a billion dollars.

Table 5.41: Loss and damages of households in agriculture sector due to disasters 2009-2014

Agriculture Products	Million (USD)
Paddy	659.64
Potato	9.22
Wheat	8.94
Jute	51.06
Pulse	28.38
Fruits	34.92
Other crops	63.01
Livestock	112.46
Poultry and Birds	28.53
Fishery	137.36
Total Loss and Damage in agriculture	1133.52

Source: BBS, 2016

Table 5.42 shows the percentage of flooded areas in Bangladesh, millions of hectares of crops damaged, millions of tons of rice harvest losses, the number of livestock lost and finally the total value of losses in billions of dollars in four different years. Table 5.43 details the loss and damages due to cyclonic events in Bangladesh between 1985 and 2007.

Table 5.42: Loss and damage in agriculture sector due to flood in different years

Item	1988	1998	2004	2007
Inundated area of Bangladesh (percent)	60	68	38	42
Crops fully/partly damaged (million ha)	2.12	1.7	1.3	2.1
Rice production losses (million tons)	1.65	2.06	1	1.2
Livestock killed (nos.)	172,000	26,564	8,318	40,700
Total losses (in USD billions)	1.4	2	2.3	1.1

Table 5.43: Loss and damages in infrastructure sectors due to cyclones and storms surge 1985-2007

Date of occurrence	Nature of phenomenon	Landfall Area	Loss/ Damage
1985	Severe cyclonic storm	Chittagong	90, 915 houses destroyed 34, 611 houses damaged 40 miles of damaged roads 53 miles of embankment destroyed 189 miles of embankment damaged

Date of occurrence	Nature of phenomenon	Landfall Area	Loss/ Damage
1991	Severe cyclonic storm with a core of hurricane wind	Chittagong	819,608 houses destroyed 882,705 houses damaged
1994	Severe cyclonic storm with a core of hurricane wind	Cox's Bazar-Teknaf Coast	45,000 destroyed houses 62,677 houses damaged 126 miles of damaged barrages 350 kms of roads and highways damaged 725 educational and religious institutions damaged 150 bridges damaged
1997	Severe cyclonic storm with a core of hurricane wind	Sitakundu	112,160 houses damaged fully 99,557 houses damaged partly 53 kms roads damaged fully 162 kms roads damaged partly 6 kms embankments damaged 165 bridge and culverts damaged 1,480 educational and religious institutions damaged 718 cyclone shelters damaged
1997	Severe cyclonic storm with a core of hurricane wind	Sitakundu	51,435 houses destroyed 163,352 houses damaged 218 kms of roads destroyed 2,379 kms of roads damaged 280 kms of embankments damaged 85 bridges and culverts damaged 475 educational and religious institutions damaged
1998	Severe cyclonic storm with a core of hurricane wind	Chittagong Coast near Sita Kundu	10,000 houses damaged 12 police camps destroyed 3 police camps damaged
2007	Cyclone Sidr	Khulna- Barisal Coast near Baleshwar River	564,967 houses destroyed 957,110 houses damaged 1,714kms roads destroyed 6,361 kms roads damaged 1,875 kms embankments damaged 1,687 bridges and culverts damaged 4,231 educational and religious institutions destroyed 12,723 educational and religious institutions damaged

Source: BBS Statistical Yearbook, 2012 and 2014

5.12 Adaptation Cost for Key Economic Sectors

Introduction

Climate change is identified as a destabilizing factor to natural and socioeconomic systems. It is viewed as an externality to production and consumption of goods and services. All economic sectors are affected but those dependent on nature are most at risk. Scientific studies present clear evidence that climatic events are set to occur with higher intensity and frequency if the current pace of climate change cannot be avoided. As a result, climate change induced impacts and vulnerabilities will be exacerbated and the cost in terms of losses of lives and livelihoods and damages to properties will be high. The extent of such losses and damages to any system will depend on the geophysical context, exposure, sensitivity and adaptive capacity. It is possible to reduce climate change related losses and damages through undertaking appropriate adaptation measures and building adaptive capacity.

Studies dealing with the cost of climate change generally provide estimates that are highly aggregated on a global scale or regional basis. Few studies provide projections on cost at national, sub-national and sectoral level. Future climate change scenarios are developed based on different models over a period of the next 50 or 100 years and the consequent impacts and vulnerabilities are assessed through discussions. As uncertainty is inherent in the future projection of climate scenarios, the impacts and vulnerabilities and the associated losses and damages due to climate change induced impacts are also subject to uncertainty. In order to address such uncertainty, climate change projections often include a range with a lower limit, an upper limit and an average figure. The World Bank carried out a noteworthy study dealing with the cost of climate change and cost of adaptation for Bangladesh (Economics of Adaptation to Climate Change, 2010). The study took BCCSAP (2009) as its starting point. Within its scope, the study attempted to: a) examine the potential physical impacts of climate change; b) assess the associated loss and damages in key economic sectors and in the overall economy; c) estimate specially desegregated costs of adaptation options that can reduce these impacts; and d) sequence the adaptation action over time. The study provides estimated damages and loss for a baseline scenario and one which accounts for climate change.

Cost of Climate Change (Loss and Damage):

5.12.1 Tropical Cyclone and Storm Surges

The World Bank Study (EACC, 2010) estimates that under the baseline scenario, the damages and losses stand at $4.6 billion from single cyclone/storm surges for a ten year return period. With climate change, the damages and losses would increase to $9.16 billion including $4.5 billion that are attributable to climate change.

Table 5.44: Additional Damages and Losses Due to Climate Change in 2050 (million USD)

Sector	Damages & Losses	Share of Damages & Losses
Housing	1947	43
Industry/Commerce/Tourism	1172	26
Agriculture	910	20
Transport	293	6
Power	210	5
Coastal Protection	17	0
Education Incrustation	10	0
Other	n/a	n/a
Total	**4560**	**100**

Source: EACC, World Bank 2010

The housing sector would suffer the worst damages/losses due to cyclonic storms, accounting for 43% of the total damages and losses. Industry commerce/tourism comes next with 26% followed by the agriculture sector with 20% of the damages and losses due to climate change induced storm surges. Damage and losses due to tropical cyclones and storm surges that accounted for 0.3% of the GDP under the baseline scenario would rise to 0.06% of GDP in 2050.

5.12.2 Inland Flooding:

Bangladesh historically incurs substantial damages and losses due to devastating inland flooding. However, relatively speaking, damages and losses have decreased over the years as a result of improved macroeconomic management, increased resilience of the poor, progress in disaster management and flood protection infrastructure. The 1974 flood, a 1-in-99-year event, resulted in damages equivalent to 7.5% of the GDP. The 1998 flood, a 1-in-99-year event caused damages which amounted to 4.5% of the GDP. In absolute terms, the damages of major floods were $0.9 billion in 1974, $1.4 billion in 1988, $2.2 billion in 1998, $1.8 billion in 2004 and $1.1 billion in 2007.

Economy Wide Damages and Losses:

The ADB study (2014) conducted an economy wide impact assessment based on the integrated assessment models for the South-Asia region. The results of the assessment show that the average temperature is projected to rise by 2°C by 2050. By 2100, the average temperature is expected to rise around 4°C under the business as usual scenario. The rise in temperature will cause significant damage and losses to the economy. Bangladesh would face annual GDP losses of around 2% by 2050. However, there is a 10% chance that the losses will be over 4%.

In the longer term, if no action is taken to adapt to or to mitigate global climate change, the average total economic losses are projected to be 9.4% by 2100. The projected average losses do not include impacts of extreme events such as cyclone/storms, floods and droughts.

The GDP losses would be lower at around 1.5% by 2050 and roughly 2.5% by 2100 if GHG emission and consequent temperature rise are kept below 2°C.

5.12.2.1 Agriculture:

The EACCA study by the World Bank provides estimate of damages and losses in agriculture especially in rice and wheat production due to climate change. The study estimates the change in production of three seasonal rice varieties –*aus, aman and boro* - as well as wheat, due to climate change (CO_2, temperature and precipitation only are considered) the production of *aus* and *aman* would increase by 2% and 4% by 2030 and 2050 respectively. Wheat production would also increase by 4% by 2050. *Boro* production, however, would decline annually 8% by 2080.

Production changes due to flood damages as estimated by the study show that *aus* and *aman* would fall by 2.4% and 4% respectively by 2050. *Boro* and wheat are assumed to be unaffected by flood. However, *boro* can be affected by flash floods in areas like haor.

Considering all climate change impacts (CO_2 fertilization, temperature and precipitation changes, flood changes, sea level rise), the median of all rice crop shows a declining production. *Boro* will undergo the worst decline with median loss of 3% in 2030 and 5% in 2050 (ECCA, 2010). The losses in *aus* and *aman* production would range between 0.6% to 1.5%.

Among the different sub regions, the south-east (Khulna) region will experience the highest losses with up to 10% for *aus, aman* and wheat and up to 18% for *boro*.

The study estimates that cumulative production will be reduced by 80 million tons between 2005 and 2050 as climate change exacerbates the negative impacts of existing climate variability.

It is further projected that agricultural GDP would be 3.1 percent lower each year as a result of climate change. This will cost Bangladesh $129 billion in total GDP, equivalent to $2.9 billion overall loss each year. The annual loss increases to $5.1 billion under the worst climate scenario.

A 2014 ADB study on costs of climate change and adaptation in South-Asia shows that climate change would lead to a substantial reduction in the yield of rice in Bangladesh. Among the different climatic regions, maximum yield reduction will occur in the south-eastern and south-western regions of Bangladesh. Rice yield would decline by 5.3% for *aus,* 4.9% for *aman* and 4.6% for *boro* in the south-eastern regions by 2030. Further deterioration of rice yield would occur beyond 2030. Rice yield in the south-eastern region will decline by 10.3% for aus, 9.5% for *aman* and 5.5% for *boro* by 2050. The decline in rice yield in the south-western region is projected at 6.2% for *aus* 5.6% for *aman* and 4.9% for *boro* by 2050.

5.12.2.2 Water Sector

The ADB study shows that water availability under median climate change scenario (A1B), would fall initially up to 2030 but after 2030 the situation would start improving and a significant improvement in water availability would take place by 2050. However, under the high emission scenario (A2), the availability of water would fall by a small margin by 2030 but by a large margin by 2050.

With regard to the impact of water quantity stock on real GDP in Bangladesh, the ADB study found that under the A1B scenario GDP would decline by 0.78% by 2030. By 2050 the situation would improve from a 0.30% loss to an increase of 0.72% in 2080 compared to the baseline year 2009. This is due to a significant improvement in water availability in the 2050s. Under the A2 scenario, due to the small impact on sectoral production to 2030, real GDP would fall by a small margin at first but by a large margin in 2050 and 2080, the study predicted. Under the B1 scenario, the negative impacts of water quantity stock on GDP would be larger than those under the A2 scenario.

5.12.2.3 Energy Sector

Energy use in Bangladesh has been growing rapidly over the decades to keep pace with economic growth. This trend is likely to continue in the foreseeable future as the country aims for a high rate of GDP growth. Aside from common determinants such as population and economic development, climate change will increase the demand for energy. Rise in temperature will increase energy requirements for irrigation in agriculture and for energy. However, energy demand for warming will be reduced. Increases in high intensity extreme events such as storms and cyclone may cause damages to or losses of electrical system.

The ADB study shows that under all three scenarios A2, A1B, B1, there will be excess demand for electricity. Given the existing supply constant, the supply-demand imbalance would be widened, affecting both production and household welfare. The consumer price index (CPI) would increase by 0.43% to 0.96% by 2050 due to the impact of electricity supply shock attributable to climate change, as per the projection made by the study.

The study also shows that, on average, there will be an energy demand-supply gap of 2.94% in 2030, which will rise to 4.56% in 2050.

5.12.2.4 Infrastructure

The ADB study highlights that climate change and the resultant floods and cyclones will have a significant impact on the infrastructure of Bangladesh. Due to the impact of climate change, the capital stock in the construction sector would be depleted by 0.05% annually until 2100 and the magnitude of these negative impacts would intensify beyond the end of the century. The study points out that a negative stock on infrastructure as a result of climate change will have serious adverse effects on the overall economy of Bangladesh. Different economic sectors linked to infrastructure services would experience large falls in production. Actual GDP would continue to fall by 0.62% by 2030 and 1.07% by 2100. The poor status of infrastructure is a serious constraint to the country's development efforts; improving the country's infrastructure system will be essential for achieving high economic growth.

5.12.3 Cost of Adaptation

As has been mentioned earlier there are relatively few studies dealing with the cost of adaptation, especially for developing countries like Bangladesh.

An estimation of the global cost of adaptation has been attempted by different agencies and they have arrived at quite diverse figures because of variations in methodology and the extent of coverage of the adaptation options (Table 5.45). The World Bank (2006) estimated the global adaptation cost at $9-41 billion per annum for 2030 but arrived at a much higher figure ($70-100 billion) for the year 2050 (World Bank 2010). The higher estimation of adaptation cost in 2010 is attributable to a larger coverage of adaptation options involving different sectors of the economy. UNDP (2007) estimated the global adaptation cost at $86-109 billion for 2015 and OXFAM presented a figure for current adaptation cost at more than $50 billion.

Table 5.45: Estimates of global costs of adaptation

Study	Results ($ billions per year)	Time frame	Sectors	Methodology and Comments
World Bank (2006)	9-41	Present	Unspecified	Cost of climate proofing foreign direct investments, gross domestic investments and Official Development Assistance
Stern (2007)	4-37	Present	Unspecified	Update of World Bank (2006)
Oxfam (2007)	>50	Present	Unspecified	World Bank (2006) plus extrapolation of cost estimates from national adaptation plans and NGO projects
UNDP (2007)	86-109	2015	Unspecified	World Bank (2006) plus costing of targets for adapting poverty reduction programmes and strengthening disaster response system
UNFCCC (2007)	28-67	2030	Agriculture, forestry and fisheries; water supply; human health; coastal zones; infrastructure	Planned investment and financial flows required for the international community
World Bank (2010a)	70-100	2050	Agriculture, forestry and fisheries; water supply; human health; coastal zones; infrastructure; extreme events	Improvement on UNFCCC (2007): more precise unit cost, inclusion of cost of maintenance and port upgrading, risks from sea level rise and storm surges

Source: Modified from Agrawala and Fankhauser (2008) and Perry et al. (2009) to include estimates from World Bank (2010a)

5.12.3.1 Adaptation Cost for Tropical Cyclone and Storm Surges

For Bangladesh, the EACC study estimates a total adaptation investment cost of $4.88 billion of which $2.4 billion is attributable to climate change (Table 5.46). In addition to the cost of investment, an annual recurrent cost of $50 million would be needed by 2050.

Table 5.46: Cost of Adaptation for Tropical Cyclone and Storm Surges by 2050 ($ million) for Bangladesh

	Climate Change Scenario		Additional Cost due CC	
	Investment Cost	Annual Recurrent Cost	Investment Cost	Annual Recurrent Cost
Polders	3354	18	893	18
Foreshore afforestation	75		75	
Cyclone shelters	1219	24	1219	24
Cyclone Resistant Housing	200		200	
Early Warning and Evaluation Systems	39	8+	39	8+
Total	4888	50+	2426	50+

Source: EACC study, World Bank (2010)

5.12.3.2 Adaptation Cost for Inland Flooding

The EACC study does not provide any estimate of the cost of protecting against the existing risks of severe inland monsoon flooding. However, the study provides estimates of the incremental cost of climate proofing of key infrastructures: a) road and rail network; b) river embankments and embankments to protect highly productive agricultural lands; c) drainage systems; and d) erosion control measures for high value assets such as towns.

The incremental cost of climate proofing is estimated at $2.7 billion in investment costs and $54 million in annual recurrent costs by 2050. The study mentions that addressing the existing flood risk would require the same or a larger investment.

Table 5.47: Total Adaptation Cost for Inland Flooding ($ million)

Description of Cost Component	Investment	Annual Recruitment cost
Roads - highway enhancement	2122	42
Roads -cross-drainage	5	-
Railway benefit enhancement	27	1
Embankment benefit enhancement	96	2
Coastal polders – cross drainage	421	8
Erosion control programme		1
Total	2671	**54**

Source: EACC, World Bank, 2020

5.12.4 Economy wide Adaptation Cost

The ADB study (2014) provides estimates of adaptation costs associated with different climate change scenarios for South Asia (Table 5.48) but not for individual countries.

The average annual cost of adaptation for the South Asia region ranges from $40.2 billion to $110.9 billion corresponding to the low and high envisioned scenarios. The low and high estimates account for 0.48% and 1.32% of the region's GDP. The estimates are highly aggregated as adaptation costs for different sectors have not been worked out separately.

Table 5.48: Annual Average Adaptation Cost for South Asia during 2010-2050 ($ billion)

Scenario	Average Annual Cost	% GDP
High emission scenario	110.9	1.32
Low emission scenario	40.2	0.48

Source: ADB (2014)

Taking into consideration climate uncertainties, annual adaptation costs rise to $198 billion under the high emission scenario and to $71.5 billion under the low emission scenario.

5.12.4.1 Adaptation Cost for Agriculture

Although the EACC study provides estimates of current damages and losses in the agriculture sector due to climate variability and change, no projection on adaptation cost is given specifically for the agriculture sector.

The BCAS-IIED, (2011) study attempted to project the adaptation cost involving the agricultural sector government agencies for three coastal districts of south-east Bangladesh. The study provides a projection on the adaptation investment that will be needed for research, extension and storage and marketing facilities in 2030 considering the trends of climatic hazards such as salinity intrusion, sea level rise etc. It is projected that for extension services, the Department of Agricultural Extension (DAE) would require an annual budget of $2.5 million in 2030 against a current budget of $0.8 million. The Bangladesh Rice Research Institute (BRRI) would need $13.4 million in 2030 for the development of new varieties and laboratory facilities that can adapt to salinity and other climate change effects. The estimated current cost for such activities is $6.7 million. In other words, BRRI needs to double its annual budget to adapt to the climate change impact in coastal districts.

The Bangladesh Agricultural Development Corporation (BADC) would require an estimated budget equivalent to $19.90 million in 2030 for correction and re-excavation of canals for storing sweet water and drainage, installation of power pumps and monitoring of management of ground water.

The Directorate of Agricultural Marketing (BAM) would require a budget of $2.2 million for constructing green storage, $2.6 million for marketing facilities including cool vans and $0.8 million for the development of an assembly centre in the three coastal districts of south-west Bangladesh.

5.12.4.2 Adaptation Cost for Energy

The adaptation cost for the energy sector is projected at $89.3 million in the 2030s which will increase to $363 million by 2050 (ADB 2014).

5.12.4.3 Adaptation cost for Health

Adaptation of health to climate variability and change depends, inter alia, on access to health services as well as basic infrastructure facilities. Basic infrastructural development can be an important means to reduce the health burden attributable to climate change impacts. There is a general dearth of information and statistics concerning the cost of adaptation to climate change impacts in the health sector of Bangladesh. The World Bank study has attempted to provide estimates of adaptation costs in the health sector under the given constraints and limitations of the relevant data.

The study emphasizes that many childhood illnesses and premature deaths could be averted through investing in basic infrastructure (safe drinking water sources, sanitation and electricity) female education and children's nutrition. The study provides projections of the health burden for the year 2050 due to a temperature rise of 2 C and increase in frequency of excessive rainfall (from 30 to 40%). The projection, however, is made for only three childhood diseases viz. ARI, fever and diarrhea. According to this projection, the incidence of ARI and fever will increase but the incidence of diarrhea will remain the same; from these three childhood diseases the health burden is projected to be about 14 million disability-adjusted life years (DALY) accounting for 3.4% of GDP by 2050. This projected figure is an underestimation of the health burden as it is limited to three diseases and children only and does not take into account either other diseases or the adult population.

The World Bank study provides estimated cost data of different adaptation measures such as water supply and sanitation and child nutrition programmes. The estimates show that the effective nutrition services covering the country would require in the range of $130-170 million per year. It is also estimated that the country has invested in the range of $120-200 million per year over the past four decades for disaster risk mitigation and achieved good results in reducing the number of deaths due to disasters.

Cost estimates for achieving 100% access to safe water and sanitation is in the range of $300-500 million per year.

The following table shows the required investment cost for three different interventions.

Policy options	Annual cost million US$
100% accruement of safe water and sanitation	300 – 500
Elimination of stunting through nutrition programmes	130 – 170
Early warning and risk management	120 – 200

Source: World Bank, 2014

Based on a cost effectiveness analysis (CEA) i.e. in terms of the number of deaths averted per $1 million investment, the study demonstrates that investment in child nutrition programmes to eliminate stunting is the most effective of the three adaptation policy interventions.

In another initiative, the health professionals and officials of the Directorate General of Health Services (DGHS), under the Ministry of Health and Family Welfare identified the potential impacts of climate change on health and estimated the investment cost that would be needed to address the impacts for a 15 year period (2016–2030).

According to their estimates, DGHS would require $4.01 billion for the 15-year period, equivalent to $272.1 million per annum. The diseases and challenges identified by the health professionals include diarrhea, kala azar, filariasis, dengue/malaria, chikungunya, chronic obstructive pulmonary diseases, other NCDs, injuries/drowning, malnutrition, emerging and remerging diseases and health care infrastructure.

The share of health care infrastructure is around 30% of the total cost as estimated by DGHS sources.

The costs estimated by DGHS for adaptation to climate attributable diseases are as follows:

Disease	USD (million)
Diarrhea (3.5 episode person/yr@BDT 50 per episode)	142.94
Kala azar	161.76
Filariasis	51.47
Dengue, Malaria, Chikungunya etc.	308.82
Chronic Obstructive Pulmonary Diseases and other NCDs	617.65
Injuries, Drowning etc.	602.94
Malnutrition	735.29
Miscellaneous (emerging and re-emerging diseases, emergency preparedness)	220.59
Infrastructure	
Building and maintenance of health care infrastructure in coastal vulnerable areas (population of 36 million at risk)	1,240.50
Total	4,081.96 (m) $\simeq$ 4.1 billion

Source: DGHS, Ministry of Health & Family Welfare, Bangladesh.

5.13 Conclusion

Bangladesh is one of the most climate vulnerable countries in the world and will remain so in the future under the climate change regime. Presently, recurring extreme weather events are a threat to sustainable development and to the economic growth of the country. In the future, the frequency, magnitude and extent of extreme weather events could increase in Bangladesh and that could put life and livelihoods of rural and vulnerable urban population at further risk. Although in the past decades, Bangladesh has substantially increased its capacity to tackle these hazards and disasters, future climate change could erode the gains of the past.

Overall, Bangladesh experienced increases in mean temperature during the period 1961-2014. A few meteorological stations have experienced decreases in temperature. Country-wide, rainfall has also increased but a few stations demonstrated a decrease in rainfall.

Water is the lifeline of the 158 million people of Bangladesh and will continue to remain so in the future. Water is essential for agriculture, industry, river transportation, and for urban and rural water supplies and acts as an important determinant of economic growth. However, too much water in the form of floods and storm surges has a significant impact on agriculture and infrastructure In the future, Bangladesh will experience water shortages in the dry season and extreme floods in the monsoon. Both shortages and excessive water would affect the economy of the country significantly. Snow and glacier melt in the Himalayas and transboundary water sharing issues could complicate the situation further.

Despite a gradual reduction in its contribution to GDP, agriculture still plays a vital role in providing employment, livelihood and food security. This sector is particularly sensitive to climatic extremes and extreme weather events. The slow onset of drought causes significant damage to agriculture especially in the north-western part of the country. Flash floods in early monsoon damage standing crops in the north-east. Extreme riverine floods and storm surges also damage crops significantly over the large flood plains of the Ganges, Brahmaputra and Meghna rivers.

Damages to crops have a direct effect on the food security and poverty levels of the rural and urban poor. However, extreme weather events have a lesser effect on forestry, livestock and fishery components of the agriculture sector in general with an exception of marginal farming communities. A cyclonic storm together with high surges could significantly impact the livelihoods of poor people living in the vicinity of the Sundarbans mangrove forests.

Changes in temperature, variations in rainfall, heat waves, floods, and droughts will directly affect human health. In addition, people's health may be indirectly affected because of climate change impacts on crop production which will reduce calorie intake. Climate change could affect the health sector in Bangladesh in three ways. First, increased climate variability and extremes would affect a large section of the population. Second, rapid urbanization and a growing urban slum population are quickly changing the population dynamics in Bangladesh. Water supply and sanitation conditions are very poor in slums and this puts their inhabitants at various levels of health risks. Climate change will adversely affect living conditions in the slums and exacerbate health risks. Third, public resources for the health sector are presently unevenly distributed, negatively affecting public health services for the poor and disadvantaged section of the population.

The urban centres in Bangladesh are more vulnerable because they were developed without taking climate change into consideration and lack climate resilient infrastructure. By 2050, about 50% of Bangladesh's projected population will live in urban centres. Urban centres are already under serious pressures from overpopulation, aging infrastructure, flooding, the urban heat island effect, poor waste management, health risks, and water and air pollution. Climate change will modify the urban micro-climate potentiality and affect the health of city dwellers in multiple ways.

Most of the Bangladesh's industries are located in the flood plains and on the coast. Floods and storm surges often inundate industries causing damage to industrial infrastructure. Further loss occurs from lost production time. Fertilizer, textile, dying, bleaching and finishing, chemical products, pharmaceutical, cement and power plants in various industrial locations of the country will be at low to medium risk from future climate change. New industrial areas should take into account the highest historical flood levels in their design and provisions for the drainage of storm water in the case of heavy precipitation need to be made.

The livelihoods of rural populations are by and large natural resource based. Extreme weather events impact these resources and therefore affect the financial well-being and livelihoods of people who are dependent on agriculture, water, fisheries, industries, livestock and poultry.

Extreme weather events cause disasters. As Bangladesh is highly vulnerable to extreme weather events, the country has designed a number of disaster mitigation tools and methods. Conventional disaster preparedness approaches (for example, relief and rehabilitation) are becoming ineffective in the context of rapid climate change and its forceful impacts and efforts have been made to find linkages between climate change adaptation (CCA) and disaster risk reduction (DRR). However, there is further need for integration of the two approaches at the local/community level, at a regional level among climate affected zones and at the national level in policy, strategies and programmes.

Adaptation and improving climate resilience are important to reduce damage from climatic hazards. Therefore, a multifaceted approach is required to address climate impacts: investment in early warning systems; improved irrigation and water management; improved operation and maintenance and upgrading of coastal embankments and polders; and upgrading of flood protection embankments and drainage systems. Adaptation cost estimates for all key economic sectors have not been made for Bangladesh. In 2010, the World Bank estimated that by 2050, adaptation costs for tropical cyclones and storm surges will be $5,516 million and the annual recurrent cost will be $112 million, while for inland monsoon flooding the cost will be $2,671 million and the annual recurrent cost will be $54 million. Adaptation costs for climate related diseases (diarrhea, kala azar, filariasis, dengue/malaria chikungunya and chronic obstructive pulmonary diseases) would be $4.01 billion for the 15 year period (1915-2030) which is equivalent to $272.1 million per annum. The implementation of identified adaptation measures is critical to increase the resilience of the country to climate change and Bangladesh has already implemented some key adaptation activities as urgent and immediate needs of the country. It has been estimated that Bangladesh will need to invest $44 billion from 2015 to 2030 in order to implement identified adaptation measures to address the adverse impacts of climate change for tropical cyclones, monsoon flooding and climate related diseases.

Chapter 6

Other information considered relevant towards achieving the objective of the UNFCCC and Constraints and Gaps: Related Financial, Technical and Capacity Needs

6.1 Introduction

This chapter will provide information on past and ongoing initiatives to integrate climate change in the national planning process, information on the status of activities related to technology transfer, an overview of climate change research and systematic observation, information on research programmes related to impact and adaptation, initiatives on climate change education, training and public awareness, and the current status of information and networking.

6.1.2 Objectives

The main objective of this chapter is to provide support in strengthening the areas of research, capacity building, technology and integration of climate change into the national development planning process. It will help in the long run to make development more climate resilient and avoid maladaptive actions being taken. The specific objectives of this chapter are to:

- Identify to what extent the national policies and national development planning process address climate change issues;
- Identify the constraints and gaps, needs for technology transfer/adoption, and provide an assessment of technical, capacity and financial needs to be covered for institutionalizing the periodic preparation of national communication in future; and
- Assess the need for public awareness, capacity building, research, information sharing and education programmes on climate change issues.

6.1.3 Steps taken to integrate climate change

In this section the following questions have been discussed and answered as far as possible:

- How is climate change being considered in the relevant development planning processes of Bangladesh?
- What are the national priority issues and how is climate change linked to these issues?
- Is there any progress in implementing the development plans addressing climate change issues explicitly?
- What are the national policies enacted on climate change?

6.2 Mainstreaming Climate Change in the National Development Planning Process

Given the cross-cutting nature of climate change impacts, it is necessary that adaptation policies or strategies are formulated as part of broader policies for development rather than as a separate hub. Therefore, the mainstreaming of climate change issues in the national development planning processes is a crucial tool to ensure climate change adaptation and to ensure that other development goals are implemented simultaneously (UNDP, 2011).

6.2.1 Perspective plan: Making Vision 2021 a reality

The Government of Bangladesh has developed this plan as a gateway to achieve a prosperous Bangladesh in 2021 within the principles of sustainable development. Understandably, the sustainable development of the country may be affected by climate change and environmental degradation. Land degradation, water pollution and arsenic in water, floods and cyclones, as well as rising levels of sea water can easily threaten the sustainability of poverty reduction strategies if appropriate measures are not taken to protect the environment and address climate change issues.

The Perspective Plan has proposed appropriate adaptation measures to combat the adverse impacts of climate change. Along with encouraging adaptation to climate change, the plan proposes to undertake supportive measures such as strengthening regional and national mechanisms for scientific assessment, forecasting and information sharing while building national and local capacities for greater ecological literacy and agro-ecosystem monitoring, and for assessing and managing risks. The plan also proposes a set of key management strategies to combat the climate change impact for ensuring sustainable development.

Finally, for effective and efficient implementation of the plan, it has been proposed to judge progress made against the goals and targets set through a strategy of pro-poor, climate resilient and low carbon development, based on adaptation to climate change, mitigation, technology transfer and adequate and timely flow of funds for investment, with an inviolate framework of food, energy, water, livelihood and health security. Specific strategies and the task of implementation of this plan are elaborated through two five-year plans, the Sixth Five Year Plan (2011-2015) and the Seventh Five Year Plan (2016-2020) (Planning Commission, 2012).

6.2.2 Progress under the Sixth Five-year Plan (FYP) (2011-2015)

The Sixth FYP made considerable progress in increasing per capita income and reducing poverty through a strategy of pro-poor economic growth. Bangladesh has shown success in developing national and local level expertise and actions on issues of environmental sustainability. Since monitoring and evaluation is still weak, it becomes difficult to assess progress adequately. Progress has been made to sharply reduce the loss of lives and injuries based on a combination of early warning systems, construction and availability of shelters and timely provision of relief and support measures. Management of the river system however, remains a major challenge. The formulation of the Bangladesh Delta Plan, 2100 and its timely implementation during the Seventh FYP will be a major long-term policy and institutional initiative for building resilience and reducing the effects of disaster (Planning Commission, 2015).

6.2.3 Seventh Five-year Plan (2016-2020)

The Seventh FYP has been formulated in light of the achievement of the Sixth FYP with special focus on various dimensions of development where the country is lagging behind. The main theme of this plan is 'Accelerating growth, Empowering citizens' and the plan centres on three themes:

- GDP growth acceleration, employment generation and rapid poverty reduction;
- A broad-based strategy of inclusiveness with a view to empowering every citizen to participate fully and benefit from the development process;
- A sustainable development pathway that is resilient to disaster and climate change; entails sustainable use of natural resources; and successfully manages the inevitable urbanization transition (Planning Commission 2015b).

The five-year plans are implemented through what is called an annual development plan (ADP) which is a collection of public sector development projects. The government is in the process of thoroughly examining exactly how climate change issues may be integrated within project designs and understanding where this must be done and where this may not be needed.

6.2.4 Bangladesh Climate Change Strategy and Action Plan, BCCSAP (2009)

BCCSAP is an integral part of the overall development strategy of the country. It is a Ten-year programme (2009-2018) under six thematic pillars which are: food security; social protection and health; comprehensive disaster management; infrastructure, research and knowledge management; mitigation and low carbon development; and capacity building and institutional strengthening. A total of 44 programmes are listed under these six pillars (MoEF 2009a.). This list is by no means exhaustive; it only outlines the first set of activities that are to be undertaken in line with the needs of communities and the country's overall development programme. The main focus of the programme is adaptation to climate change impacts and the basic approach is to address economic development and climate change issues in an integrated fashion to increase the resilience of the people and manage climate change impacts through effective adaptive activities.

6.2.4.1 Implementation status of BCCSAP

The implementation of the BCCSAP is through the Bangladesh Climate Change Trust Fund (BCCTF)

As of June 2016, 440 projects had been undertaken, 377 projects implemented by the government, semi-government and autonomous agencies, and 63 projects implemented by NGOs managed by PKSF (MoEF, 2014).

(Source: Planning Commission 2015[a])

6.2.5 Sustainable Development Goals (SDGs)

The Rio+20 conferences (the United Nations Conference on Sustainable Development) in Rio de Janeiro, June 2012, initiated a process to develop a new set of Sustainable Development Goals (SDGs) which will carry on the momentum generated by the MDGs. At the seventieth session of the UN General Assembly on 25 September 2015, Member States adopted the Sustainable Development Goals (SDGs) with 17 goals (UNDP n.db). The SDGs place special emphasis on climate change issues, stating the intention to: *'Implement the commitment undertaken by developed country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible'* (United Nations General Assembly, 2015).

To implement SDG 6, which ensures availability and sustainable management of water and sanitation for all, the United Nations and the World Bank formed a High-level Panel on Water (HLPW) in April 2016. The Prime Minister of the Government of Bangladesh was selected as one of the members of HLPW and the representative of Asia. The Government of Bangladesh has started preparing action plans to meet SDG goals. For example, the Department of Public Health Engineering (DPHE) has prepared draft action plans on water supply and sanitation (SDG goal 6.1 and 6.2) in three phases 2016-2020, 2021-2025 and 2026-2030. Particular focus has been placed on reducing the effects of climate change.

6.2.6 United Nations Development Assistance Framework (UNDAF) 2012-2016

The UN System in Bangladesh developed its first five-year strategic programme framework in 2006, a reflection of its commitment to national development priorities. Building on the first experience and emerging guidance, the country's second UN Development Assistance Framework (UNDAF, 2012- 2016) was formulated based on the outcome of the MDGs in Bangladesh, on national priorities outlined in the Government of Bangladesh's Perspective Plan 2010-2021 (Making Vision 2021 a Reality) and the Sixth Five-year National Development Plan. This framework comprised seven pillars, one of which was: Climate Change, Environment, Disaster Risk Reduction and Response (Lead Agency: UNDP). It brought together UN partners to address the priorities under 'MDG 7: Ensure Environmental Sustainability' and the government's priority areas of promoting better environmental sustainability and building better energy and other infrastructures. The expected outcomes under this pillar were:

Outcome One: By 2016, populations vulnerable to climate change and natural disaster would become more resilient to adaptation to risk;

Outcome Two: By 2016, vulnerable populations would benefit from natural resource management (NRM); environmental governance and low-emission green development (UNDP, 2011b).

6.2.7. National Plan for Disaster Management

A Standing Order on Disaster was introduced in 1997 by the Ministry of Food and Disaster Management (now the Ministry of Disaster Management and Relief). The government launched the National Plan for Disaster Management to be implemented in the period 2008 to 2015. The plan document relates to climate change and country development policies and explains how different parts of the country become vulnerable to disasters. It analyses the socio-economic dimensions of disasters, acknowledges the poverty-disaster interface and the impact of disasters on economic and social activities of the poor. It also acknowledges that floods and riverbank erosion are rendering people homeless. It does not however address the issue of migration any further as a strategy for poor people to cope with disasters or adapt (Martin et al., 2013) and resettlement gets a transient mention: *'Disseminate the information for utilization in development planning and resettlement of vulnerable communities'* (The Disaster Management and Relief Division, 2010).

6.2.8 National Adaptation Programme of Action (NAPA) 2009

The NAPA was developed in 2005 with the support of LDCF, was further updated in 2009 and suggested 45 measures to address adverse effects of climate change, including variability and extreme events.

Under NAPA, one project that has been completed and received several awards is the 'Community-based Adaptation to Climate Change through Coastal Afforestation in Bangladesh' (coastal afforestation /NAPA project). This project covered 18,269 households, engaging citizens in afforestation, agriculture, livestock, and fishery-based livelihood adaptation and training measures. One of the significant adaptation response measures used is the development of the FFF (Forest-Fish-Fruit) Model, a mound-ditch model that comprises short- and long-term resource and income generation, as well as livelihood diversification (UNDP, 2015). Another project that has been completed by the Forest Department is entitled *'Integrating community-based adaptation in afforestation and reforestation programmes in Bangladesh'*. This project aims to transform the way greenbelt afforestation and reforestation programmes in Bangladesh are designed and developed. It will ensure that new afforestation programmes are made resilient to anticipated climate change risks through a combination of: (a) planting of climate resilient mangrove and non-mangrove varieties; (b) adoption of new planting and management techniques by communities that take climate change risks into account; and (c) greater and continued community participation in the management and long-term protection of new greenbelt structures, in partnership with relevant sub-national government entities.

6.2.9 Mainstreaming climate change in national policies

With the exceptions of the Coastal Zone Policy (CZP) 2005 and the more recent National Agriculture Extension Policy 2012, climate change issues have not been sufficiently highlighted in national policy. The CZP stressed the vulnerability of coastal people and the need for institutional strengthening for climate change risk prediction, and for the implementation of adaptive measures. In addition, the CZP advanced a number of steps, including the continuous management of sea dykes to protect the coastline from sea level rise, floods, cyclones, and storm surges. The CZP also proposed an institutional framework for detecting and monitoring sea level rise and for formulating contingency plans to cope with the resulting impacts (Rabbani et al., 2010)

The National Agriculture Extension Policy 2012 places special emphasis on long-term sustainability of the use and conservation of natural resources including mitigation of climate change induced vulnerabilities (MoA, 2012). The policy suggests strategic approaches in relation to coping with climate change and balancing environmental issues.

In addition, the policy also suggests channeling resources to train farmers to: adopt different cropping patterns (introducing, for example, short duration and drought tolerant varieties); develop specialist extensions for area specific climate resilient specialized cropping patterns and associated water management; and develop early warning and weather forecasting for crop production etc (MoA, 2012).

6.3 Activities Related to Technology Transfer

6.3.1 Introduction

Technology transfer plays a critical role in the effective global response to the climate change challenge. Since technology is a source of GHG emissions, achieving global reduction of GHGs requires innovation to make current technologies cleaner and climate-resilient (Source: https://www.thegef.org/topics/technology-transfer).

6.3.2 Policy, Legal and Institutional Framework

Formulating and updating a number of policies in recent years has been important from the perspective of technology transfer and development. Policies include the National Science and Technology Policy, 2011; the National Information and Communication Technology Policy (Draft), 2015; the Industrial Policy, 2016; the National Energy Policy, 2004; the Renewable Energy Policy, 2008 and the National Biotechnology Policy, 2012.

6.3.3 National Science and Technology Policy, 2011

The National Science and Technology Policy, 2011 formulated by the Ministry of Science and Technology, is an update of the 1986 policy of the same name. Its prime objective is to ensure the application of science, technology and innovation in achieving sustainable economic growth with due attention to poverty and environmental sustainability. The Ministry of Science and Technology also developed an Action Plan: NST Policy-2011 to establish Bangladesh as a middle income country by 2021 which it published in October, 2012. This Action Plan consists of 15 objectives, 11 strategic themes and 246 Activities which will be implemented by different organizations under short (18 months or less), medium (5 years or less) and long (10 years or less) term timeframes. The policy does not include climate change relevant technology development and transfer.

6.3.3.1 National Information and Communication Technology Policy (draft), 2015

The draft 'National Information and Communication Technology (ICT) Policy, 2015', aimed at the development and promotion of the ICT sector to ensure its effective use to achieve development goals, has 10 special objectives, 56 strategic themes and 306 action programmes which will be implemented by different organizations under short, medium and long term timeframes by 2016, 2018 and 2021, respectively. The policy is an updated version of ICT Policy-2009 which was a cross-cutting policy for fast data management and analysis and retrieval and dissemination in different areas including climate change and environmental management. ICT Policy-2009 paid particular attention to the need for use of ICT for pre- and post-disaster management, and the use of remote sensing and GIS techniques for environmental monitoring.

6.3.3.2 National Industrial Policy, 2016

The National Industrial Policy, 2016 is an update of previous versions of the policy formulated in 2005 and 2010. This latest version advised the government to encourage industries that had taken necessary actions to control GHG emissions to combat the adverse impact of climate change. and called for industries active on issues such as disaster risk reduction and other environmental issues to be given high priority. Further, it suggested setting up industries which will be able to control pollution and/or have a minimum impact on climate change.

6.3.3.3 National Energy Policy, 2004

The National Energy Policy, 2004 stressed the need for energy efficiency, calls for clean development mechanism (CDM) projects, and for the establishment of a Renewable Energy Development Agency. The policy was explicit in its call for technology transfer and research within the following framework:

Transfer of technology is to be given due consideration in developing the power sector;

Efforts are to be made to substitute imported goods with local products. At the distribution level in particular, locally produced materials and equipment are to be used to substitute imports;

Local industries are to be assessed in order to identify manufacturing capabilities relevant to projects within the power sector. Industries, thus identified, are to be encouraged to manufacture identified items as per standards;

A comprehensive research and development programme addressing the problems of electrical energy is to be drawn up and implemented in cooperation with local universities and research and development institutions. Adequate funds are to be made available for implementation of the research and development programme.

6.3.3.4 The Renewable Energy Policy, 2008

This policy was formulated by the government in line with its Vision and Policy Statement in February 2000 to provide electricity to the entire country by 2020. One of the major reasons behind formulating this policy was to facilitate reducing global emissions for mitigating climate change (80% reduction by 2050). In line with this, the policy identified different renewable energy sources such as solar, wind energy, biomass, biogas, hydro-power, bio-fuels, gasohol, geothermal, river current, wave and tidal energy. To facilitate the technology transfer process, the policy prioritizes the option of harnessing the potential of renewable energy resources and dissemination of renewable energy technologies in rural, peri-urban and urban areas. It has set objectives to create an enabling environment and legal support to encourage the use of renewable energy, promote the development of local technology in the field of renewable energy, and promote clean energy for CDM. The policy also proposed providing financial support in the research and development of renewable energy. Moreover, proposals have been made to establish a renewable energy financing facility that is capable of accessing public, private, donor, carbon emission trading (CDM) and carbon funds and providing financing for renewable energy investments. At local level, the policy proposed setting up a network of micro-credit support systems, especially in rural and remote areas, to provide financial support for the purchase of renewable energy equipment.

Sustainable and Renewable Energy Development Authority (SREDA) was formed by S.R.O. No. 69 Law/2014- in exercise of the powers conferred by section 29 of the Sustainable and Renewable Energy Development Authority Act, 2012 (Act No. 48 of 2012), of the Bangladesh Parliament, on 10th December, 2012 as a nodal agency to promote, facilitate and disseminate sustainable energy (SE) covering both the areas of renewable energy (RE) and energy efficiency (EE) to ensure the energy security of the country (SREDA, 2016a). SREDA was established as an authority in the renewable energy sector to maintain coordination among different ministries and departments, including the Bangladesh Power Development Board (BPDB), the Rural Electrification Board (REB), the Local Government Engineering Department (LGED), autonomous bodies like IDCOL and also parts of the private sector working on renewable energy projects. At present, SREDA is implementing a number of projects on renewable energy and energy efficiency along with some awareness raising programmes (SREDA, 2016b).

6.3.3.5 National Biotechnology Policy, 2012

The National Biotechnology Policy, 2012 of the Ministry of Science and Technology emphasized the use of biotechnology for the development of climate resilient varieties of crops to combat climate change induced disasters.

6.3.4 Priority Activities Related to Capacity-building, Enabling Environments and Investment

6.3.4.1 Capacity-building, Enabling Environments

BCCSAP has pointed to limited human and institutional capacity for understanding, analysing, planning for and managing climate change but has not given clear indications about specific capacity-building needs. There are several areas where priority action is needed to prepare the country for climate sensitive and climate change resilient development. In the case of capacity-building the following areas identified during the Second National Communication remain important:

- Continuous monitoring of weather parameters and events and their analysis for forecasting future changes both in the short- and long-term;

- Long-range weather forecasting;
- Analysis of future climate change and its sectoral, temporal and spatial dimensions;
- Integration of climate change impacts in designs of plans, programmes and projects;
- Redesigning of projects when climate change impacts are known and when not known with certainty.

Acknowledging the new challenge of climate change impacts with many other socio-economic problems being faced by societies globally, the government has taken initiative of making it mandatory for all projects, investments and technology transfer and development to be climate sensitive (GED, 2014). As a result, policy supporting adaptation has been cast as a necessary strategy for responding to climate change and supporting development, making adaptation the focus of much recent scholarly and policy research. Considering the strong interlinkages between climate change and sustainable development issues, the Planning Commission encourages scientific linkages and discussion on the opportunities they provide for integrated policy development, and the necessity to consider the risk of trade-offs as a way not only of providing new opportunities, but also as a way of successfully addressing the issues of both climate change and sustainable development. Based on a range of analyses of various economic sectors in the areas of both mitigation and adaptation, largely drawn from IPCC's Fifth

Assessment Report (IPCC-AR5, 2014), the Planning Commission also considers that climate policy responses should be fully placed in the larger context of technological and socio-economic policy development rather than viewed as an add-on to those broader policies since the feasibility of stabilizing greenhouse gas concentrations is dependent on the general socio-economic development paths of developed and emerging economies.

Generally, GoB undertakes two types of development projects - investment projects and technical assistance projects. Two standard formats are available to follow in submitting project proposals for approval to the Planning Commission. The first one is the development project proforma (DPP) and the second is known as the technical assistance project proforma (TPP). At the initial stage of project design, therefore, DPP and TPP are key enabling instruments taken into consideration for climate change, disaster and environmental mainstreaming issues. The issue of climate change and disaster was largely missing in previous DPP formats. Therefore, GED, with the technical support of the Poverty Environment Climate Mainstreaming (PECM) project, revised the DPP format which subsequently coincided with ongoing efforts of the Planning Division for the revision of DPP format (GED, 2014). It has also been made mandatory for every implementing agency to complete the DPP as per the revised DPP manual published in March, 2014 to submit the proposal of an investment project, where now climate change and disaster issues are made an integral part and environmental aspects are thus further strengthened. The DPP manual attempts to explain, step by step, how to prepare a good development project proposal based on the revised proforma integrating climate change, disaster and environment issues into the design of development projects (GED, 2014). To help the process further, the manual includes a number of reference materials along with some necessary indicators (GED, 2014).

6.3.4.2 Investment

In order to address the issue of climate change, the government has established a number of institutions/funds and other initiatives in the last few years considering the uncertainties and inadequacies of international adaptation finance from both multilateral and bilateral sources. Attempts are also ongoing to secure international finance. This section highlights the efforts of Bangladesh for managing climate funding at the national level, its attempt to harness international funding and other associated initiatives.

Initiatives at National Level

A number of institutions have been established by the GoB to address climate change. They are detailed below.

Bangladesh Climate Change Trust Fund (BCCTF) is managed and coordinated by the Ministry of Environment, Forest and Climate Change (MoEFCC). Government dedicated funding is provided to the projects under the main pillars of the BCCSAP, which include: food security; social protection and health; disaster management; infrastructure; knowledge management; climate change mitigation; and capacity building and institutional strengthening. The fund was initially Taka +300 crore and later increased to Taka +700 crore – approximately $100 milllion annually. In early 2009, the government approved the Climate Change Trust Fund Policy. Following this, in May 2010, the Climate Change Trust Fund Act 2010 was passed. Of the total amount of the fund, 66% is for climate change related project activities and the remaining amount, 34%, is to be invested or used for emergencies (GED, 2012).A high powered trustee board involving a number of ministers has been set up, supported by a technical evaluation committee, to examine the relevance of project requests and decides which projects are eligible to be implemented using the dedicated national fund (BCCTF, 2014). The trust also assists MoEF with the implementation of various activities under the BCCSAP and provides secretariat support services for BCCTF. 378 projects totaling 2600 crore taka had been approved under the BCCTF by June 2016 (MoEF, 2014). The projects undertaken so far include: the construction of embankments and river bank protective work; building cyclone resilient houses; excavation /re-excavation of canals; construction of water control infrastructures including regulators/sluice gates; waste management and drainage infrastructure; introduction and dissemination of stress tolerant crop varieties and seeds; afforestation; and installation of solar panels. Some of the key achievements of these projects are as follows: (MoEF, 2014)

- 164 kilometers of coastal sea dyke have been constructed;
- 7,218 cyclone resilient houses have been erected;
- 35,212 kilometers of embankments have been built;
- 156,792 kilometers of river bank protective work have been completed;
- 872,186 kilometers of canals have been excavated/re-excavated;
- 65 water control infrastructures including regulators/sluice gates have been constructed.
- 40,471 kilometers of drainage have been constructed in the urban areas to reduce water logging;
- 2,849 deep tube wells, 30 pond-sand-filters (PSF) and 50 water treatment plants have been installed;
- 1,050 water sources and 550 rain water reservoirs have been established;
- Agro-met stations for early weather forecasting have been set up in four upazilas;
- 1,442,000 trees have been planted and 4,971 hectares of forest land have been brought under afforestation;
- 7,800 biogas plants have been installed;
- 528,000 improved cook-stoves have been distributed;
- 17,145 solar home systems have been installed in the remote off-grid areas;
- Stress tolerant crop varieties like BINA Rice-7, BINA Ground Nut-1, 2 as well as BRRI Rice-40, 41, 47 have been introduced;
- 111,000 metric tons of stress tolerant seeds have been produced and distributed;
- 12,000 floating vegetable beds in 210 villages are planned and of these, 50% have already been established; and
- A community radio station has been set up to educate vulnerable communities on issues related to health and agriculture.

The Bangladesh Climate Change Resilience Fund (BCCRF) is a coordinated financing mechanism of the government, the World Bank, and development partners to address the impacts of climate change (BCCRF, 2013). The fund aims to provide donor-funded support to implement the programmes of BCCSAP. The fund was established in May 2010 with financial support from Denmark, the European Union, Sweden and United Kingdom. Australia, Switzerland and United States subsequently joined the fund. This mechanism enables the government to channel over $188 million in grant funds to millions of Bangladeshis to build their resilience to the effects of climate change (BCCRF, 2013). The Bangladesh Government leads on the management and implementation of BCCRF (BCCRF, 2013). The status of the major projects under the BCCRF are given in Tables 6.1 and 6.2.

Table 6.1: Status of the major investment projects under the BCCRF

Project Name and Implementing Agency	Project Amount (US$)	Total disbursement by December 31, 2014 (US$)	Status
Emergency 2007 Cyclone Recovery and Restoration Project (ECRRP) Local Government Engineering Department (LGED)	25.0 million	18.74 million	17 new disaster shelters constructed 11.50 km of road in Barguna district completed
Secretariat for BCCRF Ministry of Environment and Forests (MoEF)	0.2 million	0.2 million	Disbursement has been completed and the project closed on December 2014
Community Climate Change Project (CCCP) Palli Karma-Sahayak Foundation (PKSF)	12.5 million	5.35 million	41 sub-projects targeting fourteen in salinity-prone, eighteen in flood-prone, and nine in drought-prone areas have started their activities
Climate Resilient Participatory Afforestation and Reforestation Project –CRPARP. Bangladesh Forest Department (BFD) and Arannyak Foundation (AF)	33.8 million	7.81 million	Plantation activities completed in a total area of 4,822 ha and 539 km with approximately 95% survival rate during the first 6 months of implementation
Rural Electrification and Renewable Energy Development Project II (Solar Irrigation Project) Infrastructure Development Company Limited (IDCOL)	10 million	0.64 million	4 irrigation pumps providing service to about 100 to 120 farmers

Source: The World Bank, 2014

Table 6.2: Status of the Analytical and Advisor Activity (AAA) under the BCCRF

Projects	Amount approved (US$)	Total disbursement by December 31, 2014 (US$)	Status
Impact of climate change on climate-sensitive diseases and implications for the health sector	300,000	265,000	*"Climate Change and Health Impacts: How vulnerable is Bangladesh and what needs to be done?"* Report completed and published in draft.
Water logging of Urban Areas in a Changing Climate: Potential Damage and Adaptation	500,000	454,000	Technical reports prepared, and a book is now under preparation on *"Urban Flooding of Greater Dhaka Area in a Changing Climate: Vulnerability, Adaptation and Potential Costs"*
Guidance Note for the Urir Char-Noakhali Cross Dam	730,000	650,000	Study is nearly complete
Innovations in Flood Risk Mitigation in Dhaka	300,000	72,937	Documentary and fieldwork was initiated in August 2014 and is currently ongoing
Making Climate Data Relevant to Decision Making in Bangladesh: Spatial and Temporal Downscaling	250,000	209,000	A consultative workshop took place in Dhaka in May 2014 and was followed by a training session. An update of the World Bank Climate Knowledge Portal tool powered by Climate Wizard technology for Bangladesh is in progress

Source: The World Bank, 2014

Climate Fiscal Framework (CFF) was approved in June 2014 by the Government of Bangladesh (GoB). The CFF is a framework to ensure the effective use of domestic and international climate finance within the national budget process. The CFF identifies the demand and supply (funds, fiscal policies/green banking) of national climate finance and forecasts future climate financing needs for Bangladesh. The CFF has designed the climate expenditure tracking framework (CETF) which enables tracking and monitoring climate related expenditures in a systemic and transparent manner. Further, the CFF has also introduced a climate marker in the medium-term budget framework (MTBF) of Bangladesh and a climate dimension for the preparation of capital development

projects, linking climate change with planning and budgeting. As part of the CFF, it was proposed to establish a climate fiscal cell in the Finance Division to strengthen much-needed climate finance coordination and management. As a measure to strengthen accountability, the CFF reviews the obstacles in including climate change in the auditing systems and identifies capacity support to the auditor general's office to conduct climate finance performance audits. The CFF recognizes the need for a gender differentiated approach in its climate response.

Green banking is a system introduced by the Central Bank of Bangladesh which formulates relevant policies and supervises activities. The system makes commercial banks set aside a sum of their annual budget for the Climate Risk Fund, which is also managed by the Central Bank. The Central Bank provides other banks with incentives for example, refinancing facilities at a lower interest rate if they give loans to those investing in green activities (IIED, 2014).

The landscape of climate change finance in Bangladesh can be understood from Table 6.3.

Table 6.3: Climate Change Finance Scenario of Bangladesh

Sources of climate finance	Intermediaries	Economic and financial instruments	Financial planning systems and institutional arrangements	Uses and users climate finance
National public finance (national budget)	Bangladesh Climate Change Trust Fund Ministry of Environment and Forest	Grants Fixed deposits	Bangladesh Perspective Plan (2010-2021) Sixth Five Year Plan (2011-2015) BCCSAP (2009) Bangladesh Climate Change Trust Act (2010) National budget	Various BCCSAP initiatives, implementing government agencies, local non-governmental organizations, universities, research organizations
National private finance	Green banking through Central Bank Commercial Banks	Concessional loans Refinancing	Policy guidelines for green banking (2011)	Renewable energy, green buildings, clean transportation, water management, waste management, land management
Multi-donor international public finance	Bangladesh Climate Change Resilience Fund World Bank	Grants	BCCSAP	Various BCCSAP initiatives
International public finance	Climate Investment Funds Multilateral development banks Ministry of Environment and Forests	Grants (45%) Concessional loans (55%)	BCCSAP	Improving climate resilient agriculture and food security, strengthening the security and reliability of fresh water supply, sanitation, infrastructure, enhancing the resilience of coastal communities and infrastructure
	GEF (Least Developed Countries Fund)	Grants	BCCSAP GEF policies and procedures	Biodiversity, climate change, land degradation

Initiative for International Funding

Strategic Programme for Climate Resilience (SPCR) Bangladesh: The Climate Investment Funds (CIFs) at the World Bank proved to be controversial at their inception in 2008 with DFID in the UK as a principle funder, when it announced allocating what at that time were termed the Environmental Transformation Funds through the World Bank. As the modalities of the Adaptation Fund were agreed in Bali at COP 13, when there were disagreements about the role of the GEF, it seemed to many in civil society that this was an unwelcome proliferation of funds at a critical point, to an institution which was part of the problem, not the solution, and that support for poor countries affected by climate change should be in the form of loans not grants. These issues were resolved by blending in grant components and providing concessional loans, but procedures involved in developing what became the PPCR have been very slow, in part as a result of the formalities involved in constructing a transparent credible process and structure (GED, 2012).

An amount of $110 million in the form of grants ($50 million) and concessionary loans ($60 million) from MDBs was approved for Bangladesh in October 2010 for "piloting" adaptation activities in climate vulnerable areas through the PPCR. It was one of the first countries selected. A significant amount of these funds has been allocated to top up major investment projects, which had already been planned, and are also being funded with a loan component. The lead agency is the Asian Development Bank with the World Bank and IFC who are taking responsibility for different components (GED, 2012).

To its credit, the CIF process is comparatively transparent and well-documented. This means there is a considerable amount of information which can be analysed. Development was more transparent than that of the two trust funds. There were several preparatory meetings ahead of the formal mission, and there was a stakeholder consultation workshop. From these discussions, four thematic areas were identified, which *"support one of the country's top priorities: protecting people and land in low-lying coastal regions"*, according to the World Bank press release (GED, 2012). The four areas are:

- Promoting climate resilient agriculture and food security;
- The improvement and afforestation of coastal embankments;
- Improvements in securing a coastal climate resilient water supply, sanitation, and infrastructure;
- Technical assistance, climate change capacity building and knowledge management.

There is considerable ambition for the SPCR as stated in GED (2012), with significant expected outcomes, which is somewhat surprising as essentially it is a pilot programme. Expected outcomes are:

- Increased resilience of coastal infrastructure (housing, connectivity, flood control and improved drainage systems within polders, improved water supply and sanitation) for withstanding effects of climate induced seasonal and natural disasters;
- Reduced water and soil salinity and improvements in agricultural and fisheries production;
- Improved capacity of MoEF to manage and coordinate investments in and knowledge on climate resilient initiatives.

Clean Development Mechanism (CDM) is a flexible mechanism of the Kyoto Protocol under the UNFCCC. It allows a developed country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol to implement an emission-reduction project in developing countries. Bangladesh has established a two-tier designated national authority (DNA) to implement CDM activities in Bangladesh. DoE is giving secretarial support to the DNA of Bangladesh. To date, 13 CDM projects from Bangladesh have been registered by the CDM Executive Board. An additional eight projects have been approved by DNA and host country approval letters have been issued. Some key projects are:

- Using municipal organic waste;
- Energy and water saving promotion programme for textile dyeing process of Bangladesh Textile and Garment Industries;
- Improving kiln efficiency in the brick making industry;
- Improved cooking stoves;
- Installation of solar home systems;
- Collection of heat for production processes from waste heat recovery boilers.

Joint Crediting Mechanism (JCM) is an initiative of the Japanese Government which is a simplified version of clean development mechanism (CDM) of the Kyoto Protocol under the UNFCCC. Japan is not able to participate in the CDM activities under the Kyoto Protocol since it has not ratified the second commitment period (2013-2020). It has therefore developed a similar mechanism, under which the Japanese government assists JCM member countries with energy efficient technologies and equipments which will reduce green house gas (GHG) emission. Japan and Bangladesh signed the bilateral document for the introduction of the JCM on March 19th, 2013. Japan has so far signed agreements with 16 countries including Bangladesh, Indonesia, Laos, Mexico, Mongolia, Saudi Arabia, Thailand and Vietnam.

The Department of Environment serves as the secretariat of the JCM Bangladesh chapter. The Japanese government provides grants of up to 50% to partner countries to acquire energy efficient technologies. So far one energy efficient technology on centrifugal coolers has been transferred to Bangladesh, three others have been selected (including a 50 MW solar power plant at Mymensingh) and are in different stages of implementation.

Climate Technology Centre & Network (CTCN) is the operational arm of the UNFCCC technology mechanism to facilitate the transfer of technologies among the member countries of the UNFCCC. The Department of Environment (DoE) is the national designated entity (NDE) of the CTCN in Bangladesh. As the NDE, DoE is working closely with the relevant government agencies and organizations to assess and identify their technical adaptation and mitigation needs for tackling climate change and supporting the formulation and prioritization of their technical assistance requests and proposals to CTCN. With the help of respective agencies/organizations, the DoE has identified one proposal on technology on mitigation and three proposals on technologies on adaptation proposals and sent all four to the CTCN Secretariat.

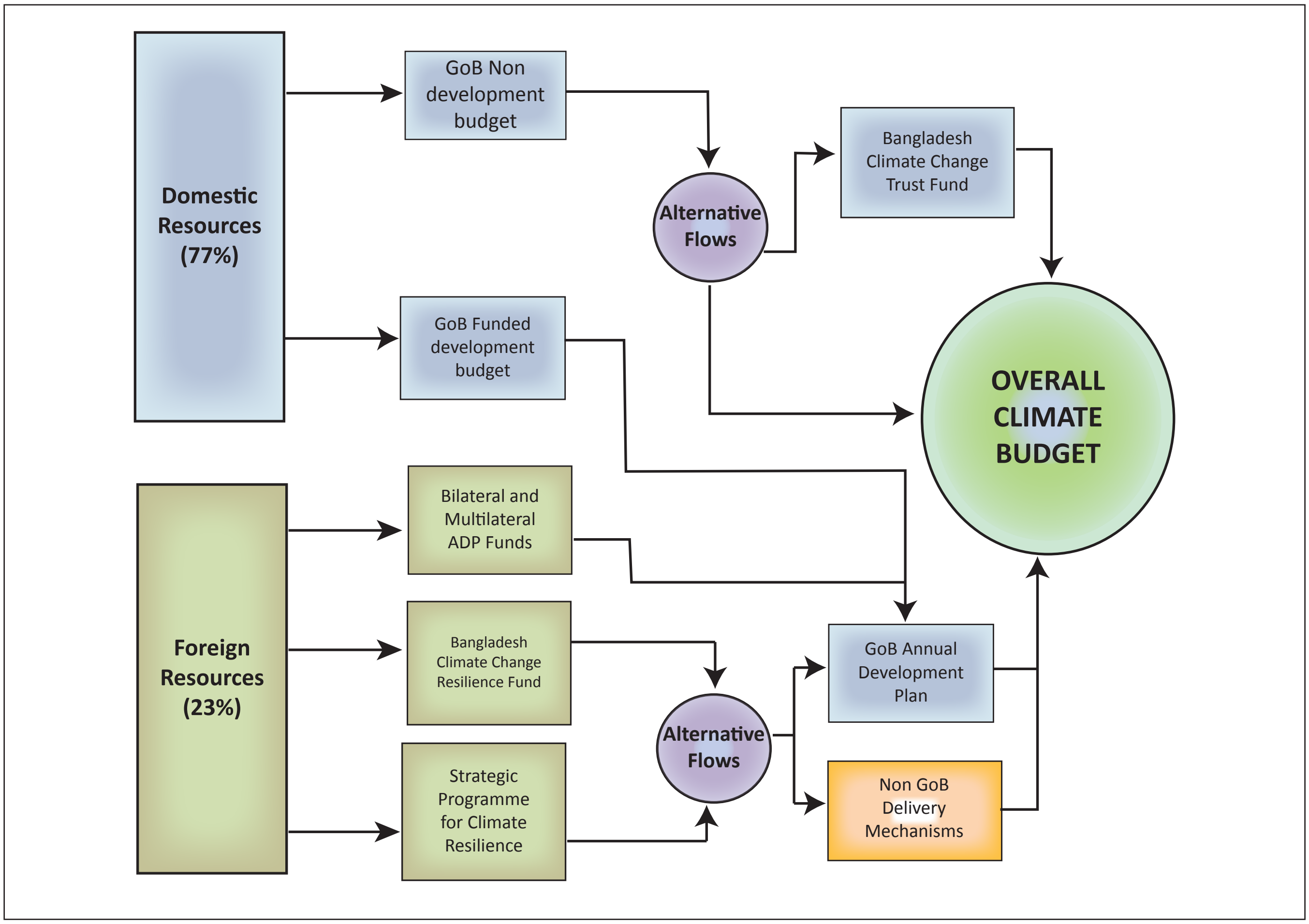
The Adaptation Fund (AF) was established to finance concrete adaptation projects and programmes in developing countries that are parties to the Kyoto Protocol and that are particularly vulnerable to the adverse effects of climate change. The AF is financed from the share of proceeds on CDM project activities and other voluntary sources of funding. The share of proceeds amounts to 2% of CERs issued for a CDM project activity (Adaptation Fund, 2015)

The MoEFCC has nominated a representative from the GoB to liaise with the AF and perform the role of the designated authority (DA). The DA is tasked with working with a national implementing entity (NIE) to seek project specific funds from the AF and to help the said NIE to identify fundable projects and their respective executing agencies. GoB has not yet been successful in ensuring accreditation of its NIE.

The Green Climate Fund (GCF) is the newest actor in the multilateral climate finance architecture. It became fully operational in 2015, approving $168 million for its first eight projects covering mitigation and adaptation measures in November 2015 just weeks before COP 21. The GCF is the only dedicated operating entity of the UNFCCC's financial mechanism. The eight projects include one project with German development bank KfW on climate resilient infrastructure mainstreaming where GCF funding is $40 million. The implementing entity is the local government engineering department and the worth of co-financing is $40 million.

Review on Climate Expenditure

During the Climate Public Expenditure and Institutional Review (CPEIR) of 2008/2009 to 2011/2012, government financial records revealed that an estimated 6%–7% of the GoB's annual combined budget was spent on climate-sensitive activities; this equates to an annual sum of approximately $1 billion at current exchange rates (LD4a, after 2012). The financing of the annual expenditure is estimated to be largely funded from domestic resources to the order of 77% for the years 2009/10–2011/12, with the remaining 23% from foreign donor resources. As a percentage of the average annual funding reflected in the indicative CPEIR figures, the BCCRF and SPCR contribute relatively small incremental amounts of around 2%–3% to overall climate-sensitive spending. A simplified overview of the flow of domestic and foreign resources in Bangladesh shows the various sources and flow of funds that together constitute the overall climate budget for the country (Figure 6.1).



Source 6.1: Adapted from UNDP 2012. Bandladesh: Climate Public Expenditure and Institutional Review. Bangkok.

Figure 6.1: Flow of funds of overall climate budget for the country

6.3.5 Intended Nationally Determined Contributions (INDC, now NDC)

The INDC sets out a number of mitigation actions to limit the country's GHG emissions. These mitigation actions will play a key role in realizing the move to a low-carbon, climate-resilient economy and to Bangladesh becoming a middle-income country by 2021. The INDC includes both unconditional and conditional emissions reduction goals for the power, transport, and industry sectors, alongside further mitigation actions in other sectors, which Bangladesh intends to carry out. The foundation of this INDC is in line with Bangladesh's existing strategies and plans, in particular the Bangladesh Climate Change Strategy and Action Plan (BCCSAP), Renewable Energy Policy 2008, the Energy Efficiency and Conservation Master Plan (E&CC Master Plan), the forthcoming National Adaptation Plan, the National Sustainable Development Strategy, the Perspective Plan (Vision 2021), the National Disaster Management Plan and the Disaster Management Act. As per this INDC, Bangladesh will provide an unconditional contribution to reduce GHG emissions by 5% from Business as Usual (BAU) levels by 2030 in the power, transport and industry sectors, based on the support of existing resources and a conditional 15% reduction in GHG emissions from BAU levels by 2030 in the above sectors subject to appropriate international support (MoEF, 2015). Bangladesh has started to prepare its INDC implementation road map in which it intends to implement adaptation activities worth about $40 billion.

With the entry into force of the Paris Agreement, the INDC has become NDC. Bangladesh has already drafted the NDC Implementation Road Map and Sectoral Action Plans for the power, industry and transport sectors. NDC is expected to be one of the key bases of future climate change actions in the country to address national and global climate change under UNFCCC process.

Country Investment Plan (CIP) for Environment, Forestry and Climate Change

The Ministry of Environment and Forests prepared and launched the Country Investment Plan for Environment, Forestry and Climate Change (EFCC CIP) on 13th December 2017. The EFCC CIP is a cross-sectoral and whole-of-government investment framework for mobilizing and delivering effective, coordinated, sustainable and country-driven investment programmes in environmental protection; sustainable forest management; climate-change adaptation and mitigation; and environmental governance. It is a tool to translate government policies into investment programmes and projects. The EFCC CIP is a response to the urgent need to address environmental degradation in Bangladesh and to improve the country's ability to meet the threats posed by climate change.

The EFCC CIP lays out priority investment areas organized in four pillars, 14 programmes and 43 sub-programmes. At least 77 government agencies (ministries/divisions/ departments) will implement various EFCC investment programmes. It is estimated that approximately $11.7 billion will be required to implement the EFCC investment programmes, as described in the CIP. Presently, the GoB is funding approximately $4.7 billion of EFCC programmes through the GoB's annual development plans, leaving an investment gap of around $7 billion over the next five years, and development partners are requested to address this gap with necessary support. The CIP will be monitored on an annual basis to track the impact of investments, identify success stories and challenges, and provide recommendations for improvements.

Process, Key Outcomes and Funding of the Technology Needs Assessment

Technology needs assessments (TNA) are a set of country-driven activities that identify and determine the mitigation and adaptation technology priorities of parties other than developed country parties, and other developed parties not included in Annex II, particularly developing country parties. The TNA process involves identifying country development priorities, identifying priority sectors/sub-sectors and/or areas, and prioritizing technologies for these sectors/sub-sectors and/or areas. In this process, TNA offers support for conducting multi-criteria assessments in a stakeholder context. Bangladesh has prepared its own technology needs assessments (TNA) report in line with the BCCSAP, 2009.

This report has identified and prioritized sector-specific mitigation technologies that have synergies with the country's long-term development priorities i.e. making the country's prioritized sectors resilient to climate change vulnerabilities now and in the future and embarking on a clean development path. The criteria for technology prioritizations of climate change mitigation measures are considered as development benefits, implementation potentials and contributions to climate change response goals.

Proposal in the Report

SDG13 calls for protectionof the planet and the sectors and sub-sectors of agriculture, industry and power generation and use, require technological support if they are to contribute to the reduction of GHG emissions and complement the country's development priority.

The sub-sectors under each sector are scored categorically on the basis of their economic, social and environment priorities using numeric value ranges from one to five. Additionally, the GHG reduction potential of each sub-sector is scored putting numeric value ranges from one to five. On the basis of scores given to different sub-sectors, the criteria contribution graph was drawn up and provides an overview of the contribution of each sub-sector on criteria identified as areas with high potential for future mitigation action. Examples are: i) gas-based technology; ii) coal-based technology; iii) solar power generation; and iv) domestic lighting.

Energy efficient technologies in households, means of transport, industries and agriculture are the only options to follow a low carbon development plan and technologies should be both cost-effective and able to reduce pollution, including greenhouse gases. Mitigation activity must be consistent with the need for the country's energy security as the demand for energy will enhance with the increasing pace of economic and infrastructure development.

Table 6.4: Short listed mitigation technologies in power generation and use

Power	Category	Technology
Power generation	Gas -based	Advanced combustion turbine
		Natural gas combined cycle
		Advanced natural gas combined cycle
	Coal -based	Advanced Pulverized Coal (APC) Single
		Unit Advanced Pulverized Coal (APC)
		Double Unit Integrated Gasification
		Combined Cycle (IGCC) Single unit
		Integrated Gasification Combined Cycle (IGCC) Double unit
	Solar	Solar Home PV
Power use	Domestic Lighting	Linear fluorescent lamp (LF)
		Compact fluorescent lamp (CFL)

Technologies should aim to:

Minimize GHG emissions;

Maximize effort towards low carbon development; and

Maximize development priority benefits in terms of environmental, social and economic benefits and also maximize the co-benefits of emission reduction e.g. reduction of health hazards caused by pollution etc.

For climate change mitigation technology prioritization, the following criteria have been considered in the discussion and decision-making of technology prioritization (MoEF, 2012):

Environmental Improvements

Reduced or avoided local air pollution for improving air quality by reducing short-lived climate pollutants such as SO_x, NO_x, suspended particulate matters, non-methane volatile organic compounds, dust, fly ash and odour.

Reduced water pollution to improve water quality for safe drinking water and sanitation, safe water bodies such as rivers, canals, streams, wetlands, tanks and lakes to ensure ecological process for productivity

Reduced waste to improve overall environmental quality of air, water and soil as well as ecosystems for ensuring clean environment

Reduced resource use particularly in terms of the reduction in use of the primary fuel for generation of power and to improve sustainable management of natural resources.

Social improvements

Health improvement by using clean technology

Improved quality of life (which may come about through lowering of drudgery, better lighting, space cooling etc.)

Education (through improved quality of life for children)

Equality (through women's empowerment with improved prospects for study, income earning opportunities and consequent social mobility)

Economic improvements

Poverty alleviation (such as a reduction in the number of poor due to better income and consumption prospects)
Job creation and quality (more jobs available due to establishment of new enterprises or expansion of old ones with availability of electricity)

Skills improvement (as with better prospects for jobs, people may train for skills improvement)

Enterprise stimulation (growth or expansion of business enterprises)

Balance of payments effects (due to increased costs of imported technology)

6.3.6 Existing and planned climate-related technology transfer programmes/projects

Information regarding initiation of any pilot programme that directly addresses the technology transfer component relating to climate change is not available. But CDM projects, as identified under the Second National Communication Report, although not directly related to technology transfer, can be taken as a good example.

Role of the various stakeholders

A number of governmental, autonomous, non-governmental institutes and NGOs are trying to adopt existing technologies for the local context and develop new technologies and research with expertise in their field of activities. Among such institutes, BUET, CEGIS, IWM, WARPO, BCAS, NACOM, BIDS, BUP, Waste Concern, IUCN, NIPSOM, CNRS, BIRRI, BARC, and BMDA are worth mentioning.

In addition to the above-mentioned organizations, there are other entities (both public and private) like SPARRSO, BMD, SRMC, BCSIR, and other earth, environment and life sciences school of public and private universities which have their own capacities on technology exploration and utilization.

6.4 Climate Change Research and Systematic Observation

6.4.1 Status of National Programmes

Monitoring the scope of climate related phenomena is somewhat limited in Bangladesh, as the human and institutional capacity for conducting research and generation of required data is bound by technical and financial constraints. In this regard, it helps to understand the status of meteorological, hydrological and oceanographic related research.

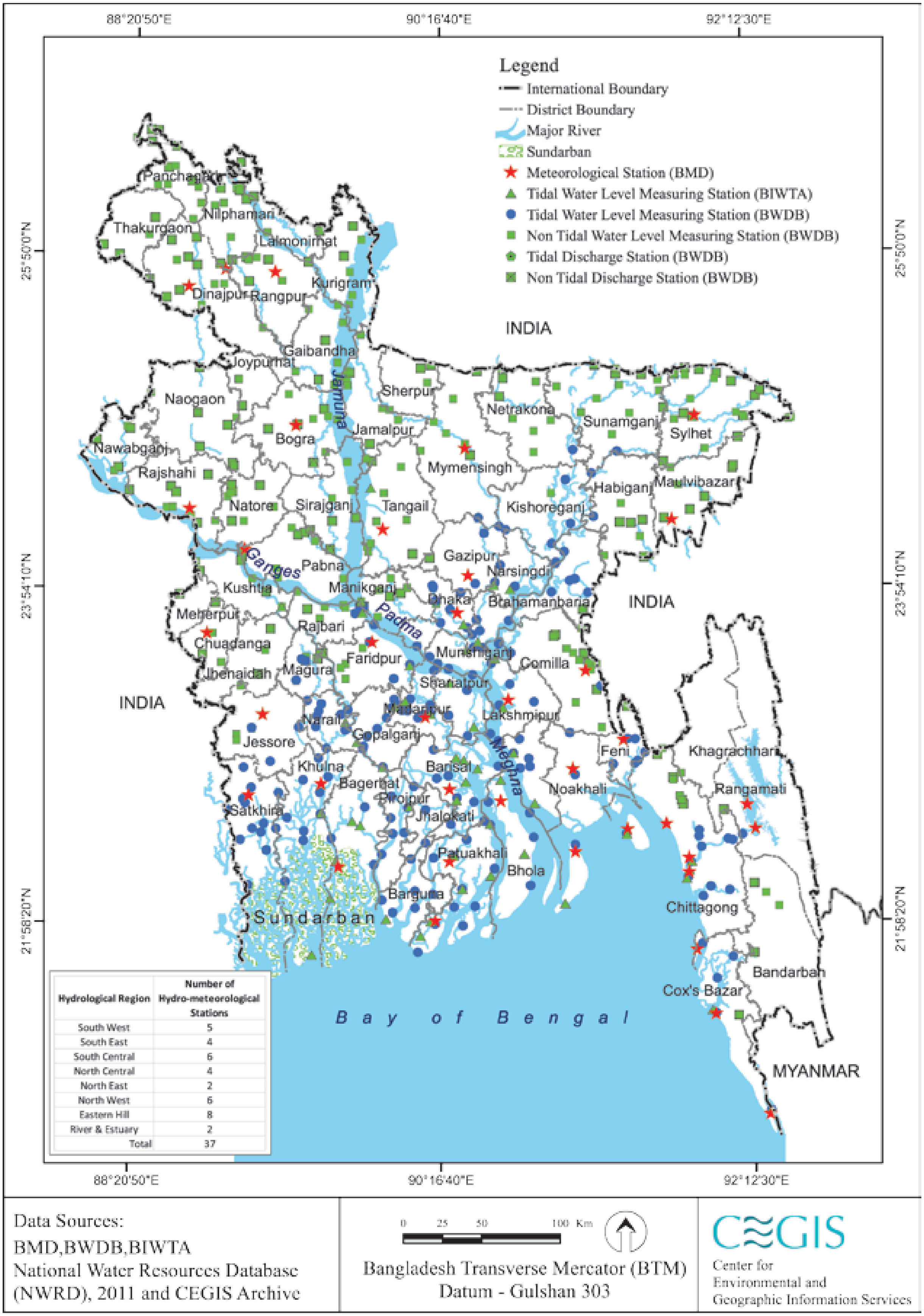
The Bangladesh Meteorological Department (BMD) is the forerunner in generating, acquiring and handling meteorological data as it collects data from its 37 climate data stations all over the country. This climatic data includes evaporation, humidity, solar radiation, rainfall, sunshine hours, temperature wind speed and so on. The Bangladesh Water Development Board (BWDB) collects hydrologic information such as water level and discharge data as well as meteorological information. The Bangladesh Inland Water Transport Authority (BIWTA) collects water level data from its 43 tidal stations. Additionally, the Flood Forecast and Warning Centre (FFWC) is an organization under BWDB that generates and provides flood forecast and warning information to enhance the disaster management capacity of national agencies and communities using the best scientific principles, real time data, weather forecast information and mathematical models available. It functions as a centre of emergency response through Flood Forecasting and Warning Services (FFWS) to minimize or mitigate loss of life and damage of properties in a more effective manner to meet the national needs of disaster risk reduction. Currently, FFWC provides forecasts through its 54 forecast stations throughout the country. A brief profile of the category of hydro-meteorological data, corresponding period of data availability and total number of available stations along with their respective organizations is given in Table 6.5. The spatial distribution of hydro-meteorological network in Bangladesh is shown in Figure 6.2.

Air quality data and salinity data are monitored by the Department of Environment (DoE) and the BWDB on a daily and fortnightly basis along the coastal region of Bangladesh. Local level salinity measurements are carried out by agencies such as Khulna Newsprint Mills, Mongla Port Authority and Chittagong Port Authority. Data can also be acquired on a project basis for predefined periods and can be used for historical trend analyses.

Table 6.5: Hydro-meteorological Stations and Record of Data in Bangladesh

Organization	Data Type	Data Availability	No of Station
BMD	Evaporation	1983 to 2011	14
BWDB	Evaporation	1964 to 1998	47
BMD	Humidity	1948 to 2015	35
BMD	Solar radiation	1983 to 2008	10
BMD	Rainfall	1948 to 2013	35
BWDB	Rainfall	1957 to 2015	315
BMD	Sunshine hours	1961 to 2015	35
BMD	Temperature	1948 to 2015	35
BMD	Wind speed	1980 to 2015	35
BWDB	Discharge	19 34 to 2007 (Non Tidal), 1964 to 2006	136 (Non Tidal), 16 (Tidal)
BWDB	Water Level	1910 to 2010 (Non Tidal), 1909 to 2009 (Non Tidal)	281 (Non Tidal), 181 (Non Tidal)
BIWTA	Water Level	1977 to 2010 Tidal	43 (Tidal)

Existing Hydro-meteorological Station in Bangladesh



Hydrological Region	Number of Hydro-meteorological Stations
South West	5
South East	4
South Central	6
North Central	4
North East	2
North West	6
Eastern Hill	8
River & Estuary	2
Total	37

Figure 6.2: Locations of Hydro-meteorological Stations in Bangladesh

6.4.2 Level of Participation in the Global Observation Systems

The Bangladesh Meteorological Department (BMD) is connected to the World Meteorological Organization (WMO). Meteorological observations are transmitted and received globally through the Global Telecommunication System (GTS). Additionally, it is associated with PTWC and JMA through BMD's GTS link, fax, telephone and internet to receive tsunami advisories/warnings and tsunami watch information. As part of global cooperation, WMO provided assistance to Bangladesh in 2008 to improve the current national agro-meteorological station network to ensure timely delivery of agro-meteorological information and products.

6.4.3 Research Initiatives on Climate Change Scenario Generation and Physical Processes

Since the early 1990s, efforts have been made to develop climate change scenarios of various sorts as well as to analyse underlying processes. Scenarios were based on data collected by organizations working on climate change issues as well as data existing since the British period. Research has been carried out both for individual academic purposes and also as part of institutional efforts, and includes early speculative studies to models of increasing sophistication and complexity as well as applicability to ever smaller grids. Model building has been helped by many studies which have tried to understand the various underlying processes of climate change and its physical impacts. One strand of analysis was pattern recognition from observed data on climate variables and another was related to natural phenomenon.

Many research programmes on climate change issues have been conducted by a number of national and international organizations in recent years. Gobeshona, a knowledge sharing platform for climate change research on Bangladesh, shares information about completed publications, ongoing research, upcoming events and researcher opportunities relevant to climate change in Bangladesh through its web portal. As of October 2016, around 1,360 publications on research programmes with direct or indirect links to climate change issues in Bangladesh conducted since the 1970s had been published in this web portal and of these, 900 publications were published from 2012 to 2016. These research programmes were conducted on trend analysis; vulnerability and risk assessment; impact of climate change; impact on water sector; impact on water supply and public health; impact on coastal zone; impact on agriculture; impact on forestry; impact on biophysical sector; impact on fisheries; impact on environment and ecology, climate induced disasters and their management; societal impacts; impact on urbanization; adaptation techniques; climate finance, negotiation and governance; impact on gender etc.

The annotated bibliography on climate change research initiatives in Bangladesh published by the Climate Change Cell under CDMP in the 2009 identified a total of 118 national and international research institutes which have participated in different research initiatives in Bangladesh related to climate change; the number of such research institutes is believed to have since increased though the exact number is not known. The distribution of different categories of institutes as identified in the above-mentioned annotated bibliography is given in Table 6.6 which shows a clear picture of the level of involvement and cooperation with bilateral and multilateral institutions working on climate change research in Bangladesh.

Table 6.6: Institutions involved in Climate Change Research

Category	Number of institutions
Academic Institutions	11
Donor/Inter-governmental agency	30
International research institution	1
International research institutions/NGOs	35
Ministries	8
National research institutions/NGOs	20
Public agency	11
Public trust	2
Grand Total	118

6.4.4 Institutional responsibilities for monitoring network

Climate change issues are no longer confined only to the climate change specialist institutions in Bangladesh; they are now a multi-disciplinary and multi-ministerial issue within the government (Ayers & Huq, 2009). GoB, acknowledging the importance of climate change and its impact, has developed a number of policies and plans since the 1990s. It recognizes that tackling climate change requires an integrated approach involving many different ministries and agencies, the civil society and the business sector and monitoring of climate change impact also needs multi-institutional involvement. The primary ministry directly involved with climate change is the Ministry of Environment, Forest and Climate Change (MoEFCC) through its agencies such as the Department of Environment (DoE), the Forest Department (FD), the Department of Disaster Management and the recently dissolved Comprehensive Disaster Management Programme (CDMP). They are responsible for the preparation of national communications, and the formulation of national adaptation programmes of action, providing approval for disaster management projects, attending international negotiations and facilitating mainstreaming at the sectoral level.

The water resource sector, highly susceptible to climate change impacts, is monitored closely by the Ministry of Water Resources (MoWR) which is responsible for addressing climate change impacts on irrigated areas, water conservation, surface and ground water availability, and river basin management. The MoWR acts as the umbrella institution under which a number of other organizations are working such as the Water Resources Planning Organization (WARPO) which was established with a view to undertaking integrated water resources planning and is tasked with the responsibility for national, regional and basin planning. Under the MoWR, trust organizations such as the Centre for Environment and Geographic Information Services (CEGIS) and Institute of Water Modeling (IWM) provide technical support through conducting climate modeling, hydrological studies and surface water modeling. The Hydrology Directorate of the Bangladesh Water Development Board (BWDB) is responsible for hydro-meteorological data collection of water level, discharge, sediment sample, surface water quality, rainfall and evaporation. Aside from dealing with hydro-meteorological monitoring, BWDB is the principal implementing agency in the water sector and exercises the right to control the flow in all channels, rivers and aquifers, and undertake the construction of and develop the guidelines for water management structures. The Ministry of Agriculture, the Bangladesh Rice Research Institute (BRRI), the Bangladesh Agricultural Research Council (BARC), the Bangladesh Agricultural Research Institute (BARI) and the institutions under the National Agricultural Research System carry out research on the development of different crop varieties resilient to different climate stresses. They arrange for keeping stocks of seeds, fertilizers and insecticides; for the training of various levels of officers for participation in different steps of cyclone preparedness activities; allocation of funds for the purchase and distribution of seeds and fertilizers; and the implementation of post-disaster relief operations.

The primary responsibilities of the Bangladesh Meteorological Department (BMD) are to observe different meteorological parameters; analyse weather charts and make interpretations on the basis of analyses; provide weather forecasts; issue warnings for severe weather phenomena such as tropical cyclones, tornadoes, nor'westers and heavy rainfall; maintain surveillance of weather radars for probing impending tropical cyclones, nor'westers and tornadoes; exchange meteorological data, forecasts and warnings to meet national and international requirements; receive round-the-clock satellite imageries for timely use in operational meteorology; and extract and process, archive and publish climatic data for use of various interested agencies at home and abroad. The Flood Forecasting and Warning Centre (FFWC) of the BWDB is responsible for flood monitoring and early warning dissemination at the national level. Existing tidal water level monitoring stations for measuring the change in the sea level are grossly inadequate to represent the climate change induced sea level rise at local scale, as most of the stations are influenced by morphological and anthropogenic responses. The Survey of Bangladesh measures sea level rise quite efficiently through only one existing station at the coast. Moreover, the Bangladesh Inland Water Transport Authority (BIWTA) is also responsible for measuring water level, both tidal and non-tidal at different locations.

The Ministry of Local Government, Rural Development and Cooperatives, and its associated implementing organizations such as the Local Government Engineering Department (LGED) are responsible for encouraging local government agencies to build roads, bridges and culverts for communication to cyclone shelters and growth centres geared towards climate change adaptation. LGED is responsible for integrating climate change impacts on various infrastructural development projects. Among the various other agencies and service providers, the notable ones are the Department of Fisheries and the River Research Institute (RRI). The Soil Resource Development

Institute (SRDI) is responsible for measuring soil salinity level and so on. It is clear that monitoring the evidence and future of climate induced hydro-meteorological disasters is already built in with the day-to-day responsibilities of different organizations, but integration is grossly inadequate to reach a common consensus on the evidence of climate change and to combat the incremental risk exposures.

The Ministry of Health and Family Welfare/DG-Health is responsible for leading country-wide disease surveillance; ensuring adequate availability of ambulances, medicines, vaccines and surgical equipment in the health centres of disaster prone areas; educating people about health care through radio, television, newspaper and other media during floods and after cyclones; and establishing temporary hospitals and cyclone shelters to meet emergency needs.

GoB has already formed a Climate Change Cell in the Department of Environment under the administrative jurisdiction of CDMP, a collaborative initiative of the Ministry of Disaster Management and Relief (MoDMR) and UNDP with the core objective of strengthening national capacity to manage risks related to disasters, as well as the immediate response and recovery efforts. It is a two-phase project with phase I extending from 2004 to 2009 and phase II from 2010-2014; phase I laid the foundations for institutionalizing risk reduction approachs and frameworks and phase II focused further on the integration and mainstreaming of disaster risk reduction (DRR) and climate change adaptation (CCA) into other relevant sectors. Although this project has officially ended its tenure, it can however, through its outcomes, play a significant role in establishing a national level climate monitoring centre encompassing SPARRSO, BCAS, Bangladesh Institute of Development Studies (BIDS) and other government and independent institutions that have a significant role in carrying out research about climate change and global warming.

6.5 Capacity Building

Climate change is not a new concern for Bangladesh as it is for other countries. Whatever policies or plans Bangladesh has formulated, they cannot be effective unless strong action is taken for capacity building. Different concerned organizations and authorities are trying to improve and strengthen capacity building programmes in Bangladesh and these will be discussed in the following section.

6.5.1 Status of national programmes

The existing BCCSAP, 2009, NAPA, 2009 and the 'Outline of the Perspective Plan: Vision 2021' addressed capacity building on climate change adaptation programmes. Noticeably, NAPA, 2009 gave special emphasis to institutional capacity building to implement a climate change adaptation programme. It suggested a short-term project in relation to this entitiled *'Strengthening human resource capacity by Ministry of Planning and other respective Ministries' (MoEF, 2009b).*

Ministry of Planning implemented Poverty, Environment and Climate Mainstreaming (PECM) with the outcome of supporting the integration of climate change and environmental considerations into national development planning and budgeting processes. Under this project, advocacy and training at the national level are organized by the PECM project to enhance the capacity of the planning commission and other development agencies to design and implement pro-poor, environmental friendly, climate and disaster resilient development projects. This project was initiated in 2010 and completed in December 2013 (UNDP, UNEP & GoB 2014).

More than 400 projects have been approved under the BCCTF for adaptation, mitigation, technology transfer, action research and knowledge management. The investment to implement six thematic areas of BCCSAP shows that 44.24% (the highest allocation) goes to infrastructure and 1.93% (the lowest) goes to capacity building and institutional strengthening (Pervin, 2013). The programmes implemented under this plan are detailed below.

6.5.1.1 Cluster-Capacity Development Technical Assistance (C-CDTA), 2009

ADB approved C-CDTA on 16 March 2009 for Supporting Implementation of the BCCSAP with an amount equivalent to $2 million equivalent for the Government of Bangladesh. The aim of the C-CDTA was to enhance the capacity of the MoEF and other relevant ministries and line agencies for project preparation, implementation, and policy formulation in relation to BCCSAP (ADB, n.d.).

6.5.1.2 Strengthening the Environment, Forestry and Climate Change Capacities of the Ministry of Environment and Forests and its Agencies (September 2013-August 2016)

The project aimed to strengthen the human and organizational capacity of the MoEF and its agencies by improving their effectiveness, organization and sustainability to better address challenges in environmental, forestry and climate change issues. Key activities include developing a country investment plan (CIP); preparing a research master plan, a gender strategy and action plan and a monitoring and evaluation strategy and plan; and arranging trainings, workshops, seminars, and consultative stakeholders' meetings. This project was funded by FAO and implemented by MoEF. Project expenditure was BDT 3486 million (FAO, 2016).

6.5.1.3 Bangladesh: Climate Change Capacity Building and Knowledge Management (2013-2015)

ADB provided technical support to institutionalize climate change information and knowledge management (CCIKM) and enhance government capacity on climate change adaptation (CCA). Major components of the TA included:

- A web-based portal on climate change information and knowledge management (CCIKM) network at MoEF. The web was approved by MoEF and hosted by Bangladesh Computer Council in 2014;
- Institutional capacity enhancement of MoEF and relevant agencies with respect to information and knowledge management (IKM) on climate change adaptation (CCA). A report on capacity needs assessment on CCA was prepared and disseminated; and
- Prioritized research to fill the current knowledge gaps on CCA. A report on knowledge gap assessment on CCA was prepared and submitted to MoEF on 29th October, 2013 (ADB, 2016).

6.5.1.4 Bangladesh Climate Change and Gender Action Plan, 2013

In 2013, realizing the need to mainstream gender issues in development initiatives to increase resilience, the government facilitated preparation of the Bangladesh Climate Change and Gender Action Plan. The document is a result of consultations with the representatives of ministries, universities, civil society and development practitioners, contextualized especially by the pillars of Bangladesh Climate Change Strategy and Action Plan 2009 (MoEF, 2013). This plan provides guidance on policy issues and initiatives that need to be taken into consideration by government and development practitioners, in collaboration with different institutions to address climate change in a gender sensitive manner.

6.5.2 Information on education, training and public awareness

Education is an indispensable component when it comes to effective implementation of adaptive measures. It is of great value when those who need help can already, to some extent, help themselves. The concept of climate change has to be incorporated in a mass information system through careful structuring and dissemination. Information deliverance should be carried out on a need-to-know basis. Poor communities affected by climate change for instance, have no use for knowledge regarding the science behind the climate change mechanism, but can instead benefit profoundly from knowledge regarding the specific relevant impact of climate change and how to best cope with it through proper utilization of available resources. From such vision stems the obligations of parties under article 6 of the convention which deals with climate change education at its broadest sense. It envisages that an absolute requirement for raising global climate action is to first ensure that everyone concerned knows both the dangers of climate change and the enormous opportunities that arise by adopting the solutions to it. This section thus deals with the current state of affairs regarding climate change education, training and public awareness as guided by the user manual provided by UNFCCC (UNFCCC, 2003) for preparing the national communication and particularly following the template for preparing the activities (UNFCCC, 2007).

6.5.2.1 Institutional Framework

The Ministry of Education has adopted a syllabus which promotes the study of climate change. A number of public and private universities have introduced honours, master's and/or diploma courses on climate change related curricula including adaptation to climate change induced disasters and risk mitigation. The Institute of Water and Flood Management (IWFM) under Bangladesh University of Engineering and Technology (BUET) provides both diploma and masters courses on climate change, climate hazard and disaster risk management and climate change adaptation. The Institute of Disaster Management and Vulnerability Studies under the University of Dhaka (DU) is an academic and research institute, sharing disaster and vulnerability related experiences and knowledge through training and regular curricula. Some of the universities in Bangladesh have joint progammes with foreign universities to introduce climate change intensive research and training at post-graduate level. The Bangladesh Public Administration Training Centre (BPATC) has initiated training programmes on climate change for public service cadres.

The International Centre for Climate Change & Development (ICCCAD) is focused on the connections between climate change and development and offers high quality short courses to staff from NGOs, universities, government departments and so on. It is the first international centre based in a developing country that links development with climate change, and aims to build capacity for those faced with the challenges of adaptation in the context of development.

6.5.2.2 Level of awareness and understanding

Awareness building among those most vulnerable in the population is of importance in effective climate change response and has increased in recent years. Recent UNDP support has ensured the inclusion of disaster risk reduction and climate change adaptation skills into the National Curriculum and Textbook Board for school-age children (UNDP, 2014). In addition, a number of non-governmental organizations (NGOs) and civil society organizations (CSOs) are working in facilitating awareness raising on basic concepts of climate change, the risks involved, and possible ways to address related issues (The Asia Foundation, 2012).

6.5.2.3 Implemented or planned initiatives and activities

A Climate Change Study cell has been established in the Bangladesh University of Engineering and Technology (BUET) in collaboration with the Department of Environment (DoE) to make it into a premier knowledge centre on climate change risk and adaptation in Bangladesh. There have been several important training programmes from time to time by the Climate Change Cell (CCC) of the DoE as well as by the Climate Change Study Cell (CCSC) of BUET in various organizations that provide higher education.

6.6 Information and Networking

6.6.1 Efforts to facilitate information sharing

The most common ways of information sharing are seminars and workshops, publications and on websites, this last being the best means across countries. A concerted effort needs to be made to ensure government websites are up to date with information regarding research, project statuses, training workshops, conferences and publications.

Several web-based networks have been developed for information sharing. The Disaster Management Information Network (DMIN) Portal under the Ministry of Disaster Management and Relief shares, coordinates and disseminates disaster management information, programmes and guidelines. An Integrated Coastal Resources Database (ICRD) has been set up to formulate and implement the Integrated Coastal Zone Management Plan (ICZMP) of Bangladesh. Initial tasks include: performing needs assessments; preparing data inventory; linking with NWRD; installing hardware and software and implementing database structures; and preparing interim reports. The Water Resources Planning Organization (WARPO) has developed a National Water Resources Database (NWRD) to meet the demand for authentic data and information related to the water sector. As part of its mandated functions, WARPO maintains, updates and disseminates the NWRD continuously.

In addition, Bangladesh has also developed an international network to disseminate information and seek cooperation with and the support of other countries in combating climate change impacts. Bangladesh is a member of the Climate Vulnerable Forum where leaders of countries most vulnerable to climate change actively seek resolutions to the growing climate crisis. The government of Bangladesh hosted a ministerial meeting of the Climate Vulnerable Forum in November 2011 in Dhaka, and at the meeting the Dhaka Declaration of the Climate Vulnerable Forum was adopted by nineteen climate vulnerable countries. One of the aims of the declaration was to enhance international collaboration and support on capacity building to respond effectively and comprehensively to minimize the risks and impact of climate change. It also includes technical assistance for public and private sector capacity building and targets the development, registration and scaling-up of Clean Development Mechanism (CDM) projects with high payoffs for adaptation.

Bangladesh was also a participant at COP 21 held in Paris 2015. The aim of this conference was to achieve a legally binding and universal agreement on climate, with the aim of keeping global warming below 2°C. In this conference, leaders of 30 nations jointly issued a historic declaration linking the hands of the world's most vulnerable countries across continents. The declaration is an ambitious agreement among middle income, least developed and small island developing states worldwide for full decarbonization of the world economy, 100% renewable energy by 2050, and zero emissions by mid-century in order to keep the world on track for below 1.5 degrees of warming (The Climate Vulnerable Forum, 2015).

Along with government initiatives, a number of private initiatives also exist. International Institute for Environment and Development (IIED) helped to set up the International Centre for Climate Change and Development (ICCCAD), an organization providing world-class training on climate change and development, with a focus on adaptation to climate change. Based at the Independent University, Bangladesh (IUB), and established in 2010, it is the first such specialist training institution working in a developing country. ICCCAD provides training that draws on local experience, knowledge and research into climate change adaptation in Bangladesh. ICCCAD runs regular short courses for NGOs, donors, the media, government staff and the private sector. In 2013 it launched a Masters programme in Climate Change and Development at the Independent University, Bangladesh. Another initiative is the Capacity Strengthening of Least Developed Countries for Adaptation to Climate Change (CLACC) which is a network of fellows and international experts from Africa and Asia. They work under IIED auspices to support Least Developed Countries (LDCs) as they adapt to climate change impacts (IIED n.d.).

6.6.2 Efforts to Engage in and Facilitate Regional and International Networking

There are several regional and international networks of which Bangladesh is a part. The networks have proven to be an efficient and effective tool for scaling up capacity development action on the ground, bringing international attention to local experience and for the rapid dissemination of best practice and basic principles.

Networks include:

International Network for Capacity Building in Integrated Water Resources Management- Cap-Net. (Cap-Net, 2014).

The South Asian Network for Development and Environmental Economics (SANDEE). SANDEE is a regional network that uses economic tools and analyses to address South Asia's environmental challenges. Since 2000, SANDEE has been transforming research on economic development and environmental change into knowledge mobilization for policy reforms. SANDEE works in seven countries in South Asia – Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka (SANDEE, 2015).

The Climate Action Network (CAN).

CAN is a global network of 1,100 members in over 120 countries which promotes government and individual action to limit human-induced climate change to ecologically sustainable levels. Several Bangladeshi NGOs are members of CAN (Climate Action Network-International n.d.).

The Global Water Partnership (GWP).

GWP is a dynamic network with over 2,000 partner organizations around the world. The network is open to all organizations involved in water resources management: developed and developing country government institutions; UN agencies; bi- and multi-lateral development banks; professional associations; research institutions; NGOs; and the private sector. GWP has several stakeholders from Bangladesh, both individuals and NGOs. Such a network helps to connect water resources planning and operations on different levels - trans-boundary, regional, national and local - for more integrated and sustainable action.

6.6.3 Constraints in information sharing and networking

Information sharing and networking itself is not an easy task. Organizations need to work across organizational boundaries to build relationships and create a shared understanding of problems. Since climate change is a cross-cutting issue, no single authority coordinates information sharing, and the process can be fragmented.

Chapter 7

Limitations, Uncertainties, Completeness, Constraints and Gaps: Lessons Learnt

7.1 Preamble

The Initial National Communication and Second National Communication (SNC) of Bangladesh suffered from many limitations. Not only there were problems of data availability, quality and form but also of analyses based on such data. The TNC is much improved in that sense, yet it suffers from some of the same or similar problems. The issues of concern related to data, analysis, content, consistency, relevance and others by major elements of the TNC are described below:

7.2 Issues Related to National Circumstances

7.2.1 Limitations

This report could have been more informative if there were scopes of original research. In updating data and in creating nexus between climate change and other sectors (particularly, the poverty-climate nexus) empirical researches considering geo-spatial dynamics of economy and climate were found to be few and far between.

7.2.2 Uncertainties:

Climate change impact in South Asia and concurrently in Bangladesh has a lot of associated uncertainties. IPCC models display varying levels of projections for temperature rise, rainfall change and also sea level rise. Further, there are also arguments against IPCC projections. Lastly, climate variability coupled with climate change make it hard to distinguish the main factor behind any extreme natural events.

7.2.3 Completeness:

The report used recent and complete data and continued to update data until October, 2016. The analysis for this report was carried out according to the requirements of the ToR and was conducted analytically to present research and findings in an informative way. The section on climate change, poverty and gender is a vast improvement on the information available in the Second National Communication (SNC).

7.2.4 Constraints:

One major constraint in preparing the TNC was the limited number of available scientific research papers and books on climate change variability and climate change in the context of Bangladesh. Further data on different demographic characteristics, economic variables and social indicators are not aggregated in a way that could be readily used for comparison and analysis.

7.3 Issues Related to National Green House Gas Inventory

The scope of improvement with reference to the national GHG inventories presented in the TNC includes; (i) adherence to the TACCC (Transparency, Accuracy, Consistency, Comparability and Completeness) principle for developing National GHG Inventory; (ii) development of different inventory life cycle documents such as the institutional arrangement (IA), template methods and data documentation (MDD), and detailed QA/QC procedures etc. to ensure the highest quality of GHG inventory; (iii) identification of data gaps on different sectors and addressing those with proper explanation in light of IPCC GL; (iv) for the first time, the development of an and addressing those with proper explanation in light of IPCC GL; (iv) for the first time, the development of an archiving system at the DoE to preserve the necessary inventory works and data-base duly providing necessary references in it; (v) a national inventory improvement plan with a focus on addressing the data gaps and sustainable inventory development capacities within and outside of the nodal agency, i.e. DoE; (vi) inclusion of additional GHG pools identified in IPCC 2006 guidelines (IPCC 2006) for the preparation of national greenhouse gas emission inventories that were not included in INC and SNC; and (vii) a strong emphasis on QA/QC procedures as identified in IPCC Good Practices Guidance 2000 and 2003 (GPG 2000, 2003).

7.3.1 Limitations:

The limitations of GHG inventory are covered in the respective sections. In both agriculture and in the Land Use, Land use Change and Forestry (LULUCF) sector, due to the unavailability of country specific historical data or information on land use and land use change, countrywide livestock numbers and characteristics and data on organic amendment for crop cultivation, the respective estimation encounters data limitations, described in section 3.16 at length.

As the availability of quality and reliable data is a prerequisite for producing a credible national GHG inventory, for future national communications, concerted efforts will need to be strengthened in order to have an extensive data set with increased spatial and temporal coverage of all kind of land classifications. Once such a robust data collection system is developed, even Tier II GHG inventory reporting would be possible for the country in the near future.

Capacity development of the respective agencies liable for GHG data in these sectors is essential to address the data limitations issue. It is important that these agencies know what they need to provide and in which format. Also, their internal data recording systems need to be established so that they can track the information and make it available during the next phase of national inventory or for the bi-annual update to UNFCCC.

7.3.2 Uncertainties:

Estimation of greenhouse gas emissions (GHG) may encompass uncertainties for a variety of reasons such as the availability of sufficient and appropriate data and the techniques to process it. Understanding the basic science of GHG gas sources and sinks requires an understanding of the uncertainty in their estimates.

Uncertainty is higher for some aspects of a GHG inventory than for others. For example, past experience shows that, in general, methods used to estimate nitrous dioxide (N_2O) emissions are more uncertain than those used to estimate methane (CH_4) and much more uncertain than those used to estimate carbon dioxide (CO_2). If uncertainty analysis is to play a role in cross-sectoral or international comparison or in trading systems or compliance mechanisms, then approaches to uncertainty analysis need to be robust and standardized across sectors and gases, as well as among countries.

Uncertainties of the CO_2 emissions from fuel combustion are elaborated in section 3.7 at length. Since the emission factors used were IPCC default values, the IPCC default uncertainties apply. Expert judgments were used for the estimation of the uncertainties associated with activity data. In most cases the total fuel supplied to a given sector was known with very little uncertainty. The problem arose when that had to be disaggregated into user categories or end-uses. The level of uncertainties involved in the estimation of GHGs from coal and aggregated usages of liquid fuels like kerosene and diesel are described in the uncertainty chapter with all available plausible facts and expert judgement.

Approaches to estimating emissions and removals in the LULUCF sector frequently involve the use of detailed data and computer models to simulate the complex functional relationships that exist in natural systems. One consequence of using more detailed methods however is that the estimation of uncertainty also comes more into play. Despite conceptual and technical challenges, powerful tools for combining different kinds of information from multiple sources are becoming available and are increasingly being used by modellers to reduce uncertainties in the LULUCF sector. These tools allow modellers to increase their focus on model validation and on reconciling results from alternative approaches. However, one key barrier remains. Reporting under the UNFCCC and Kyoto Protocol provides only a partial account of what is happening in the LULUCF sector of Bangladesh. To close the validation loop would require the adoption of full carbon accounting. Despite improvements in approaches to estimating uncertainty in emissions and removals in the LULUCF sector, some challenges remain. The treatment of this sector in future policy regimes requires special consideration.

Although the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000) recognizes that the uncertainty of estimates cannot be totally removed, the main objective should be to produce accurate estimates, i.e., estimates that are neither underestimated nor overestimated, while at the same time, whenever possible to look for ways to improve estimate precision. The estimates of emissions of greenhouse gases from agriculture sources presented in this inventory are subject to uncertainty due to several causes. Key uncertainties arise from the emission factors and activity data or lack of precision of basic data, and lack of comprehensive knowledge of the processes that cause emissions of greenhouse gases. In addition, because of the absence of country-specific emission factors for different sources, the emission is either underestimated or overestimated. There is no continuous or regular monitoring of all agricultural sources of GHG emission in the country. Therefore, due to a lack of adequate data, the uncertainty in emissions could not be statistically analysed. However, based on expert judgment and data quality, an effort was made at least to present qualitative estimates of uncertainty for CH_4 and NO_2 emissions from different agricultural sources.

7.3.3 Completeness:

Data by activity and fuel types for different sectors are found at different states of completeness. The data on natural gas is relatively complete. Other liquid fuels were available as being aggregated, but detailed breakdowns were not available in many cases. However, the relative accuracy is perhaps not very important because natural gas is by far the largest fuel source in Bangladesh. Table 3.18 in Chapter 3 presents a summary of the fuel combustion activities in different sectors, data source, fuels used in those sectors, and comments on the state of completeness or availability of data. Table 3.19 in the same chapter also presents the CO_2 emissions.

With respect to the completeness of the GHG inventory of Bangladesh, the following observations can be made:

1. The fugitive emissions from gas related activities could not be accounted for. As discussed in the section on uncertainty, there are no estimates in the country of how much leakage is occurring in transmission and distribution lines. The problem is aggravated by the fact that the reported system loss includes both leakage and unaccounted for gas (UFG). Leakage has to be accounted as methane emission, while UFG is carbon dioxide emission. As a result, IPCC default procedures were followed.
2. Even though the total supplied diesel is shown as consumed in various sectors, it is common knowledge that between 100,000 and 300,000 tonnes of diesel are smuggled into neighbouring countries because of the favourable price differential. This represents an unknown quantity that the inventory could not account for.
3. The actual consumption for many fuel items at the consumer or device level could not be known. These all had to be estimated either from the supply side or by using expert judgment. For example, diesel use in farm equipment, country boats and generators is not known; gasoline use in small household generators is not known; coal use in brick kilns is not known; kerosene use for cooking is not known.
4. The fraction oxidized for coal is not known because the combustion process takes place in a crude kiln, and often the unburned coal is sold to rural commercial establishments such as restaurants.
5. Quantity of furnace oil (FO) in different sectors is not known. But from expert judgment, it is known that the predominant use is in the energy sector. All FO was, therefore, allocated to that sector.
6. A certain quantity of FO enters the country as bunker fuel from end-of-life ships, imported to be broken down for steel scraps. This could not be accounted for.
7. Lack of good data at the device level posed a big challenge in preparing the sectoral approach inventory. Even though this did not affect the CO_2 emission estimation, the estimation of the other gases is greatly affected.
8. Only the three main GHGs have been reported. The inventory has not dealt with other gases such as CO, NOX, SO_2 and NMVOC.

7.3.4 Constraints & Gaps

There was no systematic import data found on imported coal from neighbouring India. One of the main reasons is cross-border smuggling. As a result, based on the number of operational brick kilns and other secondary reports published by the World Bank and the ADB, coal data was in-putted in the inventory analysis. This represents a data gap which could be addressed by systematic record keeping in national inventory.

Data collection from different government and private agencies is being constrained mainly due to lack of institutional capacity and awareness regarding the importance of national GHG inventory. Many countries have resolved this problem with the help of consensus government executive orders to make all the agencies accountable for providing reliable data to the national GHG inventory. In the case of Bangladesh, we may need to do something similar to attain greater accuracy in data activity.

7.4 Programme Containing Measures to Mitigate GHG Emission

Modelling mitigation measures was achieved using the LEAP model. This is an energy model that calculates GHG emissions based on fuel consumption, electricity consumption and generation capacity. For non-energy sectors (e.g. agriculture and waste), GHG emissions were calculated off-model, with the resulting GHG figures being inputted into LEAP.

For the energy-related sectors, BAU emissions were calculated by combining fuel consumption with the appropriate emissions factors in LEAP. Where possible, fuel demand was calculated by looking at current activity (e.g. numbers of appliances, numbers of vehicles etc.) and current efficiency (e.g. current efficiency of appliances, current fuel efficiency of vehicles etc.) and making assumptions about how these will change over time. In some cases, lack of detailed data meant having to estimate GHG emissions from fuel consumption data, without disaggregating it by activity.

The BAU was calculated as a 'without measures' scenario, meaning that rather than predicting the future effect of government policy, it forecast emissions on the assumption that no further action was taken.

For mitigation options, a long list of possible mitigation measures was produced based on a review of key documents, including the Second National Communication, Bangladesh's Technology Needs Assessment and the Bangladesh Climate Change Strategy and Action Plan, and by adding other possible measures where the project team deemed it appropriate. This long list was then reduced to a shortlist by assessing each measure against four criteria – abatement potential, cost, technical feasibility and co-benefits. The shortlist of mitigation measures, and the reasons for including them, is outlined in the detailed chapter.

7.4.1 Limitations, Constraints and Gaps:

A business as usual (BAU) scenario was modelled covering all sectors of the economy apart from the land use, land use change and forestry sector (LULUCF) due to difficulties in obtaining the necessary data. In addition to the BAU scenario, three mitigation scenarios were modelled by making different assumptions about the level of effort possible. The analysis of mitigation potential was carried out for all sectors apart from LULUCF (for the reasons mentioned above). These represent those sectors for which data on abatement potential and cost was most available and robust.

Different analytical approaches were taken for different sectors. Where more robust data was available, future GHG emissions were calculated on the basis of preferred technologies, looking at numbers and efficiencies of individual technologies (or in the case of the non-energy sectors, activity numbers and emissions factors). This approach was taken for the power sector, for electricity use in the household sector and for non-energy emissions from agriculture and waste. Where detailed data was not available, a more high-level approach was taken, for example calculating sectoral emissions from projections of fuel use for the sector as a whole (e.g. commercial buildings, industry). For the transport sector, a hybrid approach was taken. For the road transport sector, emissions were calculated for individual modes using data on fuel efficiency, distance travelled and number of vehicles per mode. For the other transport sectors (rail, water and air), a lack of reliable data meant that GHG emissions were simply calculated by taking the emissions figures from the Second National Communication and projecting these forward based on projections of activity (e.g. passenger numbers).

The energy efficiency improvements were based on expert judgement following discussions within the project team. The proportion of the sub-sector taking up the energy efficiency measures was based on the timetable for energy audits set out in EE&C Master Plan. Hence the team made assumptions on the proportion of sub-sectors taking up energy efficiency measures for lower, medium, and higher ambition scenarios.

- The project team decided to model the effect of all mitigation measures together, i.e. energy efficient appliances and energy efficient lighting, cooling measures, and rainwater harvesting. The figures chosen for modelling the energy efficiency improvement for the overall sector in the three scenarios are: 12%-20%-25% for the low, medium and high ambition scenarios respectively. The project team started by using as reference the energy efficiency and conservation potential for the commercial sector in the EE&C Master Plan, i.e. 50% of potential. However, the team felt that the full potential was not reasonably achievable because of limitations in building design and other technical factors. Consequently, it was considered that half of the full 50% potential (i.e. 25%) was achievable in the higher ambition scenario.
- The team modelled the overall fuel consumption for the BAU in line with GDP growth, but instead of 1:1 growth GDP/fuel, 1:0.5 was used as there is no more land for extensive agriculture, but growth in food production will increase due to intensification and therefore the growth of diesel for irrigation will not go up exponentially. No mitigation measures were modeled for this sector.
- Given the timescales over which migration options are to be assessed (the next 15 years) and the fact that at present residual waste collections are not fully in place across urban areas, the mitigation options available to be introduced are limited.
- The project team took current HCFC consumption (2010) from a 2011 report prepared by the Government of Bangladesh and the United Nations Development Programme (UNDP)[37], and an assumption was made that there was no f-gas consumption in 2006-2012. Assumptions were made about which f-gases the HCFCs would be replaced by, based on a report from the Bangladesh University of Engineering and Technology. A rate of phase-out of HCFCs was assumed based on the Montreal Protocol. In the absence of any reliable information on replacement rates, we assumed this to be 1:1 (this is a simplifying assumption and could be improved with better data). Growth in consumption for the different uses (e.g. air conditioning, foam manufacturing, refrigeration etc.) was assumed to be 2% a year. This is based on the statement in the 2011 report mentioned above that: *"If left unrestricted, the total HCFC consumption would grow at least 10% in the next 5 years".* 10% in 5 years equates to a 2% year on year growth. The global warming potentials were applied (6.3 in most cases, except for R32 which is 675).

7.5 Issues Related to Adaptation and Vulnerability

Uncertainties and Limitations

Climate change comes with inherent sources of uncertainty, including uncertainty about extent and patterns of future climate change. These are primarily dependent on uncertain socio-economic development pathways and climate policies, and uncertainty about the reaction and adaptation of ecosystems (IPCC, 2014). Climate change associated uncertainties and limitations are eventually propagated to the assessment of future vulnerabilities, impacts and adaptation and may influence policy and decision-making processes for adaptation. The following are the major uncertainties and limitations in the Bangladesh context:

Projections for climate change scenarios are required to assess future vulnerabilities and impacts and to forge ahead with adaptation planning, design and implementation. Uncertainties in climate change scenario projections arise from three primary sources: (1) natural climate variability resulting from natural processes within our climate system. These processes cause changes in climate over relatively short time scales; (2) uncertainty in the emission of future greenhouse gases that is linked to socio-economic and technological development, energy uses and policies to reduce emissions; and (3) modeling uncertainty arising from incomplete understanding of earth system processes, interactions of various components and their incomplete incorporation in the climate models.

The second level of uncertainty arises from models used for estimating impacts on water, agriculture, fisheries, livestock, and human health. These models range from simple to complex and the number of model parameters

37 Bangladesh: HCFC phase-out management plan (HPMP STAGE-1) for compliance with the 2013 and 2015 control targets for ANNEX-C, GROUP-I substances, August 2011

varies largely. Many of the parameters are not measured from the fields, are approximated by trial and error and could be unrealistic. The model parameters' uncertainties are finally propagated to the results. Uncertainty could also arise from the boundary conditions, for example, in the case of hydrologic modeling of an international river basin. Uncertainty associated with prediction of future pests, disease, and invasive species remains high (Dukes *et al.,* 2009).

Apart from climate change uncertainty, the future adaptation of Bangladesh's water, agriculture sectors and coastal ecosystems (e.g., mangroves in the Sundarbans) is highly dependent on a consistent and adequate water supply in international rivers. Increased water withdrawal and uses in the upstream catchment areas and uncertainty in downstream flows will certainly affect Bangladesh's own water and agriculture adaptation planning and development in the future.

The geographical location of Bangladesh in the Ganges, Brahmaputra and Meghna river systems adds uncertainties in terms of the management of natural disasters, particularly floods. The country's coping mechanism would benefit from cross-border timely communication of flood forecasting and warning. Basin-wide disaster management and adaptation planning would also reduce uncertainties for all co-basin countries.

Engineered adaptation options typically have two limitations. First, they must often cope with uncertainties associated with projecting climate impacts arising from assumptions about future extreme weather, population growth, and human behaviour (Dawson, 2007; Furlow *et al.,* 2011). Second, the engineering and cost of engineered infrastructure affect the feasibility of a project at the outset (Koetse and Rietveld, 2012).

A variety of tools are required in adaptation planning and implementation. Successful adaptation planning requires information and knowledge on climate risks from various stakeholders and organizations. There are institutional limitations and uncertainty in Bangladesh regarding the gathering and supply of such information and knowledge in coordinated and systematic ways.

The cost-benefit analysis of an adaptation project under uncertainty remains a major challenge. The analysis process uses subjective probabilities for different climate futures. The 'best' project is one that maximizes the expected net present value of costs and benefits. Cost-benefit analysis requires market and non-market valuations of costs and benefits. Valuation of non-market impact is difficult because of values and preferences heterogeneity (IPCC, 2014). There are also methodological limitations of cost-benefit analysis.

Organizing adequate financing for the future remains a challenge for Bangladesh. Uncertainty is already looming on the pledges made for adaptation funding under the Paris Agreement. Although Bangladesh has made significant economic and social progresses in recent years, continued investment is required for poverty alleviation and development of social sectors. Investment for climate change is an additional burden and in the context of other priorities, there is an uncertainty regarding the country's own contribution towards adaptation funding.

7.6 Other Relevant Information

The information provided here is by and large qualitative and there is not much uncertainty about it. The requisite information is however scattered over many institutions and a challenge to collect. One type of information which is lacking is that concerning the effects and impacts of various climate change related interventions and policies by type of sector or activity.

7.7 Assessment of the TNC Experience

Two problems have arisen and need to be kept in mind for future such exercises which will be somewhat more complex as these NCs may be used for MRV as well as as the basis for biennial updates of GHG emissions and mitigation measures. The first of these is the lack of relevant and quality data. To remedy the problem, there should be a continuous data and knowledge management system and the development of relevant data bases for use in NCs as well as for other climate change management purposes. The second is the lack of requisite analyses of climate change, mitigation, vulnerability and adaptation measures. For this, a number of modeling exercises have to be undertaken and continuously improved. In this regard, a substantial scaling-up of capacity at various levels and institutions, including formal educational programmes at the level of higher education, should be undertaken.

Annexure-A

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