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Second National Communication of Bangladesh to the United Nations Framework Convention on Climate Change

Ministry of Environment and Forests
Government of the People's Republic of Bangladesh

October 2012

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FOREWORD

Climate change is now considered as one of the greatest challenges not only to the national and regional governments but also to the world community. The international scientific community has proved that global warming of the climatic system is unequivocal. As a result of global climatic disorder the sufferings of humankind have already increased remarkably specially in Least Developed Countries.

All Parties 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, need to periodically report to the Convention a National Communication as per Article 4.1 and 12.1 of the UNFCCC.

Towards fulfillment of obligation under the Convention, Bangladesh submitted its Initial National Communication (INC) to the UNFCCC Secretariat in 2002.This Second National Communication to the Conference of the Parties reflects the firm commitment of the Government of Bangladesh to the Convention, its ultimate objective and principles.

I am pleased to note that the publication of Bangladesh Second National Communication will provide an overview on the climate change issues and status to the key stakeholders at local, national, regional and global arena. This document contains National Circumstances, Greenhouse Gas (GHG) Inventory, Programmes containing measures to mitigate climate change, Vulnerability and Adaptation and the lines of research, education and systematic observation specific to the topic.

Bangladesh's Second National Communication Project funded by the Global Environment Facility (GEF) through the 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.

The project has alerted policy makers to the need to mainstream climate issues in the national policy and legal framework. It has helped to enhance the capacity of the scientific and research communities of Bangladesh in formulating and planning mitigation and adaptation policies, options properly. The project has further highlighted the need for stronger effort to spread awareness among stakeholder groups and decision-makers.

Bangladesh needs to strengthen the coordination, networks and information flows between ministries, different levels of government and civil society to have a more efficient integration of climate change variables 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 and Forests, Department of Environment, other related government and non-government organizations, consultant team and individuals for their dedication and commitment in the preparation of the document through a participatory process, which included a series of workshops, seminars and meetings involving all key stakeholders.

Finally, I request all the officials, experts and stakeholders to make their best efforts to utilize the information and knowledge of this document for our national, regional and global benefits.

Dr. Hasan Mahmud, MP
Minister
Ministry of Environment and Forests

PREFACE

As a part of the global obligation under the United Nations Framework Convention on Climate Change (UNFCCC), the Government of Bangladesh has prepared its Second National Communication in accordance with the guidelines for the preparation of National Communications from non-Annex I Parties (17/CP.8) adopted by the COP, and to strengthen the national communication process.

Bangladesh submitted its Initial National Communication report in 2002 and where the focus was given on emission inventory and also on the impact and vulnerability of climate change on different sectors and bio-physical systems. But in the Second National Communication (SNC) report an updated status of emission inventory along with the impact, vulnerability, adaptation and mitigation issues are elaborated.

Climate change already impacts overall development efforts. It threatens to undermine development achievements and slows progress towards the achievement of the millennium Development Goals (MDGs), especially those dealing with hunger and poverty reduction and ensuring environmental sustainability. The agriculture and forestry sectors are central in this regard because they are not only affected by climate change and contribute to greenhouse gas (GHG) emissions but also offer opportunities for cost-effective mitigation options with additional benefits for development and food security. Besides, energy, industry and waste sectors also contribute to GHG emissions. Hence, with appropriate planning, mitigation initiatives and climate change adaptation can be integrated into sustainable development initiatives resulting in mutually beneficial outcomes.

This is indeed a great pleasure for us to see the Second National Communication report. Dissemination of the document is going to be a milestone event for Bangladesh.

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, non-government and private organizations, technical committees, consultants team of Bangladesh Centre for Advanced Studies and Center for Environmental and Geographic Information Services, peer reviewers, national consultant (compilation) Dr. M. Asaduzzaman, Ms. Gabriela N. Walker of NCSP, Dr. Sarwat Chowdhury of UNDP Bangladesh, Director General, Department of Environment & National Project Director Monowar Islam and Project Manager Sheikh Moazzem Hossain of SNC project for their valuable contribution and inputs for making this endeavor a success.

Mesbah

Mesbah ul Alam
Secretary
Ministry of Environment and Forests

ACKNOWLEDGEMENTS

The Second National Communication of Bangladesh is an effort of series of studies that were conducted by the Department of Environment under the Ministry of Environment & Forests. The policy makers, key government officials, experts, academia, NGOs, civil societies& media were involved to prepare this significant document.

At the outset, I would like to express my gratitude to the Honourable Minister, Ministry of Environment and Forests (MoEF), Dr. Hasan Mahmud, MP for his effective leadership in preparing this important document. I am also grateful to the Secretary, Ministry of Environment and Forests (MoEF) Mr. Mesbah ul Alam for his guidance for successful implementation of the project.

I would also like to thank our former Secretary, MoEF, Dr. Mihir Kanti Majumder for his support during the initial and mid-stage implementation period of the project.

My sincere thanks to the collective wisdom of Bangladesh Centre for Advanced Studies (BCAS), Center for Environmental and Geographic Information Services (CEGIS), experts, professionals, researchers, and environmental practitioners for their valuable contributions in preparing the Second National Communication 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. I am especially indebted to Ms. Gabriela N. Walker of National Communication Support Programme (NCSP) for her comments for developing various chapters of the document.

Special gratitude is due to Former Director General of the Department of Environment and National Project Director, SNC project Md. Nojibur Rahman and Zafar Ahmed Khan for their service rendered in the initial stage of the project. Also thanks goes to Mirza Shawkat Ali, Deputy Director (International Convention) for his involvement in the preparatory phase of SNC.

Finally, I would like to gratefully acknowledge the contribution of all the members of the National Steering Committee, National Advisory Technical Committee, Core Sectoral Working Groups, national consultants (peer reviewers), national consultant (compilation) and all the professionals of the Ministry of Environment and Forests and the Department of Environment, professors of Bangladesh University of Engineering and Technology and Dhaka and Jahangir Nagar Universities for providing guidance and suggestions in developing the document and preparing the final version of the Second National Communication of Bangladesh.

Monowar Islam
Director General, DoE
&
National Project Director
Second National Communication

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ACRONYMS

AEZ	Agro Ecological Zone
BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Centre for Advanced Studies
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BEN	Bangladesh Environment Network
BIWT	Bangladesh Inland Water Transport Authority
BMD	Bangladesh Meteorological Department
BPDB	Bangladesh Power Development Board
BSC	Bangladesh Shipping Corporation
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CANSA	Climate Action Network South Asia
CBA	Community Based Adaptation
CCGT	Combined Cycle Gas Turbine
CCTF	Climate Change Trust Fund
CCC	Climate Change Cell
CCU	Climate Change Unit
CDM	Clean Development Mechanism
CEGIS	Center for Environmental and Geographic Information Services
CH_4	Methane
CO_2	Carbon dioxide
CO	Carbon Monoxide
COP	Conference of the Parties
DMI	Dry Matter Intake
DMIN	Disaster Management Information Network
DRR	Disaster Risk Reduction
DSSAT	Decision Support System for Agro technology Transfer
EF	Emission Factor
GBM	Ganges-Brahmaputra-Meghna
GCM	Global Circulation Models

GDP	Gross Domestic Product
GEF	Global Environmental Facility
Gg	Giga grams
GHG	Greenhouse gas
GIS	Global Information System
GoB	Government of Bangladesh
GTS	Global Telecommunication System
GWAVA	Global Water Availability Assessment
GWP	Global Warming Potential
GWP	Global Water Partnership
Ha	Hectare
HDI	Human Development Index
HFCs	Hydrofluorocarbons
HRAs	High Risk Areas
HYV	High yielding Varieties
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LDC	Least Developed Country
LUCF	Land Use Change and Forestry
MAGICC	Model for the Assessment of GHG Induced Climate Change
SCENGEN	Model for the Assessment of Greenhouse-gas Induced Climate Change/ SCENario GENerator
MDGs	Millennium Development Goals
MoEF	Ministry of Environment and Forests
MPO	Master Plan Organisation
MSL	Mean Sea Level
MT	Metric Tonnes (Tons)
NAPA	National Adaptation Programme of Action
NAI	Non-Annex I Countries
NAMA	Nationally Appropriate Mitigation Actions
NCSP	National Communication Support Programme
NGO	Non-Governmental Organisation
N_2O	Nitrous Oxide
NOx	Nitrous Oxides

NMVOC Non Methane Volatile Organic Compound

PDO-ICZMP Program Development Office for Integrated Coastal Zone Management Plan

PFC Perfluorocarbons

R&D Research and Development

RE Renewable Energy

RVCC Reducing Vulnerability to Climate Change

SAARC South Asian Association for Regional Cooperation

SANDEE South Asian Network for Development and Environmental Economics

SF6 Sulfur hexafluoride

SLR Sea Level Rise

SNC Second National Communication

SO_2 Sulphur dioxide

SOx Sulphur Oxides

ST Steam Turbines

TNA Technology Needs Assessment

T&D Transmission and Distribution

UNDP United Nations Development Programme

UNFCCC United Nations Framework Convention on Climate Change

WARPO Water Resources Planning Organization

WHO World Health Organisation

WMO World Meteorological Organisation

Executive Summary

PREAMBLE

National Communication is a reflection of aggregate actions on mitigation and adaptation of a country to address the climate change. Each developed country Party is pledged bound to prepare a national communication on an inventory of anthropogenic emissions by sources and removals by sinks of all GHGs and a detailed description of the policies and measures that it has adopted to implement its commitment under Article 4, paragraph 1, and Article 12, paragraph 1 of the United Nations Framework Convention on Climate Change (UNFCCC). The preparation of National Communication by the Non-Annex I country parties are not mandatory but they will prepare this after a certain interval with the support of Annex I country party. Against this backdrop, Bangladesh submitted its Initial National Communication in 2002. Bangladesh has prepared its Second National Communication (SNC) in May 2012 to submit it to the Convention with the financial and technical support of Global Environment Facility / United Nations Development Programme (UNDP).

NATIONAL CIRCUMSTANCES

Location and Physical Characteristics: 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 bounded by India on the west, the north and the northeast and Myanmar on the south-east. The Bay of Bengal demarcates the southern border with a long coastline. The Himalayas is close to the northern border of Bangladesh. The country consists of low and flat land except the hilly regions in the northeast and the southeast and some areas of highlands in the north and northwestern part. The floodplains occupy about 80% of the country.

Three major rivers – the Ganges, the Brahmaputra and the Meghna, (GBM) - which bring inflow from India - meet inside Bangladesh before discharging into the Bay of Bengal through a single outfall. The mean combined discharge is the third largest in the world after the Amazon and the Congo. Yet, the seasonal variation in the combined flow is highly pronounced with abundant water during the monsoon and a much lower volume during the dry season. Groundwater is a significant natural resource of Bangladesh, which is used for domestic, industrial and agricultural purposes.

Climate: The mean annual temperature is about 25°C within the country. 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 during May to September. The humidity is relatively high throughout the year and it is over 80% during June to September.

Natural Resources: Land and water constitute the major natural resources of the country. Land use includes forestry. The Sundarbans is the single largest natural mangrove forest in the world. It individually covers 40% of the total forest area, which accounts for 4.07% of the country's land mass with an area of 610,700 hectare. Bangladesh is very rich in biodiversity of all types, terrestrial, marine and estuarine as well as that in wetlands inside the country. The list of medicinal plants includes more than 500 species. Timber plants number reach 224. The Sundarbans supports a very rich and diverse fish fauna of 400 species, over 270 species of birds and over 300 species of plants. Despite such richness, the biodiversity is under threat due to pressure of increasing population and other factors.

The country has a fair deposit of natural gas as well as other mineral resources including a modest quantity of good quality coal,hard rock, limestone, ceramic clay and glass sand. The main source of primary energy apart from biomass is natural gas which is used for producing electricity. Natural gas contributes more than 87% of the net power generation by the public (BPDB) and private sectors meets 24% of the country's total fuel consumption. Other primary sources of energy are hydro-electricity and solar energy.

Socio-economic Conditions: The total population of the country is around 148 million with nearly 30 percent living in the urban areas. The average population density is 993 per sq km. The national average literacy rate of male and female of the country is 49.6% and 40.8% respectively.

GDP is rising at rates higher than 6-6.5% in recent years. Per capita income in 1999/00 was around US$ 367. By 2010/11, it has risen by 122% to US$ 818. Poverty has fallen over time from nearly 60 percent in 1991/92 to 25.1 percent by 2011. The Human Development Index for Bangladesh has risen from 0.328 in 1980 to 0.543 in 2007.

The literacy rate in Bangladesh for population 7 years of age or over has increased from 51.9 to 57.9 percent over 2005-2010. It is lower in the rural areas at present (53.4%) compared to urban (70.4%). Bangladesh has progressed far in imparting primary education to its children as enrollment has risen to just about 92% by 2010 with gender parity more in favour of girls.

Agriculture, broadly defined accounts for only around 21% of the GDP but just about 45% of the labour force. Agricultural land mostly dominates the land cover of the country of which arable land occupies about 59%. The cropping intensity of the country is increasing which at present is more than 175%.
Manufacturing industry contributes just about 18% to GDP, but the main industry, readymade garments and knitwear accounts for the bulk of exports. Various kinds of services contribute nearly 60% to GDP. Among these trade and transport as well as construction services account for the major part.

There are 20,995 kilometers of highways of varying quality. The country has a total of 2,855 kilometers of rail line. Waterways constitute a major transport network.

Bangladesh has made considerable progress in the health sector especially in terms of noticeable reduction of infant and child mortality rates. The mortality rate of children less than five years of age declined in the country from 151 deaths/1000 live births in 1991 to 52 deaths/1000 live births in 2007. Bangladesh has made significant progress in extending access to safe drinking water in most districts although arsenic contamination of groundwater in Bangladesh has become a major public health issue. The sanitation situation is gradually improving.

Poverty and low income has many correlating factors including frequent natural hazards. Natural hazards, the impact of climate change and poverty have multi-dimensional relationship. For example, floods and cyclones affect culture fisheries severely while drought, salinity intrusion, erratic rainfall, heat wave, cold wave, and fogginess lead to loss of livelihood of the rural poor through their adverse impacts on productive sectors such as crop agriculture which could also increase the poverty level.

Vulnerability to Hazards: Bangladesh is one of the most natural hazard prone countries in the world because of its geographical setting and due to other associated environmental and socio-economic reasons. Bangladesh experiences tropical cyclones, storm surges, floods, riverbank erosion, droughts and many other natural disasters every year. Floods affect around 80% of land in Bangladesh at one time or other.

GREENHOUSE GAS INVENTORY

The SNC has made an inventory of Greenhouse Gases (GHG) emission for the year 2001 and 2005. The inventory covered the major categories viz. Energy, Industry, Agriculture, Waste, Land Use, Land Use Change and Forestry. The GHGs considered in the Inventory are Carbon dioxide (CO_2), Methane (CH_4), and Nitrous Oxide (N_2O) by sources and removals by sinks. The inventory also reports emissions from several other gases but not gases such as SF_6, PFC and HCF.

Energy sector: The *tier* 2 methodology has been adopted for the Energy Sector. Not all combustion activities and sectoral splits in the guidelines are relevant for Bangladesh, so only the appropriate ones have been selected. The emission of CO_2, N_2O and CH_4 were then calculated using the default heating values and emission factors for each type of fuel. Total emission by each fuel in aggregate has been estimated by way of a Reference Approach. The two methods (Sectoral and reference) compare reasonably well as there was at most 3% discrepancy between the two for some years while for the year 2005.

The summary of CO_2 emission from different sub-sectors considered under the Energy Sector. The rise of emission from 30.2 mnmt to 37.9 mnmt i.e. by a quarter or so over 2001-2005 in this sector. While most sub-sectors have experienced similar growth, four among them stand out which are energy industries, manufacturing, transports and residence. The first two accounts for a rise of 4.5 mnmt out of 7.7 mn total rise or more than one-half. Note that these two sectors already account for 63% of total energy-related emission in 2005. The summary of Energy Sector CO_2 Emission is shown in Table 1 below:

Table 1: Summary of Energy Sector CO_2 Emission (Gg)

Energy Sub-Sectors	**2001**	**2005**
1. Energy Industries	10,693	12,780
2. Manufacturing & Construction	8,755	11,276
3. Transport	4,551	5,500
4. Residential	3,811	4,675
5. Agriculture	1,625	1,993
6. Commercial	226	270
7. Non-Specified Sector	549	1,426
Total Emission from Combustion	**30,210**	**37,920**
Fugitive CO_2 Emission	23	30
Grand Total	**30,233**	**37,950**

Total Emission 2005: The contributions of the different sectors along with the total emissions for the year 2005 are summarized in Table 2. It is seen that Bangladesh in 2005 emitted only 59 mnmt of carbon di-oxide of which combustion for energy related activities accounted for nearly 38 mnmt (56%). Another 18 mnmt (or, 26.5%) was contributed by LUCF. For non-CO_2 emission, agriculture is the main source. Of the total emission of nearly 1.8 mnmt of methane, 1.2 mnmt or nearly two-thirds were contributed by agriculture. Agriculture, particularly poultry litter management accounted for the bulk of the nitrous oxide emission.

Table 2: National GHG inventory by sources and sinks (Gg), 2005

Greenhouse gas source and sink categories	CO_2 emission	CO_2 removals	CH_4	N_2O	CO	NO_X
Total (excl. biomass & bunkers)	**59067.85**		**1879.30**	**38.85**	**145.50**	**4.00**
Energy	37949.60		26.03	0.48		
Industrial processes	2912.72					
Agriculture			1215.69	33.94	145.50	3.98
Land-use change & forestry	18205.52	0.01	0.00	0.00	0.00	0.00
Waste	0.00	0.00	637.58	4.43	0.00	0.00
International bunkers*	906.00					
Biomass burning*	44010.00					

**Note*: According to IPCC guidelines international bunkers are not added to the national total but reported as a separate memo item. CO2 emission due to biomass burning is assumed to be neutralized through regeneration.

Projected GHG Emissions over 2005-30: The total GHG emissions from all energy activities i.e., in addition to the CO_2 emissions from the demand sectors, the transformation sectors and the CO_2 equivalents of CH_4 and N_2O emissions from all energy related activities are shown in Figure 1. Fig. 2 provides the picture from the demand side for energy from various sectors. As Fig. 1 shows the total energy-related emissions may differ substantially with an increase for the year 2030 of approximately 3.5 times over the 2005 GHG emission. On the other hand, among the demand sectors which use energy for various purposes (except transformation), industries appear to be the main source of emission by 2030 while transports will also be not lagging far behind. Projection of GHG (CO_2, CH_4 and N_2O) emissions is presented in Figure 1 and 2:

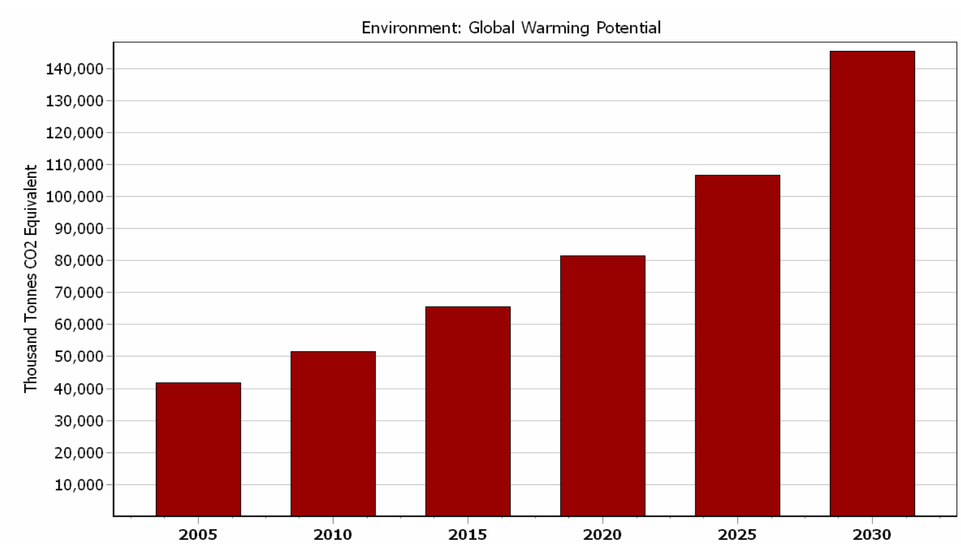


Figure1: Energy sector total GHG emissions projection for 2005-2030

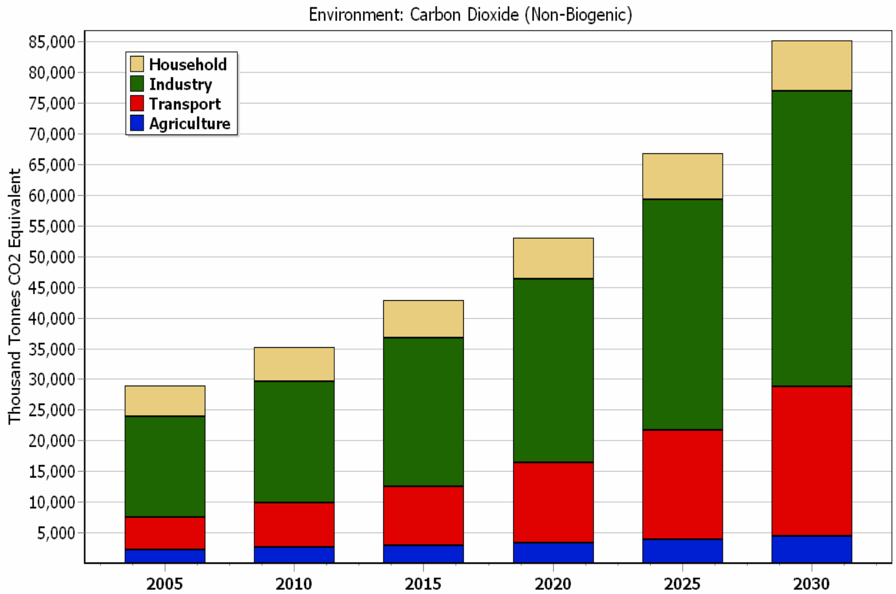


Figure 2: Projected CO_2 emissions from various demand sectors 2005-2030

Challenges in GHG Inventory and Suggested Measures

The GHG inventory faced a number of problems. The most significant of which were the lack of or limited availability of activity data in all sectors. Another uncertainly was the non-availability of local emission factors. Local emission factors may well differ from default values given by IPCC. This provoked a large uncertainly in the emission calculation. Moreover, most of the custodians of activity data were not aware of the formats in which activity data may need to be stored for practical use. Some of the custodians of data were also reluctant to supply them with a plea of confidentiality. all the data custodians needed to sensitize in order to provide the required data in a proper format that would commensurate with the data requirements for preparations of national GHG inventories.

CLIMATE CHANGE MITIGATION MEASURES

The Second National Communication considers 21 options for in-depth analysis with potentials of a total reduction of carbon di-oxide emission of 7.2 mnmt in which the highest potential contribution may come from the introduction of supercritical boilers for coal-fired power plants (1.5 mn) and new urea plants (1.3 mnmt) which together may reduce about 38-39%. However, not all may be equally costly or cost-effective. Fig. 3 compares the cost effectiveness of these options. It has been found that while options like *T&D* and *CCGT* are very expensive, like *Modal Shift from Road to Water Transport* and *Solar Lanterns*, are very attractive from a financial point of view. In fact, those measures with negative or low costs (such as those from supercritical boilers to all those to the right in the figure account for more than 5 mn. mt or 71-72% of the potential. It is worth pointing out however that because of various barriers many of these are not likely to be implemented without conscious intervention to remove them.

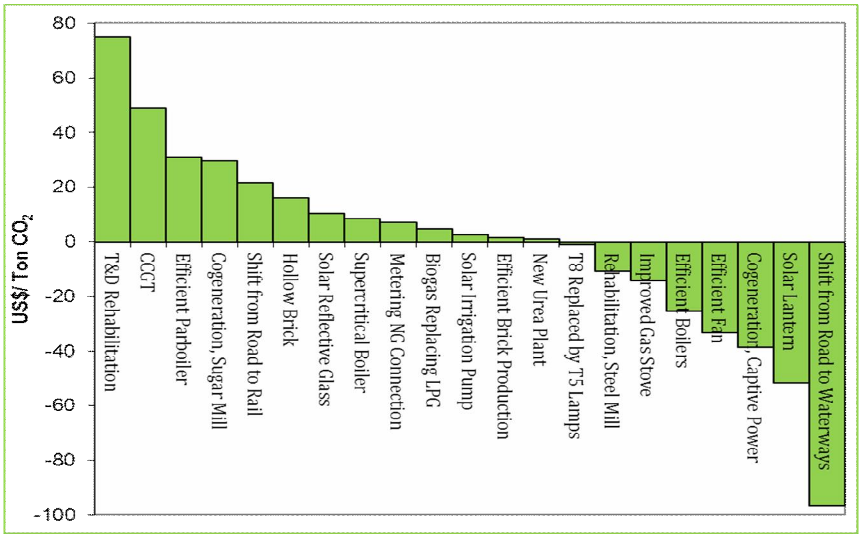


Figure 3: Cost Effectiveness of Identified Mitigation Options

Using 2005 as the base year, a GHG emission projection up to 2030 has been prepared for the SNC. This is the baseline or business-as-usual scenario. If the 21 GHG mitigation options are implemented between 2010 and 2030 according to an assumed penetration rate, emissions will be less than the baseline; this reduced emission projection is the mitigation scenario for Bangladesh. The emissions according to the baseline and mitigation scenarios are shown in Figure 4.

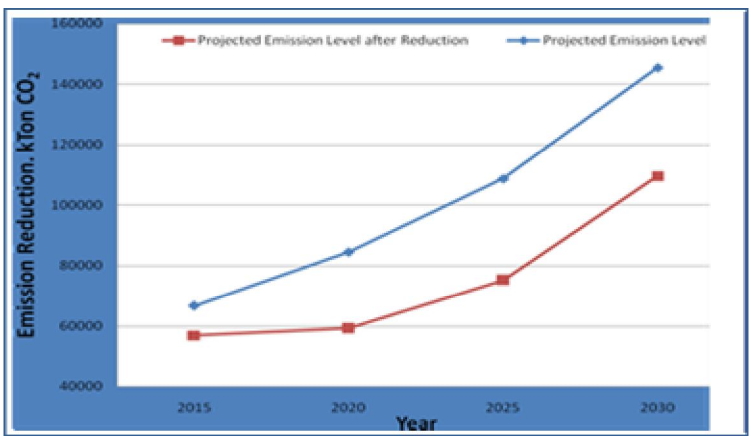


Figure 4: GHG Emissions under Baseline and the Mitigation Scenarios

Current Policies

The current policies are very conducive to energy efficiency improvement. However, the tax structure and pricing policies need to revisit to encourage the use of efficient technology and to discourage inefficient ones. Recently, the Government has declared tax exemption on solar panels and allocated nearly $15 million as soft loan for renewable energy projects. Furthermore the Government had implemented a large energy efficient lighting programme. From its own resources the Government has also created a “Climate Change Trust Fund (CCTF)” amounting to $300 million for climate change projects including GHG mitigation. Bangladesh Bank has created a separate fund around $ 25 million to support green technology in industrial and energy sector.

BANGLADESH'S VULNERABILITY TO CLIMATE CHANGE AND ADAPTATION

Bangladesh is the most vulnerable country to climate change and is in extreme risk (CCVI-Maplecroft,2010).To understand the vulnerability to climate change, one needs to first document the present climate and analyse its evolution over time, prepare climate scenario(s) for the future, assess the immediate physical impacts of climate change and how these changes along with the climate change parameters (temperature rise and precipitation changes) affects the various human systems such as agriculture, health, infrastructure, habitation patterns, other economic activities and of course the over-all growth, employment and poverty in the country. Once these are understood, only then one can discuss and analyse adaptation options in which case, the self-adaptation by people may be taken into consideration.

Methodology

Data from thirty-six stations spread over the country and at various levels of completeness have been used for trend and seasonal distribution and their analyses for temperature and precipitation over the period 1948-2008. Climate change has been measured using standard statistical procedures for parametric and non-parametric tests. The temperature records indicate a mixed picture regarding the upward trend over time.

Baseline Scenarios

For temperature, yearly maximum, mean and minimum temperatures have been analysed. For rainfall mean yearly and seasonal total rainfall volumes have been examined. A rise in the minimum temperature by 0.45˚C and 0.52˚C are observed during the winter (DJF) and monsoon (JJA) seasons respectively. The maximum temperatures are also observed to have increased during the pre-monsoon (MAM) and post-monsoon (JJA) month by 0.87 ˚C and 0.42˚C respectively.

Mean annual rainfall is about 2,347 mm, which varies within the range of 1,640 mm to 2,831 mm. The pattern of change in the rainfall is mixed and appears to indicate trend of heavier rainfall in the coastal region. Mean annual rainfall has risen systematically in only a few stations. The dry seasonal (DJF) rainfall shows little change in most cases, but where it does, the trend is downwards. During the monsoon no significant trend is observed but for post monsoon seasonal rainfall, statistically significant increasing trend has been observed in 11 out of 31 meteorological observatories (stations).

Sea Level Scenarios

Bangladesh has a large low-lying coastal zone which is very vulnerable to current coastal hazards and future sea level rise (SLR). Drainage congestion is already a growing major concern in Bangladesh due to other water management and infrastructure and is likely to be exacerbated by SLR and increased river flooding.

Observed sea level rise has shown an increasing trend over the period 1947-2003. At the southeast of Bangladesh, sea level rise was 1.4 mm/year, and in the south central part nearest to the sea it was up to 3.9 mm/year. Despite the sparse data on SLR, projections show that sea levels rise in the coast of the Bay of Bengal may reach to 27 cm by 2050. Other analyses put the rate of sea level rise to 5.05 mm to 7.4mm/yr.

How much area will be inundated by SLR depends on other weather factors such as rainfall. Depending on which of the scenarios under the GCMs is used and SLR 0f 27 cm by 2050, the area inundated may increase to 19722 sq km by 2050, for 2080 with a 62 cm SLR, the corresponding area becomes 21839 sq km. However, if there is 10% more rainfall compared to the baseline, the area inundated further jumps to 22717 sq km.

Future Scenarios

Based on the models used, the estimated rise in temperature may be an average of 1.6°C by the 2050s while aggregate precipitation will increase by 8% with respect to current averages.

Impact Analysis

Assessments of physical impacts and weather events such as floods and droughts have been made. Based on these as well as the climate changes in terms of temperature rise and fluctuations in rainfall, impact analysis has been assessed for the following sectors: Water, Agriculture, Coastal Zones, Fisheries, Forest, Livestock, Human health and Urban areas. Gender issues have been flagged as far as data allow. The assessments of the various sectoral vulnerabilities have been followed by possible adaptation measures.

Impact on Water Sector

The Global Water Availability Assessment (GWAVA) model has been used to identify water availability including changes in distribution for two scenario years, 2025 and 2050 respectively. The model results indicate that compared to the baseline condition, western parts of the country will be at greater risk of drought during two periods, the months of January – May and June – October. Drought severity will increase with increasing temperatures.

Flood is a recurring phenomenon in Bangladesh. Across most models the flooded area is estimated to increase for most of the flood season due to climate change. By applying future flooding scenarios for Bangladesh using the Master Plan Organization (MPO) flood depth classification, it is estimated that the flooded areas will increase by 6% (2030s) and 14% (2050s).

By 2050, cyclones and storm surge affected areas will increase from 20,876 sqkm at present to 23,764 sq km as a consequence of climate change and sea level rise. Currently about 8.7 million people live in cyclone High Risk Areas (HRAs). This may increase to 33.67 million (without climate change) and 38.33 million (with climate change) in the 2050s.

The coastal areas of Bangladesh face salinity intrusion and fresh water scarcity during the dry season which will aggravate due to sea level rise. The isosaline lines of 1, 5 and 15 ppt have been found to penetrate northward (i.e., inland) for the year 2050. Consequently, brackish water area could increase and continue to do so by up to 7% from 2005 to 2050. As a result, an additional 7.6 million people will be exposed to high salinity (>5 ppt).

Adaptation in water resources and disaster risk reduction (DRR), especially those which relate to water related hazards such as floods, erosion, drought, salinity ingress and water logging, largely depend on institutional adaptation than on people-led small scale community-based and individual self-adaptation. Institutional adaptations are yet to make their mark, however, despite their high potential. Such adaptation measures to ensure sustainable use of water, as proposed, include the following: revisiting and strengthening of embankment systems along the coastal zone; implementation of tidal river management in the longer run to avoid water logging; excavation (removal of siltation) of river systems; maintenance and construction of cyclone shelters; strengthening of local disaster management committee and use of indigenous knowledge and practices to solve water related problems; promotion of research on water related hazards; promotion of early warning and preparedness for all hazards (flood, cyclone, river erosion, drought); increase of water availability and usability in the southern region; and protection of the ecosystem and ensuring decreased impact in river dependant areas by regulation and treaties through international cooperation.

Impacts on Agriculture

Agriculture is still the major economic activity for an overwhelming majority of the population. Rice is the predominant crop in Bangladesh grown in three seasons under completely rain fed (aus), partially rain fed (aman) and completely irrigated (boro) conditions. All three varieties are found to be climate sensitive. Boro rice in the haor area is highly vulnerable to flash floods while Aman is the dominant crop in the coastal area frequently damaged by cyclones. Ausis highly vulnerable to floods in general.

People have been shifting over the past decades from high risk crops to low risk crops and have mainly been depending on irrigated Boro. Climate change, however, is a growing concern for agriculture, as it is greatly dependent on climatic phenomena.

Boro rice which accounts for around 60% of domestic output will be highly vulnerable to climate change impacts. Study results indicate that despite the possibility of CO_2fertilisation effect on Boro production increasing yield by 9.6% with respect to the base year, due to temperature and precipitation changes, output will reduce by 13.9% (2050). The combined effect is a net reduction of 4.74% in Boro production. Similar results are observed in cases of Aman and Aus and ultimately the production of these two crops will reduce at the annual rates of 0.62% and 1.52% respectively. The results clearly highlight that the production potential will perhaps continue to reduce under the climate change scenario, with a compounding adverse effect on food availability and security with increasing demand for common cereals. Such results warrant immediate adaptation in the crop agriculture sector.

In the agricultural sector, farmers have been trying to optimize production levels. In recent years, community based agricultural adaptation has been promoted through NGO interventions. More importantly and from the perspectives of long run sustainability, national research and extension services involving agriculture are also trying hard to develop new hazard-resistant crop varieties, with some notable success. in inventing varieties resistant to salinity, drought, extended period of flood and of shorter maturity Keeping with such parallel adaptation practices, the following adaptation measures may be envisaged involving government led institutions and NGOs:

Further research on high salt tolerant crops and crops adapted to different climatic conditions like drought, flood etc; motivation of farmers to change cropping practices; development of water management innovations; promotion of diversified crop production; development and implementation of policies and programmes to influence farm-level land and water resource use and management practices; initiation of crop insurance to reduce the risks of climate-related income loss; capacity development of the extension officers and farmers; and ensuring access to the market and storage facilities at the community level.

Impact on fisheries

Bangladesh is very rich in fresh water fisheries which plays a vital role in nutrition, direct and indirect employment (of 12-13 mn people), foreign exchange earnings and in other areas of the economy of Bangladesh. The fisheries of Bangladesh are highly sensitive to climate change and its impacts Capture fish production especially from floodplain fisheries might increase due to expansion of flooded area while culture fish production (pond fish) would decrease due to overtopping of flood water. Capture fisheries, especially overall floodplain fish production, may increase by 9% under the A2 emission scenario and 7% under B2 emission scenario in 2050. On the other hand, sea level rise could reduce habitat for fresh water fish in the delta. Therefore, production of freshwater fisheries may be hampered as the species of fresh water carp, catfish, perch etc. are highly susceptible to moderate level of salinity.

The adaptation measures for fisheries may include: protection and improvement of floodplain capture fisheries habitat; enhancement of culture fisheries by retaining water for longer period through pond deepening, removal of sludge, tree plantation on pond dykes and floating macrophytes, pumping facilities and harvesting of runoff water; raising of dyke height to reduce overtopping during flood; culture of shallow water and temperature tolerant fish species; cultivation of salt tolerant species in the coastal area; promotion of marine fisheries for consumption beside fresh water fisheries; encouragement of paddy-cum-fish polyculture; and encouragement of alternative livelihood during fish breeding.

Impact on Livestock

Livestock plays an important role in the national economy of the country, providing 15% of total employment. The increasing temperature and humidity due to climate change will make livestock, especially, cattle, vulnerable. Lower intakes of dry matter due to temperature rise along with increasing humidity leads to body weight changes and other output changes such as reduction in milk production which may decrease by 2.5% annually by 2030s . Milk output may further reduce by around 5% in the 2050s. The highest reduction occurs during March-May. In the coastal area, livestock are most vulnerable to cyclones and storm surges along with tidal flooding. About 20% of suitable area will be reduced in 2050 for livestock due to sea level rise.

Adaptation measures that can be undertaken are: increase of energy and protein intake for maintaining livestock health during hot summer; use of feeding management practices to minimize the effects of heat stress and humidity; improvement of housing facilities with adequate shade, cooling and ventilation to reduce the impact of heat stress; raising platform/plinth level of housing/*killa* for livestock in coastal and flood prone areas; initiation of training for capacity development of veterinary surgeons and awareness raising of farmers on enhanced climatic disasters; and enhancing animal health care during climate driven stressful conditions.

Impact on Forests

Climate change will have a detrimental impact on all forest ecosystems in Bangladesh. Increased monsoon rainfall would cause increased runoff leading to enhanced soil erosion from the forest floor. The erosion problem would be more pronounced in areas with low-density hill forests. In the Sundarbans, the areas suitable for Sundri (*H. Fomes*) and Gewa (*E. agalloca*) will decline drastically with increase in sea level rise but suitable areas for Goran (*Ceriops spp*.) will increase as saline environment is more favourable for its growth. It may be noted that Goran is economically a less valuable species compared to Sundri and Gewa. In other forests, enhanced evapo-transpiration in winter would cause increased moisture stress, especially in the Barind and Madhupur Tract areas, affecting the Sal forest ecosystem.

The adaptation measures may include: development of a national strategy for integrated water resources management to protect aquatic plants and animals; maintaining critical ecological zones; conservation of threatened species; creation of buffer zones or migration corridors for ecosystems; protection of corridors to allow plant and animal migration following pole-ward shifts in habitat distributions due to changes in temperature and precipitation; conservation and protection of plant and animal habitat; establishment of linkage between protected areas, wildlife reserves and reserved forests; and conservation of and afforestation in the reserve forest areas, coastal areas, and swamp forests in the wetlands.

Impact on Human Health

The risk to human health in Bangladesh is one of the major risks arising from climate change. There is emerging evidence to indicate that climate change has altered the spatial distribution of some vector borne diseases like, malaria, dengue, *kala-azar* etc. Climate change has also altered the seasonal distribution of some allergenic pollen species and increased heat wave-related deaths.

The factors influencing the growth of the two species of mosquito that spread malaria in Bangladesh include temperature, precipitation, humidity, elevation, and forest fringe areas. Due to climate change induced differences in temperature and precipitation, the dynamics of malaria will change. Malaria affected areas will increase in future and some new areas will be exposed to it.

The risk of cholera incidence is expected to increase in the coastal region, Dhaka division and Rajshahi division compared with the current situation. By the 2050s the central, eastern and southern parts of Bangladesh would be highly vulnerable to diarrheal incidence due to climate change. Other health impacts like malnutrition, heat wave related diseases, and critical access to safe drinking water will be seen.

The measures to ensure healthy environment in future are: enhancement of capacity of the existing health infrastructures and construction of new ones; increase of manpower to ensure health services during climate change adversity; strengthening of capacity of health professionals including doctors and nurses to deal with future climate change related diseases; continuous R&D and monitoring to understand the changes in the vectors, parasites and virus and bacteria to changing climate, raising massive awareness to reduce diseases related with flood, cyclones, heat wave, cold spell etc; and increasing the use of hand tube wells and sanitary latrines to reduce the threat of water contamination.

Vulnerability to Extreme Weather Events

Extreme weather-related events such as floods, heavy rains within a very short time, cyclones and storm surges cause not only loss of lives, but also destroy essential rural and urban infrastructure. With increasing flood vulnerability, physical infrastructural damages will increase. The coastal areas are particularly vulnerable to tropical cyclones and associated storm surges. Study results indicate that about 50% of national highways are under medium vulnerability while another 8% are highly vulnerable to extreme weather-related events. Similarly, 10% of regional highways and 8% of railways are highly susceptible to damage in such cases. Critical coastal infrastructure such as dwellings, ports, roads, and embankments will be subject to devastation with increased intensity of cyclones and storms.

Adaptation to impacts of extreme weather events may emphasise major investments in infrastructure to make them better withstand the ravages of nature. Apart from this other measures may be: design changes in embankments and water control structures to improve drainage congestion; maintenance and improvement of existing shelters and construction of additional shelters in coastal areas; dredging of navigation routes and canals; raising the plinth level of structures in growth centres (market places) and also other infrastructure (schools and colleges) to provide protection from inundation due to flooding and cyclonic storm surges.

Impact on Livelihood

Bangladesh has made major gains in some of the indicators of social development including that in Human Poverty Index although income inequity remains a major concern. This situation may further face new challenges due to climate change and its various impacts on the physical and human systems. The major correlates of livelihoods in a given community include employment, productivity in economic sectors and activity, food security and poverty, the conditions which are likely to be worsened by climate induced hazards such as floods, droughts and cyclones as well as due to direct impact of temperature rise and precipitation changes.

The adaptation measures to combat effects of climate change on livelihood will depend much on what adaptation are introduced in productive sectors and those facilitating productive activities. Additionally, other adaptation activities to facilitate people's livelihoods may be: enhancement of resilience of urban infrastructure and industries to impacts of climate change; promotion of adaptation to coastal crop agriculture to combat increased salinity and shortage of fresh water; cultivation of livestock pasture in newly developed char areas; strengthening of afforestation programmes by planting salinity-tolerant and local hardy species of trees; implementation of massive public awareness campaigns; promotion of community radio to address critical social issues arising out of dislocations due to climate change at community level; development of eco-specific adaptive knowledge on adaptation to climate variability; and mainstreaming of adaptation/ mitigation into national level planning in different sectors.

Impact on Gendered dimension

Understanding the issue of gender within the framework of vulnerabilities due to climate change and the associated adaptation is an extremely complex one. This is because the existing patriarchal system already determines to a considerable degree women's roles and responsibilities, mobility, and sexuality within the society. There is an emphasis on women's reproductive value and consequently access to higher education for girls is more limited than boys. The responsibilities of women tend to focus on family maintenance and the existence of succeeding generations. Within the household, decision-making and control of resources are generally in the hands of men. Women have limited access to resources, property, education, and income-earning opportunities. Climate change adds on to the existing gendered inequities and accentuates the plights of women in general compared to men.

Given the above complexities, it may be pointed out that the contexts of vulnerability to climate change in Bangladesh for women are somewhat different compared to men. Women may face certain bio-physical stresses due to CC and its impacts. These are some time accentuated by their social, reproductive and care-giver role in the family as well as their social differentiation (or discrimination) that they may face. They face the same or similar stresses of CC and its impacts as men. Such stresses may get compounded as most climate change issues, policies and programs are not found to be gender neutral.

Impacts in Urban Areas

The urban areas are gaining importance over time in terms of their contribution to the economy, livelihood and future development. The climate change extremes are already impacting the livelihood and health of urban people. The urban people are highly vulnerable to climate change induced extreme rainfall, flooding, drainage congestion, cyclone and temperature rise. The future growth potential of the cities and towns will be arrested if effective measures are not undertaken.

Adaptation measures intertwined with community based collective efforts at local level can reduce the vulnerabilities due to climate change in the cities and towns. Some of the important adaptation measures may include: mainstreaming adaptation to climate change into urban development policies and programmes; appropriate zoning regulations and development control; preservation and maintenance of the drainage areas; improvement of water use efficiency; designing alternative water sources; adequate public health resources; and awareness and capacity building programmes.

Institutional Aspects

The GoB officially launched the Climate Change Unit (CCU) under the MoEF in June 2010. The Unit has started to act as a key institution for implementation of adaptation and mitigation projects. The MoEF and CCU have already approved 84 projects under climate change trust fund for implementation in the vulnerable coastal zone as well as in drought prone areas, flood-prone and low lying ecosystems, hilly and *haor* areas, and char lands covering mainly agriculture, water, forestry, infrastructure, health, capacity building sectors etc. which will address the climate related issues.

The GoB is also seriously thinking to establish a separate Department of Climate Change specifically to look after climate change issues under the MoEF. It is expected that many of the climate change related activities of the Government will be better coordinated after establishing this specialized department. MoEF is also working to set up a Climate Change Research and Training Institute to institutionalize research and systematic observation in climatic system.

Previously, the Climate Change Cell (CCC) under the Department of Environment undertook several initiatives for increasing awareness among stakeholders, starting from the grassroots level to the policy planners of Bangladesh on climate change impact, adaptation and mitigation. As a part of this, a total of 13 booklets in Bangla and English, 17 fact sheets and two comic books were developed by the CCC for dissemination at the local and national levels to raise awareness on climate change.

The Bangladeshi communities and NGOs have been jointly innovating techniques of CBA, which are likely to be continued and replicated on the basis of needs assessments in the near future. At the same time, there has been remarkable institutional adaptation in the recent past in the field of crop agriculture including development of saline and inundation tolerant rice varieties by the National Agricultural Research System (NARS) and its institutions.

OTHER INFORMATION RELEVANT TO THE OBJECTIVE OF THE UNFCCC

Mainstreaming climate change

The "Outline of the Perspective Plan: Vision 2021" is a long term strategic document of Bangladesh which includes "Mitigating the Impact of Climate Change" as one of the strategic corner stone to ensure sustainable development. The ‘Bangladesh Climate Change Strategy and Action Plan’ proposes 44 programmesunder six thematic pillars related to adaptation and mitigation to be implemented within a 10-year period. Bangladesh has shown its progress in achieving the Millennium Development Goals (MDGs), where goal 7 directly matches the concerns related to climate change. As outlined in a progress report concerning the achievement of Goal 7, it is mentioned that Bangladesh is likely to meet quantitative targets for just three of the ten indicators namely, CO_2 emissions, consumption of ozone depleting substances and the proportion of the population using an improved drinking water source.

Bangladesh has just prepared its Sixth Five Year Plan (2011-2015) which clearly puts emphasis on the importance of managing climate change and has indicated the priorities for implementing the BCCSAP, 2009. Apart from the five-year plans, a National Plan for Disaster Management which may be considered as a medium term plan addresses the key issues like risk reduction, capacity building, climate change adaptation, livelihood security, gender mainstreaming, community empowerment, and response & recovery management.

Bangladesh has also set up a “Bangladesh Climate Resilient Fund” with the support of UK, Sweden, Denmark and the EU on 31 May 2010. The total amounts initially pledged are over

$125.5 million (In addition to that Euro 20.00 million and Australian $ 7.00 million are within the pipe line) which will be used to implement the some of the programmes under BCCSAP. Moreover, in the annual national budget, the Government of Bangladesh (GoB) has already allocated US $ 300 from its own resources in Climate Change Trust Fund to implement the BCCSAP.

Bangladesh is yet to prepare a national policy that will solely cover the climate change issues, impact and adaptation options. However, some of the sectoral policies like the Coastal Zone Policy, the Information and Communication Technology Policy, the National Agricultural Policy, the Bio-technology Policy, the Forestry Policy, the Health Policy and the Social and Resettlement Policy address climate change issues directly in the sectoral development planning. However, other important policies like the he Water Policy, and the Energy Policy have not included the climate change issues yet. Bangladesh is already working to revisit the National Environmental Policy 1992 to address climate and other sustainable development issues.

Activities Related to Technology Transfer

Some of the priority activities regarding technology transfer are identified through consultation with different stakeholders focusing on adaptation, mitigation and CDM in particular. A total of 60 activities have been identified under ten thematic areas: community-based adaptation programmes, climate resilient adaptation programmes, efficiency in the energy sector, energy efficiency in the transportation sector, promotion and expansion of CDM, promotion of carbon sinks in the forestry sector, mitigation and waste management, mitigation through the agriculture sector, national inventories of anthropogenic emissions by sources, integration of climate change considerations into social, economic and environmental policies, and promotion and transfer of technologies to reduce GHG emissions and increase carbon sinks.

Bangladesh is preparing its Technology Need Assessment (TNA) Report. An inception report for the TNA elaborated the methodology and identified a number of sectors related to adaptation and mitigation measures. Adaptation measures (in non-energy sectors) include those in agriculture, water, disaster, environment, local government works (urban development and housing), fisheries and livestock, and health. Mitigation measures (energy sectors) include those in transport, industry and forestry. Bangladesh is yet to prepare a pilot programmes to address the technology transfer component relating to climate change. However, CDM projects, although not directly related to technology transfer, are considered as a good example where the technology transfer need is crucial. Currently two CDM projects are registered in Bangladesh, two are under validation, three are submitted for DNA approval and one project is in the formulation stage. The Estimated Emission Reduction from these projects is 248 thousand mt of CO_2equiv/Yr.

A number of governmental, autonomous, non-governmental institutes and NGOs are trying to adopt existing technologies in the local context and invent new technologies. Several activities related to generation of climate change scenario, GHG abatement scenario, impact assessment and adaptation planning are being carried out by both public and independent organizations including technical universities and other institutions.

Under the thematic area 'Mitigation and Low Carbon Development' of the BCCSAP, a number of mitigation proposals have been made which contain some technology transfer components. These are: improved energy efficiency in production and consumption of energy, gas exploration and reservoir management, development of coal mines and coal fired power stations, combine cycle gas turbine, renewable energy development, lower emission from agricultural land, management of urban waste, rapid expansion of energy saving devices, energy and water efficiency in built environment, improvement in energy consumption pattern in the transport sector, and options for mitigation.

Climate change Research and Systematic Observation

Presently, the Bangladesh Meteorological Department (BMD) collects meteorological data on evaporation, humidity, solar radiation, rainfall, sunshine hours, temperature and wind speed from their 36 data collection stations all over Bangladesh. The BWDB collects hydrologic information such as rainfall, water level and discharge data. Furthermore, the BIWTA also collects water level data from 43 tidal stations. Air quality data and salinity data are measured by the DoE and the BWDB on a daily and fortnightly basis along the coastal region of Bangladesh.

The BMD is globally connected with the World Meteorological Organization (WMO). Meteorological observations are transmitted globally through the Global Telecommunication System (GTS). It is also associated with PTWC and JMA through BMD's GTS link, Fax, Telephone and Internet to get Tsunami advisory/ warning and Tsunami watch information.

The IPCC projected climate change scenarios for South Asia are very coarse (at 250-350 km grid) and therefore unsuitable for any micro-level impact assessment and adaptation planning. In this regard, it is very urgent to downscale the climate change scenario at the local level (preferably at 25-50 km interval) which will provide the basis for formulation of climate change related programmes and projects.

For predictive purposes, it is imperative to verify results of climatic forecasts and observations on a grid-by-grid basis, as the model simulated climate change scenarios are only available at some specific grid points. It is also important to track the extreme events (like cyclones) for efficient dissemination of early warning messages. The existing tidal water level stations in the coastal region need to improve for indicating the amount of net sea level rise on a reliable basis, as those are not free from natural and human induced disturbances.

Some capacity exists in the country to establish and maintain observation facilities that collect and compile climatic and biophysical data for climate change research. Nevertheless some of these institutions face financial and technical constraints; moreover there is a great need to "translate" scientific information on climate change impacts and climate model and scenarios into a language and time scales that are relevant for policy makers. It is also important to integrate scientific knowledge with indigenous/grassroots knowledge.

Information on research Programs

A total of 118 national and international research institutes have participated in different research initiatives in Bangladesh related to climate change. Much of the research is conducted in collaboration between international and domestic research institutes, and NGOs followed by development partner/inter-governmental agencies.

Information on Education, Training and Public Awareness

A National Steering Committee on climate change has been established which is chaired by the Minister, MoEF and comprises the Secretaries of all climate-related ministries and divisions as well as representatives of civil society and the business community to plan and coordinate all climate change related activities and programmes in Bangladesh including the relevant concerns regarding education, training and public awareness.

The importance of mainstreaming climate change issues in the academic curricula need to include in the National Education Policy published by the Ministry of Education. Furthermore, strengthening public education in the subject of climate change will require review of curricula, production of education/ teaching materials and orientation of teachers towards climate change issues. It is necessary to simplify and translate information and key documents on climate change into the main local languages and to hold effectively undertake public awareness building campaigns on climate change will require training programmes for mass media practitioners/ reporters as well as public education programmes. Climate change issues may also be included in the school and college syllabuses. However, some higher education institutes both public and private universities in Bangladesh have introduced masters or diploma courses in disaster management including climate change.

Capacity Building

The need for capacity building on climate change related issues were first reported in the Initial National Communication Report of Bangladesh. NAPA identified two projects that directly targeted capacity building. The BCCSAP has considered 'Capacity Building and Institutional Strengthening' as one of the thematic pillars while proposing the action plans. Recently, the Climate Change Unit under the MoEF has approved eight projects related to capacity building and institutional strengthening (in line with the BCCSAP thematic area), to be implemented by different public and private sector institutions.

The Bangladesh Capacity Development Action Plan for Sustainable Environmental Governance has identified seven synergistic areas for a capacity development action plan. These are very relevant to climate change capacity building in Bangladesh and include: institutional strengthening, legal, policy and enabling frameworks, public awareness and education, data and information collection, dissemination and monitoring, research and technology development, technical and managerial capacity building and resource mobilization.

The GoB has undertaken some significant actions and completed a number of projects that indirectly address the climate change issues related to capacity building needs both in terms of institutional and human resources capacity building. One very specific area for capacity building relates to institutionalization of long-range weather forecasting capability. This will help in various adaptations actions related to agriculture disaster risk reduction and insurance business.

Information and Networking

A number of national agencies have formed a network on climate change and three national databases have been launched for disseminating information related to climate change. These are various stages of development and operation. The institutions and the names of the databases are: the Network on Climate Change, Bangladesh; the Bangladesh Online Research Network; the Bangladesh Environment Network (BEN); the Disaster Management Information Network (DMIN) Portal; the Knowledge Network on Climate Change; the Climate Change Database; the Integrated Coastal Resource Database; and the National Water Resources Database.

A number of existing networks facilitate regional and international networking. Some of the initiatives are: Capacity Strengthening for Least Developed Countries for Adaptation to Climate Change; the Cap-Net; the South Asian Network for Development and Environmental Economics (SANDEE); the Climate Action Network South Asia (CANSA); the Global Water Partnership (GWP); and the Bangladesh Water Partnership.

Chapter 1

Second National Communication: Rationale, Process and Structure

1.1 National Communication

Article 4, paragraph 1, and Article 12, paragraph 1, of the United Nations Framework Convention on Climate Change (UNFCCC) requests each Party to the Convention to periodically provide information to the Conference of Parties (COP) on sources and sinks of greenhouse gases (GHGs), mitigation measures, vulnerability to climate change, and adaptation measures and programmes undertaken. Guidelines have been initially prepared and approved at the second session of COP (10/CP 2) for facilitating the process by Parties; later, these guidelines were revised based on a decision by COP at its eighth session (17/CP8).

A National Communication (NC) has been prepared and submitted by many Parties, including the Non-Annex 1 countries. Bangladesh prepared and submitted its Initial National Communication (INC) in 2002. The present report is the Second National Communication (SNC), which will be submitted to the UNFCCC in due process. The SNC 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 and Forests (MoEF), and its operational arm, the Department of Environment (DoE), engaged several climate experts to prepare five reports:

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
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 MoEF/DoE. These reports were then peer-reviewed and revised based on further comments and observations from reviewers. The SNC is based largely upon these final reports under the Activities. However, whenever the present consultant has thought it desirable, he has supplemented information in Activity reports with further information and analysis.

Once the SNC 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 for finalization of the Synthesis Report.

1.3 Structure

The SNC is organized following the above Activity Reports. Thus, the chapters bear the same titles as the Activity Reports and are arranged accordingly. The SNC also contains an Executive Summary. Annexes have been provided as and when necessary. Maps, charts and tables also have been provided as required. It may be noted that while the GHG Inventory refers basically to the year 2005, many measures and programmes nonetheless refer to the pre- or post-2005 situation in the country in light of various ongoing trends. For comparability purposes, the situation in 2005 has been shown wherever applicable.

Chapter 2

National Circumstances

2.1 Introduction

The User Manual for preparation of the SNC and subsequent National Communications states that the description and analyses of the National Circumstances should have the following contents:

- Geographical characteristics, including climate, forests, land use and other environmental characteristics
- Population: growth rates, distribution, density and other vital statistics
- Economy, including energy, transport, industry, mining, tourism, agriculture, fisheries, waste, health and services sector
- Education, including scientific and technical research institutions
- Any information considered relevant by the Party, e.g., information relating to Articles 4.8, 4.9 and 4.10 of the Convention

Based on the Activity 1 report on National Circumstances, and supplementing them where necessary, we discuss and analyze the above issues in the present chapter.

2.2 Geographic Information, Physical Characteristics, and Environmental and Natural Resources

2.2.1 Location

Bangladesh is located in South Asia, between 20º34´ and 26º38´ north and 88º01´ to 92º41´ east (Fig. 2.1). The Tropic of Cancer passes midway over Bangladesh. The country has an area of approximately 147,570 sq.km. (BBS, 2009) and is bounded by India in the west, north and part of the east. The remaining part of the eastern border lies with Myanmar, while the Bay of Bengal demarcates the southern border. The Himalayas are close to the northern border of Bangladesh.

Fig. 2.1: Location of Bangladesh, *Source*: Google Earth

2.2.2 Topography

Much of the country consists of extremely low, flat land. The mean elevation from sea level (MSL) ranges from less than 1metre on tidal floodplains to 1 to 3 meters on the main river and estuarine floodplains, and up to 6 meters in the Sylhet basin in the northeast (Rashid, 1991). The floodplains occupy about 80 percent of the country.

2.2.3 Physiography

Bangladesh comprises three broad physiographic regions: hills, terraces (slightly uplifted fault blocks), and floodplains. Each region exhibits its own geo-morphological characteristics. The broad physiographic regions are further categorized into 30 Agro-Ecological Zone (AEZ) units. About 12 percent of the country is occupied by hilly areas, which include the northern and eastern hills. Tertiary and quaternary sediments had underlain these hilly areas, which have been folded, faulted and uplifted, then deeply dissected by rivers and streams. An overall pattern of long, linear ridges runs from approximately north-northwest to south-southeast, with the highest elevation as high as 900 m above MSL.

Terraces occupy about 8 percent of the country. These areas are not true alluvial terraces, but are almost flat surfaces appearing above deposits formed during the Pleistocene period. The Barind Tracts in the north are composed of an uplifted, locally tilted series of fault blocks interrupted by a few major river valleys occupying fault troughs. The Madhupur Tract in the central region and the Akhaura Terrace in the east are closely dissected and broken by faults (Brammer, 1996).

The remaining four-fifths of the country is floodplain areas, including alluvial floodplain and estuaries. These are composed of predominantly recent alluvial deposits transported from the hills by rivers. Numerous natural depressions, some of which are abandoned channels, have formed as a result of changes in river courses; some have been formed in the process of delta building and as a result of the Earth's tectonic movements.

2.2.4 Morphology

River morphology is an extremely complex process and is the outcome of interactions among many variables, some of which must be considered on a rather long time scale of 100 to 200 years. Climate change will eventually influence the hydrology of the basin, and consequently, its vegetation and channel morphology. A major change in the hydrologic regime due to climate change would trigger a response that may completely change channel morphology.

To assess the impact of climate change on river morphology, it is assumed that three independent variables – discharge, sediment yield and slope –will be changed. Because there is uncertainty in assessing the sediment load, it is assumed that the load's increase would be proportional to the discharge. On the other hand, the rising of the sea level would change the river's slope, and with the processes of adjustment, it may propagate upstream. Major issues addressed for river morphology and concerned with climate change are (i) riverine morphology, (ii) coastal morphology, and (ii) estuarine morphology.

Riverine Morphology

The large discharges and heavy sediment loads carried by the Bangladesh river systems result in highly variable, dynamic channel morphologies characterized by rapid adjustments to their cross-sectional geometry, bank line positions and plan form attributes (Coleman, 1969). A number of studies have been carried out, particularly concerning morphological processes in the Jamuna River since the late 1960s. The general conclusion drawn in most of these studies is that while the main rivers of Bangladesh exhibit short-term instability, they may be considered to be broadly in dynamic equilibrium. This means that their spatially and temporally averaged morphological features are meta-stable through time.

On the other hand, recent research shows that the Jamuna and Padma rivers have gone through enormous change during the last few decades, which could be explained by the propagation of a sediment wave generated by landslides during the 1950 Assam earthquake. Landslides triggered by this earthquake generated about 4.5 X 1010 m^3 of sediment, much of which entered the Brahmaputra River in Assam either directly or through its tributaries. It was proposed by the research that the fine fraction of the sediment (silt and clay) travelled quickly through the system without disturbing the morphology of the channels before settling in the Meghna Estuary and Bay of Bengal. The coarser fraction (sand) took half a century to progress through the system, moving as a wave of bed material load with celerity between 10 and 32 km/y. During this propagation, the riverbed, along with its width and braiding intensity, had changed considerably. CEGIS (2005 & 2007a) further found that the rate of bank erosion along the Padma and Jamuna was influenced by this process. Thus, it appears that long-term effects of the Assam earthquake need to be considered to explain recent developments in river and estuary morphology.

The bank materials of the Jamuna mainly consist of non-cohesive sediments and have almost similar characteristics in terms of susceptibility to erosion (Thorne et al., 1993). Because the Jamuna is the most dynamic river in Bangladesh, it causes huge erosion every year;erosion has been the dominant process in this river for several decades (Figure 2.2.). Since 1973, a large area of floodplain (90,830 ha) has been eroded by the river, with only a small amount of land (10,140 ha) gained during this period.

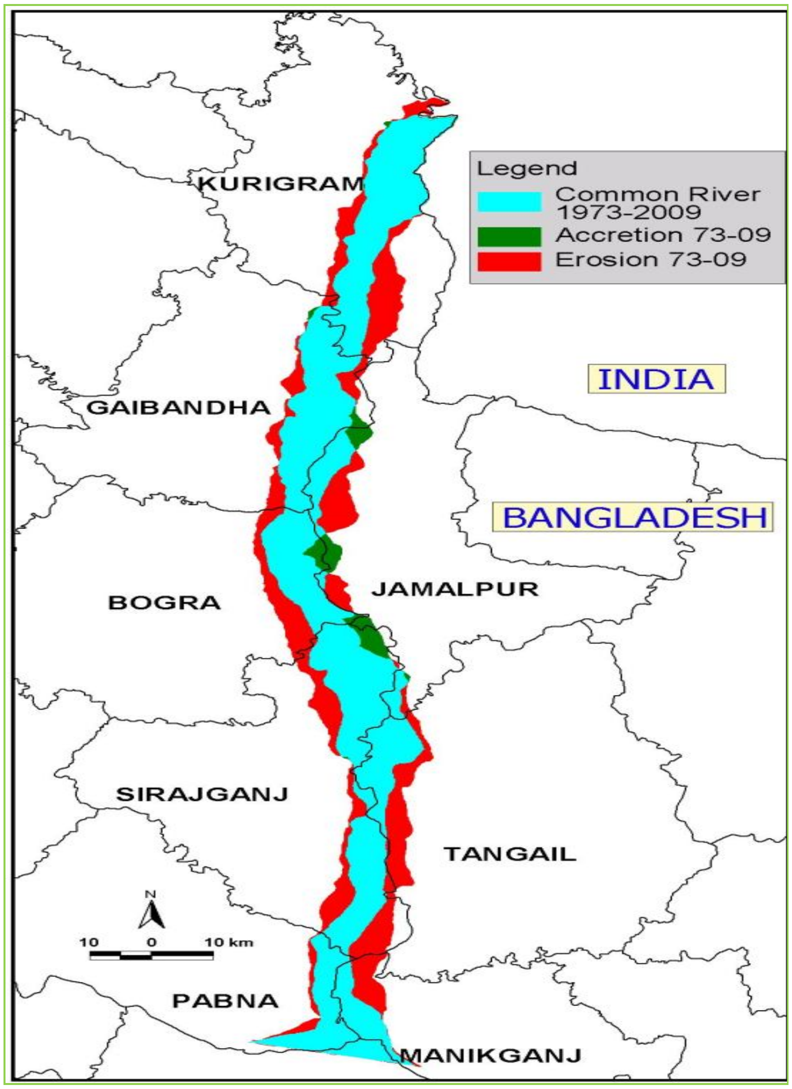


Fig. 2.2: Erosion-accretion along the Jamuna (1973-2009), Source: CEGIS (2009b)

The River Ganges is not as destructive as the Jamuna in terms of erosive capacity. Erosion-accretion were almost in balance in the Ganges (Figure 2.3) during 1973-2009; in that period, erosion stood at28,390 ha and accretion was 25,680 ha.

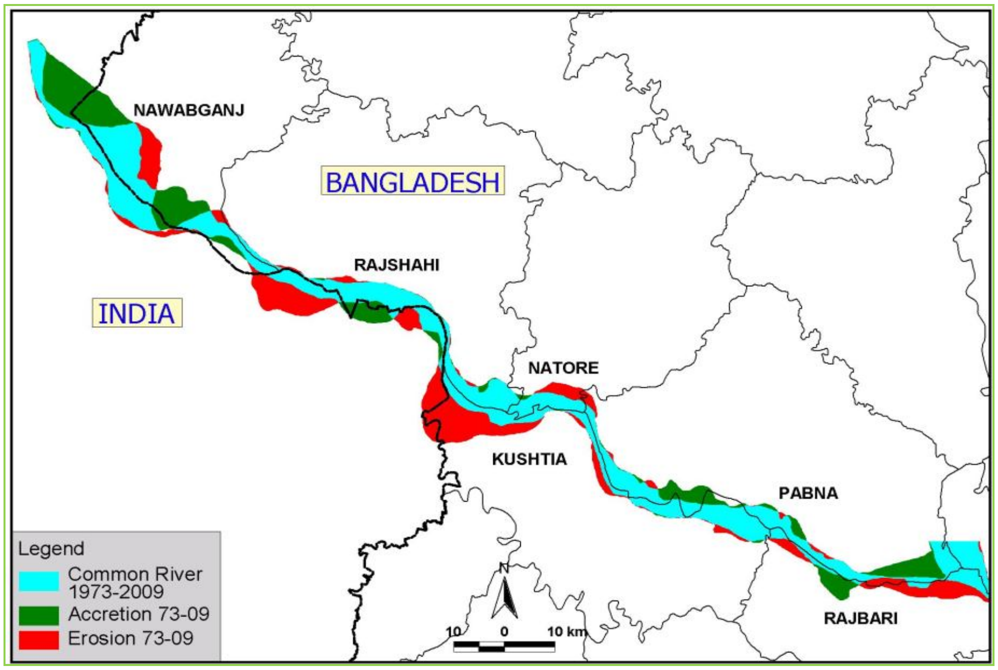


Fig. 2.3: Erosion-accretion along the Ganges (1973-2009), Source: CEGIS (2009b)

Meanwhile, study of riverbank erosion processes of the Padma River has shown that some locations along the left bank were composed of less erodible materials. During the last few decades, however, erosion has been the dominant process in the Padma, as in the Jamuna (Figure 2.4). During 1973-2009, erosion stood at around five times accretion, affecting 39,560 ha versus 8,390 ha.

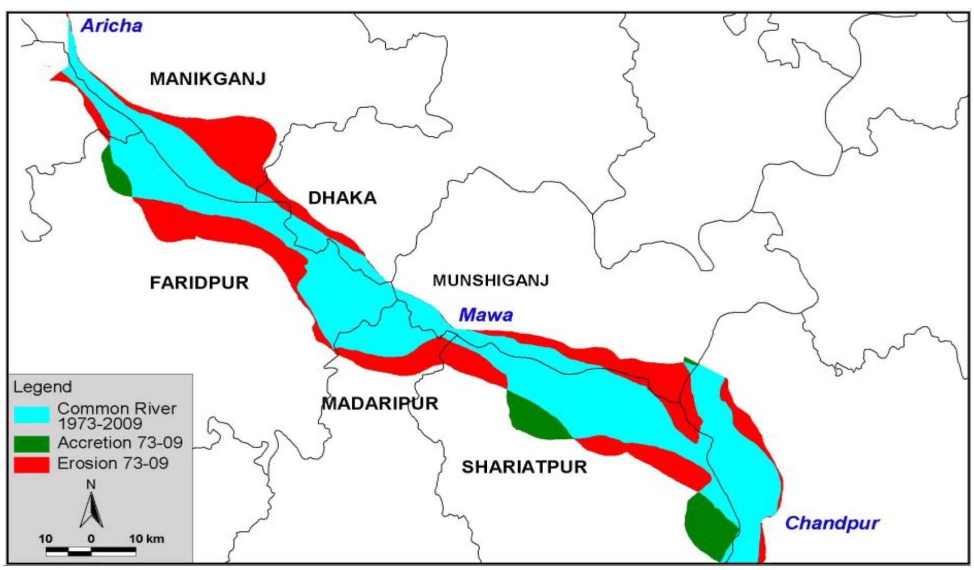


Fig. 2.4: Erosion-accretion along the Padma (1973-2009), Source: CEGIS (2009b)

Coastal morphology

The morphological timescale is an important parameter for assessing the impact of climate change. Recent research (CEGIS,2007b) suggests that the sediment input from the catchment of Bangladesh's rivers would have a great influence on the behaviors of rivers, estuaries, floodplains and tidal plains. Given that coastal rivers are very dynamic, the erosion-accretion process along the coast is also very dynamic. The 35-year change of coastal morphology is shown in Figure 2.5.

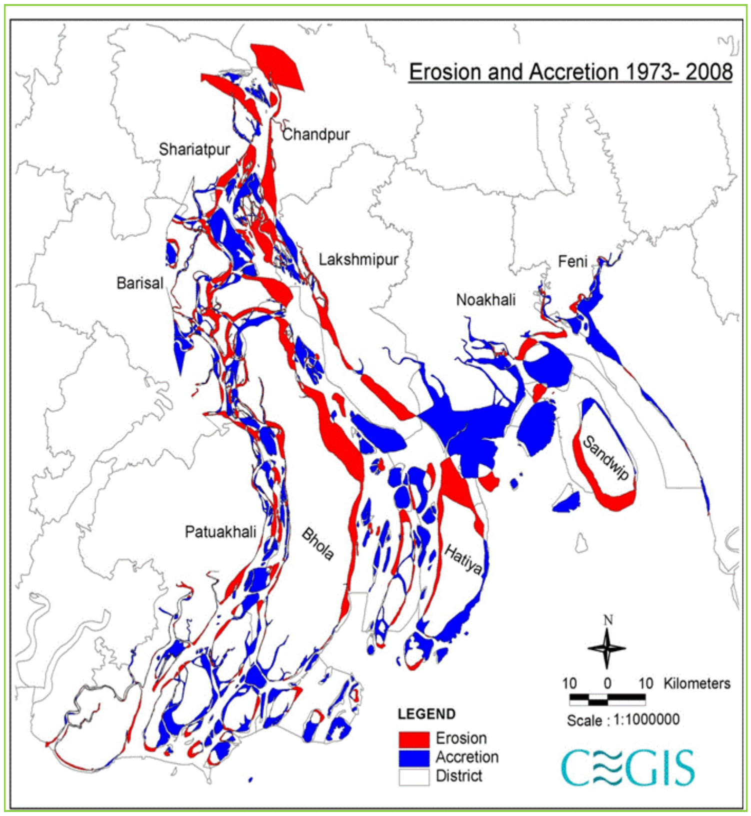


Fig. 2.5: Erosion and accretion in coastal areas (1973-2008), Source: CEGIS, 2009a

Estuarine morphology

Every year the Ganges, Brahmaputra and Meghna Rivers pour about 1012 $m^3$of water into the Bay of Bengal, along with about a billion tons of sediment through the Meghna Estuary. According to a long-term sediment balance assessment of this delta by Goodbred and Kuehl (2000b), one-third of the sediment carried by these rivers deposits on the floodplain and tidal plain, while one-third is trapped in the sub-aqueous delta and used in its vertical accretion and lateral progression. Goodbred and Kuehl were unable to assess the destination of the remaining sediment, concluding that it was probably destined for the deep ocean floor.

An important component of the Meghna Estuary's development is long shore sediment transport, the impact of which on the estuary is not known. It could be significantly smaller than the impact of the huge riverine sediment. On the other hand, recent studies such as that by CEGIS (2009a) show that land accretion in the Meghna Estuary is mainly concentrated where the tidal circulation loops end. The net accretion rate in the estuary during the last three and half decades was found to be 17 sq.km. per year, out of which about 15 sq.km. per year occurred in the estuary's northeast corner.

The upshot of the above discussion on morphology is that it is very dynamic and that changes may occur drastically within a comparatively short period. Because climate change leads to fluctuations in precipitation regimes both within Bangladesh and inits rivers' catchment areas across the border, the rivers flows – and consequently, accretions and erosions along the rivers' banks, the coastal region and the estuary – also may change in an uncertain manner.

2.2.5 Climate

Bangladesh has a tropical monsoon climate. In general, it is characterized by high temperatures, heavy rainfall, often excessive humidity during monsoon (June-September), and marked inter- and intra- seasonal variations.

Temperature

The mean annual temperature is about 25°C, while mean monthly temperatures range between 18°C in January and 30°C from April to May (Climate Change Cell 2009).Figures 2.6 and 2.7 show annual mean maximum and minimum temperatures in different locations of Bangladesh. These indicate that the northern and western parts of the country are in general hotter during summer and cooler during winter. As will be seen below, these are also areas with comparatively lower rainfall, which has implications for the type and nature of crop agriculture.

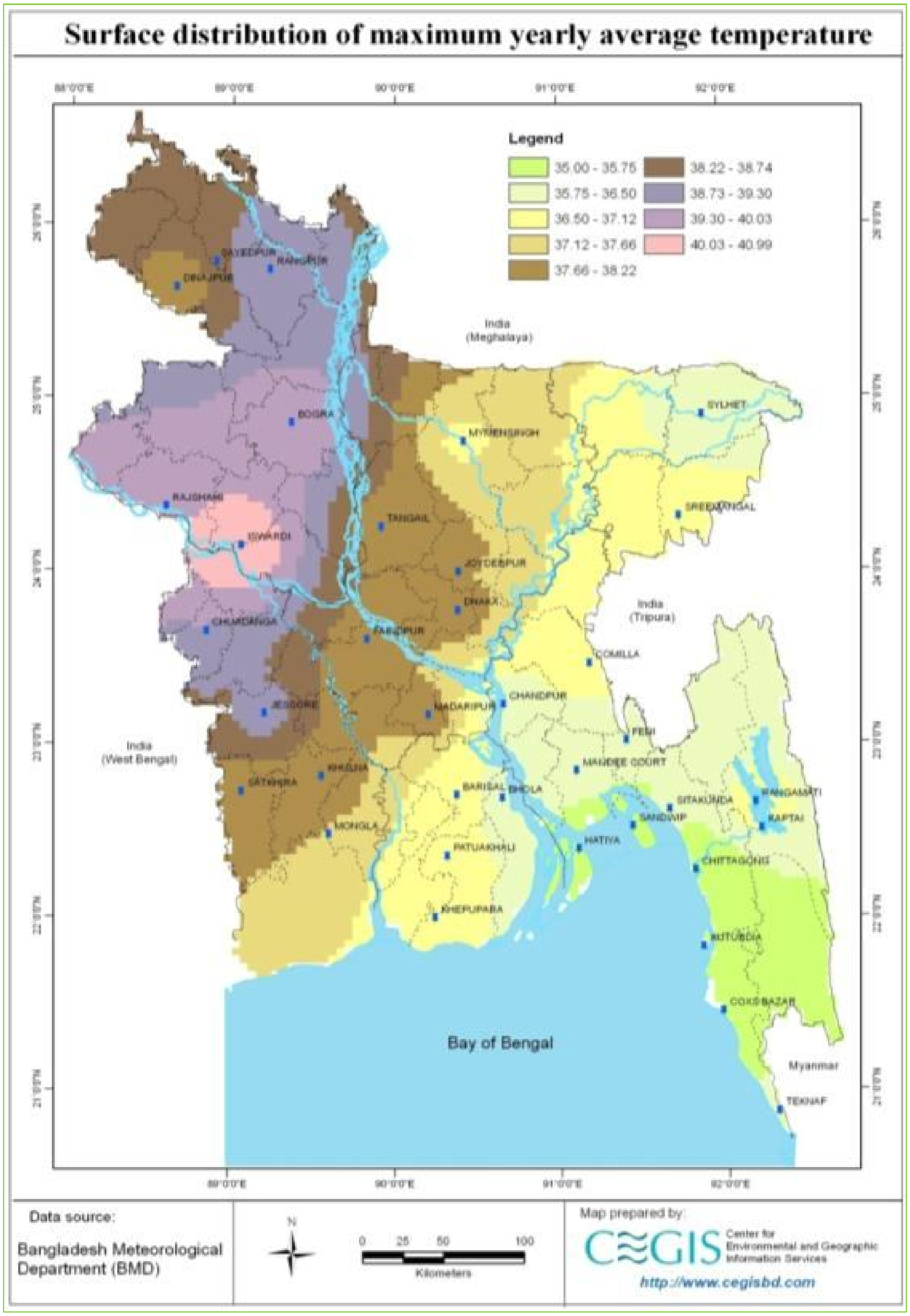


Fig. 2.6: Surface distribution of yearly average of maximum temperature in Bangladesh

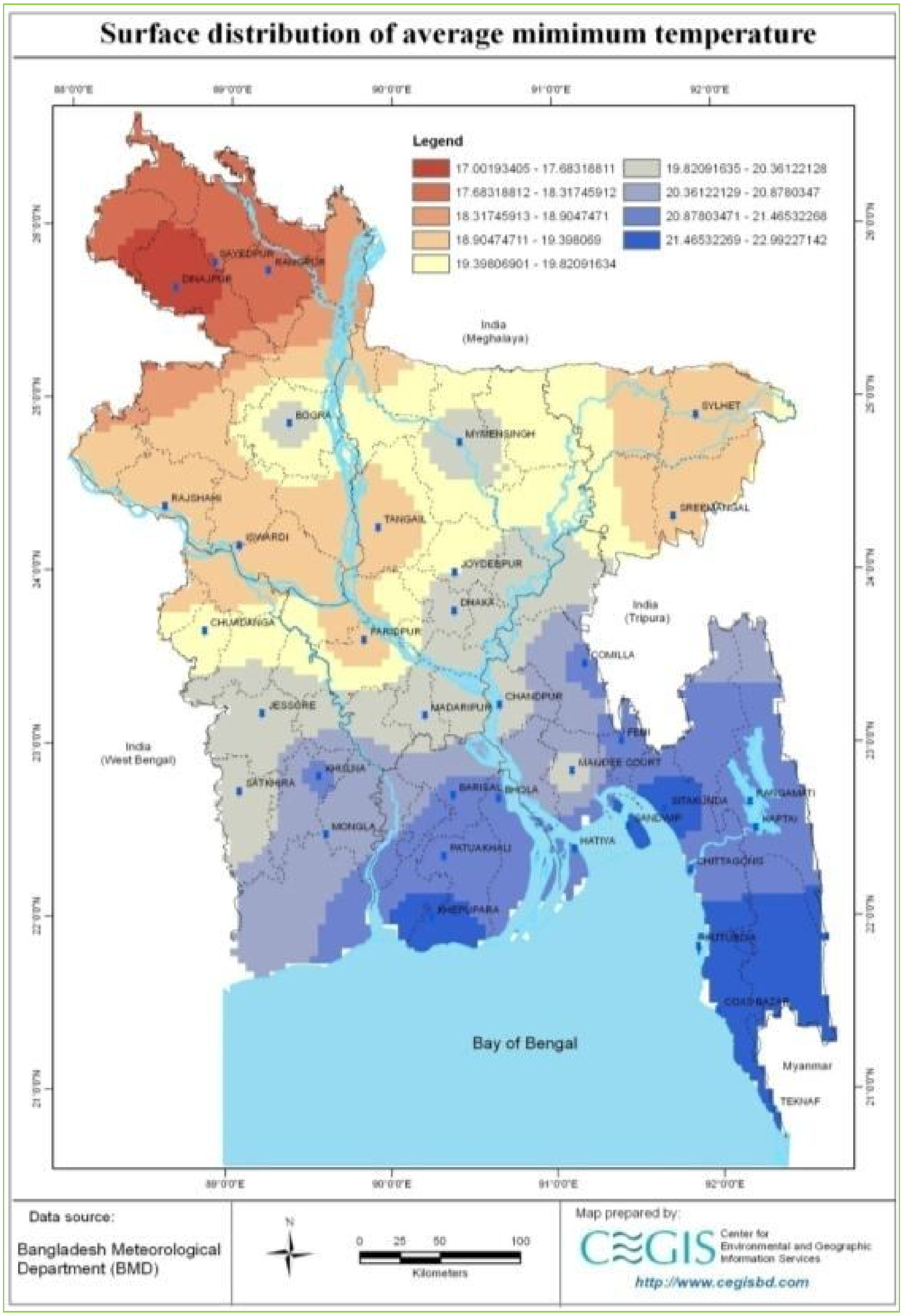


Fig. 2.7: Surface distribution of yearly average of minimum temperature in Bangladesh

Rainfall

Rainfall within the country is mainly caused by the southwesterly trade winds, known as the monsoon, during the months of June to September. The two other sources of rainfall are the western depressions of winter, mainly from the end of January to the end of February, and the nor'westers (early summer thunderstorms), mainly within the first week of May. Average annual rainfall in the country is about 2,200 mm, with about 80 percent occurring from May to September. The isohyet pattern of average rainfall is shown in Figure 2.8. Mean annual rainfall is the lowest (1,400 mm) in the Rajshahi zone near the western border. The advancement of isohyets is towards the north, east and south, reaching more than 2,500 mm in the extreme northwest, near and within the northern and eastern hills and near the coasts, and exceeding 5,500 mm near the border in the northeast. Rainfall from year to year and between seasons is highly variable; while monsoon rainfall is high to very high, rainfall during the winter is negligible.

Humidity, evaporation and evapotranspiration

Humidity is relatively high throughout the year. It stands at over 80 percent from June to September, i.e., the monsoon months. The humidity is around 58 percent in most of western Bangladesh in March and April and in the east in January to March. Evaporation rates range from about 50-70 mm per month in the dry season to 100-175 mm per month in the pre-monsoon season. In the monsoon, these are generally about 100-125 mm.

The annual potential evapotranspiration rate (modified Penman) ranges between 1,180 mm in the northeast to 1,285 mm in the centre-west. Rainfall exceeds evapotranspiration rates in the monsoon and for the year as a whole, even in dry years. However, evapotranspiration rates exceed rainfall during winter and in the first part of the pre-monsoon season. Evapotranspiration rates also exceed rainfall during drought and, most significantly, during the pre-monsoon season, both when temperatures and evaporation rates are highest (Brammer, 2002).

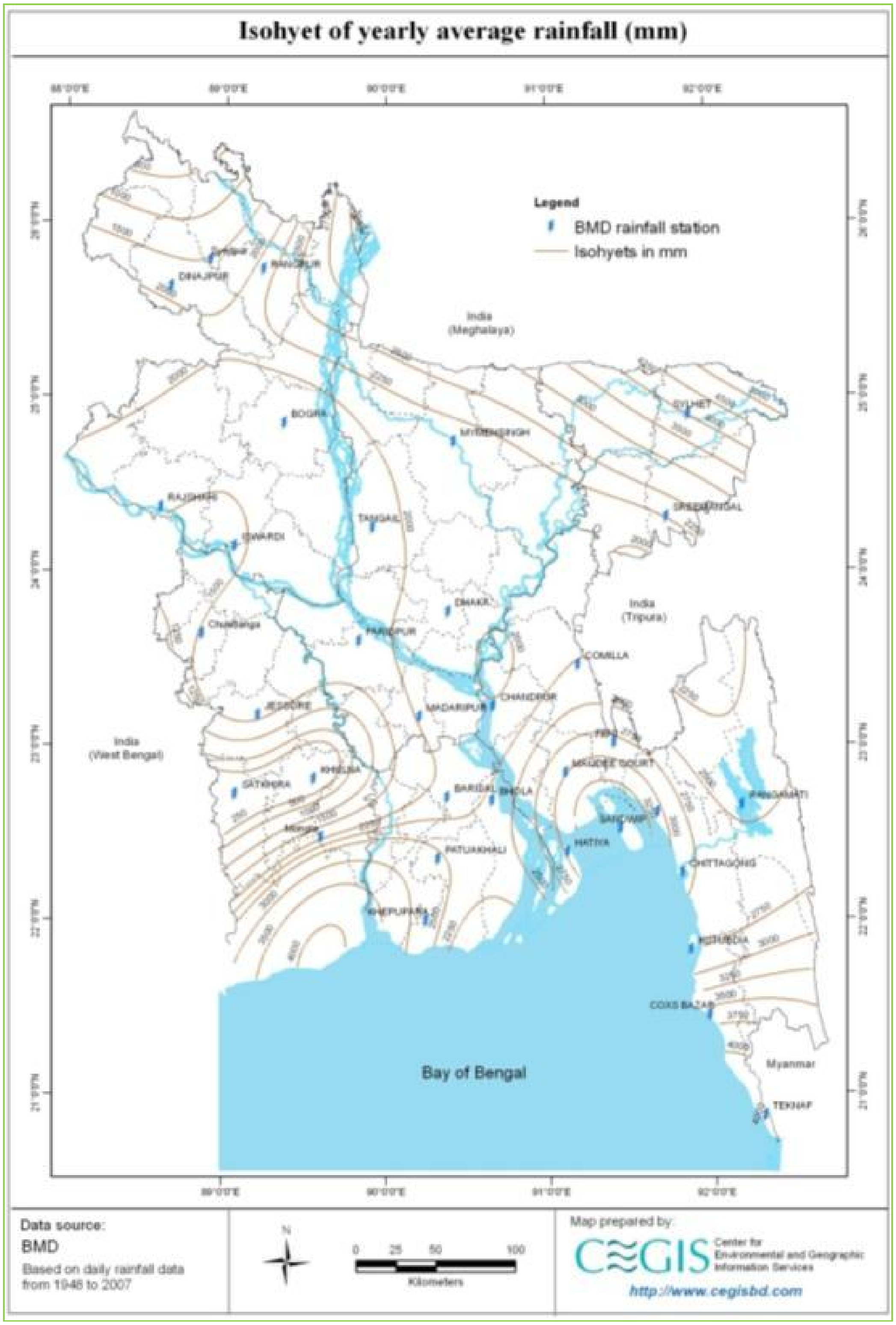


Fig. 2.8: Contour map of average rainfall in Bangladesh

Sunshine

The average bright sunshine duration in Bangladesh in the dry season is about 7.6 hours a day, and in the monsoon season about 4.7 hours. The sunshine duration in Bangladesh is in general decreasing at an alarming rate. The winter, dry season, summer and monsoon rates of decline across the country are 5.7 percent, 5.0 percent, 3.9 percent and 3.8 percent respectively for every 10 years. The overall annual decrease is about 0.36 hours a day in every decade, equal to 4.7 percent each decade (Climate Change Cell, 2009).

2.2.6 Land and Soil Resources

This section and some of the others that follow deal mainly with the country's physical and environmental resources. Energy resources will be discussed in another section. Land resources and characteristics are discussed in the present section.

Total land cover, excluding the estuarine rivers, comprises 139,813 sq.km. (WARPO,2001b). Rivers and water bodies account for nearly 9 percent, while forests, including mangroves, occupy nearly 19 percent. Settlements in urban and rural areas cover about 11 percent. Agriculture utilizes more than 59 percent of land, while miscellaneous uses take up another 2 percent. Agricultural activities will be discussed in-depth later on, as will water bodies, rivers and their characteristics. Nonetheless, because the perennial and seasonal interaction between land and water give rise to several peculiarities that are essential for understanding climate change impacts, we first discuss the resultant classification of land based on these interactions.

Floodplains

The floodplains of Bangladesh cover a significant part of the country and are formed by different rivers. A meandering river eroding sideways as it travels downstream makes floodplains. When a river breaks its banks and floods over, it leaves behind layers of rock and mud that gradually build up to create the floodplain floor. Floodplains normally contain unconsolidated sediments, often extending below the streambed. Floodplains are basically accumulations of sand, gravel, loam, silt and/or clay, which are considered very important landscapes in the context of agriculture and aquifers, with water drawn from them being pre-filtered compared to water in the stream. The floodplains of Bangladesh are divided into 18 sub-units based on location.

Floodplains serve rich ecosystems in the way of quantity as well as diversity, which can contain 100 or even 1,000 times as many species as a river (Wikipedia). This becomes all the more important in the present case, since the floodplains of Bangladesh become integrated into a single biological productive system during the monsoon. A conservative estimate of the number of freshwater bony fish species present in the system is 273, of which 13 species are exotic.

Wetlands and marshland

Wetland or marshes are known as *haors,baors* and *beels* and are generally formed on the topographically depressed areas of Bangladesh. The total area under wetlands may vary by season and has been estimated at 7 million to 8 million ha, or up to 50 percent of the country's total land surface. The areas of different categories of wetlands are given in Table 2.1.

Table 2.1: Types of wetlands and their areas (in sq.km.)

Rivers	7,497
Estuaries and mangrove swamps	6,102
Beels and *haors*	1,142
Floodplains	54,866
Kaptai Lake	688
Ponds	1,469
Baors (Oxbow Lakes)	55
Brackish-water farms	1,080
Total	72,899

Source: Akonda ,1989 and Khan,1994

Char lands

Char is the common name of islands and accreted lands on the bank of a river. Chars in Bangladesh can be considered a byproduct of the hydro-morphological dynamics of the country's rivers. Most char people (65 percent) live in the Jamuna chars. The total population in the chars during 1993 was about 631,000, a 47 percent increase over 1984. National population growth during the same period was estimated at 26 percent (Banglapedia, 2006). Thus, chars' importance in providing land for human habitation in Bangladesh is growing. Two types of chars, called islands and attached chars, are observed; island chars are always inaccessible without crossing the river arm, whereas attached chars are generally reachable from the mainland during the dry season (ISPAN, 1993).

Chars are extremely vulnerable to both erosion and flood hazards. Recent analysis of time series satellite images indicates that over 99 percent of the area within the riverbanks of the Jamuna had been char at one time or another during the period 1973-2000. The same analysis shows that about 75 percent of the chars perished between one and nine years, while only about 10 percent lasted for 18 years or more. In certain areas, however, chars can be quite stable (for example, in the Upper Meghna area) (Banglapedia). Island chars so far occupy 40percent of active river floodplain, which comprises about 6 percent of Bangladesh's total land. During the period 1984-1993, char areas increased in all rivers except in the Upper Meghna, for a net increase of 36,000 ha. The effects of riverbank erosion and widening of the river channel on people living in chars have been significant. More than half of the displacement was along the Jamuna. Island chars are found to be flooded more extensively than attached chars. Among chars within different river reaches, those in the Ganges are the most extensively flooded.

Each year a large percentage of chars flood. The flooding, if it comes early, can damage crops in the fields. People in chars build their homesteads on the highest available land, and if they stay there, they further elevate their homesteads on built-up plinths to avoid annual inundation.

Coastal islands

The islands in Bangladesh are scattered in the Bay of Bengal or the river mouth of the Padma (Figure 2.9). Major ones include Dublar Char, Bhola Island (largest island in the country), Sandwip, Hatiya, Manpura Island, St. Martin's Island, Kutubdia, Maheshkhali, Sonadia, and Urichar. Some islands that existed previously have disappeared.

Hills

Based on geology and landform, the hills of Bangladesh may broadly be subdivided into high hill ranges (about 70 percent) and low hill areas (about 30 percent). The high hill ranges, about 200-1,000 m above MSL, are steep to very steep hills and usually have a rather youthful soil mantle, ranging from a few cm to several metres in thickness over bedrocks. In contrast, the low hill areas, about 15-200 m above MSL, are nearly flat or round-topped and usually have old and deep soil.

The hilly areas cover about 17,342 sq.km., mostly in the Chittagong Hill Tracts, Chittagong, Habigonj and Moulavibazar, constituting about 12 percent of Bangladesh's total area.The Chittagong Hill Tracts alone cover 13,184 sq.km., or about 9 percent of the country.

Fertile valleys lie between the hill lines. West of the Chittagong Hills is a broad plain, cut by the rivers draining into the Bay of Bengal. The whole hilly region receives more than 2000 mm of precipitation annually, about 80 percent of which is received in four months (June-September). Only a century ago, the region was covered by tropical climax forests with diversified flora and fauna, although little is left now. As will be discussed below, very high rainfall, increased population encroachment on pristine forest, and slash-and-burn agriculture are increasingly likely to be affected by landslides as climate change brings more rain in the future.

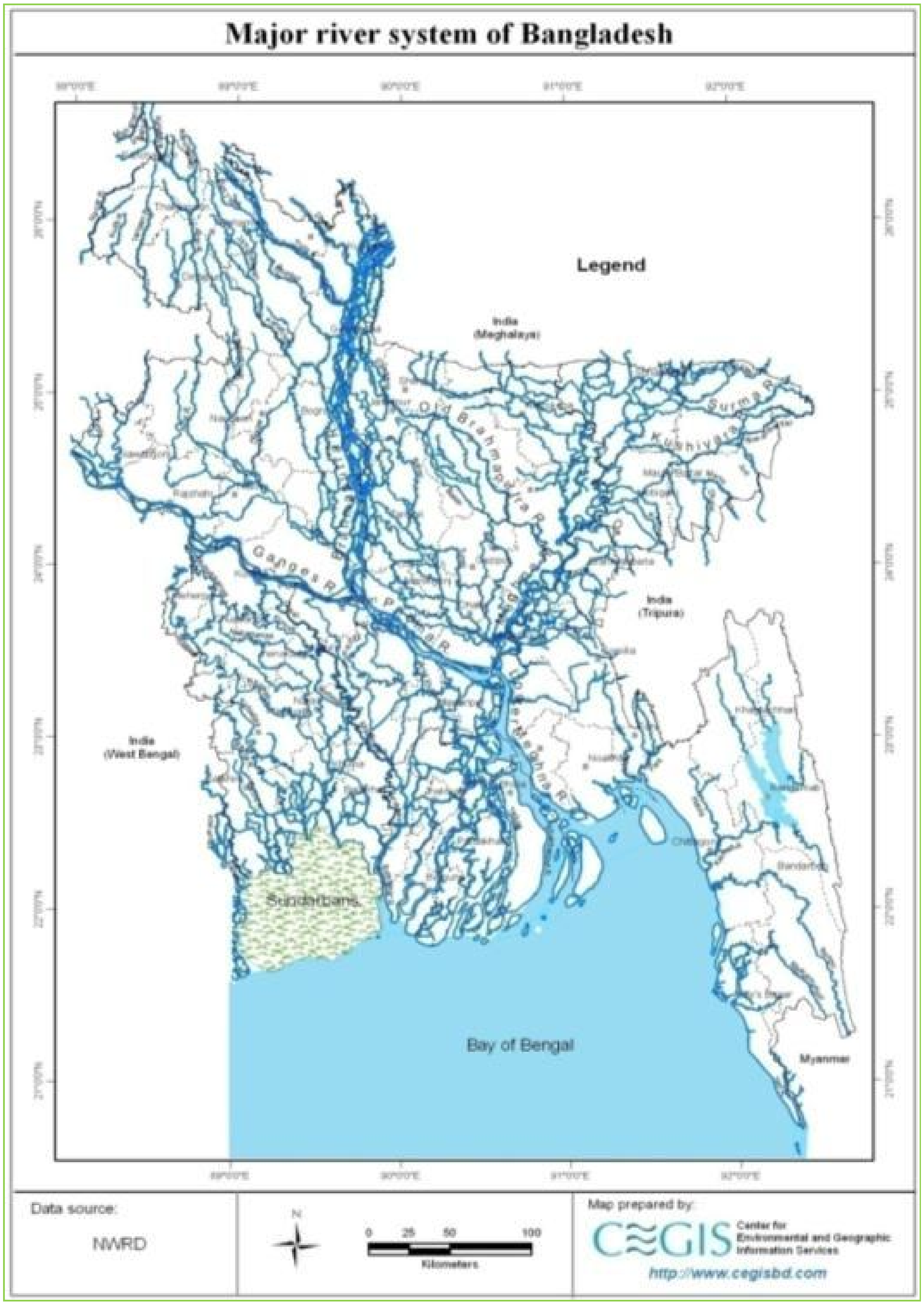


Fig. 2.9: Major river systems of Bangladesh

Elevated lands

There are three terrace or upland areas in Bangladesh. These Pleistocene uplands cover about 10 percent of the country, with an average elevation of more than 15metres above MSL. The Barind Tract, the largest upland, has an area of 7,770 sq.km. and comprises the mid- and lower western parts of Rajshahi division between the Ganges and Brahmaputra. The Madhupur Tract, another large Pleistocene inlier, consists mainly of red and mottled clays, with an area of about 4,105 sq. km;this elevated tract is probably the result of tectonic movements in the Bengal Basin. The Lalmai Hills in the north-south are an elongated low hill range about 17 km long and 1-2.4 km wide and run about 8 km westward from Comilla Township.

Soils

Bangladesh has a wide variety of soils with diverse and complex patterns that greatly influence land use, crop suitability, soil fertility and agronomic practices. The diversity and complexity of soil also have important implications for agricultural research, agricultural extension, land use planning and collection of crop statistics.

Soil resources of Bangladesh may be categorized into three major groups: floodplain, hill and terrace. The soils of two terraces (Barind and Madhupur Tracts) are diverse, ranging from deep, reddish-brown, friable and well-drained clay loams to grey, poorly drained and silty top soils over clay on level highlands. On the other hand, the hilly areas, spreading over 12 percent of the total land, have mainly loamy soils of shallow depth that are not suited for the cultivation of shallow-rooted crops because of poor water-holding capacity.

Floodplain Soils

Floodplain soils occupy 80 percent of the country's land area. Fresh alluvium is widely deposited closer to the rivers, while older deposits farther from the river are conducive to plant growth. There are 12 types of floodplain soils, depending on the elements from which these are formed as well as the acidity/alkalinity of the soil. The range of pH is 7.0 to 8.5.

During high tide the coastal floodplain is subject to flooding by saline water. This soil is saline or neutral but tends to be on the alkaline side, with pH range from 6.9 to 7.5 (Rahman et al., 1990). Seasonal flooding patterns significantly influence the physical and biological properties of soil, which also affects land use and agricultural potential.

The agro-ecological characteristics discussed above are categorized on the basis of physiography, soil and flooding characteristics (FAO, 1988). As the above discussion indicates, climate change is likely to interact in a complex manner with the soil characteristics because of changes in the water regimes (rainfall, surface flow), given that soil characteristics are already determined by these factors apart from what is brought in by the rivers from upstream. In turn, these ultimately determine the livelihoods of people through their impact on agriculture and related activities.

2.2.7 Water Resources

River network and flow regime

Bangladesh is a lower riparian country surrounded by hills on three sides. River flows are principally controlled by generation of flow in the upstream catchments of the Ganges-Brahmaputra-Meghna (GBM) basins, from relief rainfalls coupled with snowmelt in the Himalayas.

The country is crisscrossed with an intricate network of around 200 rivers, of which 57 are international rivers originating outside the boundary of Bangladesh. A map of the major river system is shown in Figure 2.9.The Ganges, Brahmaputra and Meghna are considered the major rivers that bring inflows from India. The total catchment area occupies 1.75 million sq.km., of which about 93 percent is outside the country. A total of 1.18 million cubic metres of water flows annually to the sea, of which 1.07 million cubic metres(91 percent) enter Bangladesh from India (Rashid, 1991).

The country may be divided into eight hydrological regions for water management purposes (WARPO, 2001a), yet all rivers in Bangladesh are hydraulically linked, with the exception of those in the Chittagong sub-region. All these rivers are either tributaries or distributaries of the GBM major river systems and control the flow hydraulics. From outside the country these rivers receive enough water flow to inundate the whole catchment area under 6 metres of water every year (Chowdhury et al., 1997). The Brahmaputra has the largest flood flow, followed by the Ganges and the Meghna, with a flow ratio of 4.4:2.5:1. Around 54 percent (598.908 km^3) is contributed by the Brahmaputra, 31 percent (343.932 km^3) by the Ganges and nearly 15 percent (162.772 km^3) by the tributaries of the Meghna and other minor rivers. The GBM system jointly discharges one of the highest amounts of flow in the world. Peak discharge is 100,000 m^3/s from the Brahmaputra, 75,000 m^3/s from the Ganges, 20,000 m^3/s from the upper Meghna and 160,000 m^3/s from the lower Meghna, which provides the final conjoined flow of all these rivers. While these flows are high, seasonal variation in flow is highly skewed, with abundant water during monsoon and very small flow during dry season. For the Ganges the estimated discharge ratio is 1:6 between the dry and monsoon seasons (Mirza and Dixit, 1997).

The GBM system accounts for about 85 percent of mean dry season stream flow, with the remaining 15 percent carried by smaller rivers. As a result of this discharge pattern, floods in wet season and water scarcity during dry season appear as natural hazards. Hydrodynamic features in the alluvial rivers of Bangladesh vary during low flow and flood flow (Chowdhury et al.,1997; Salehin et al, : 2007). All these indicate the necessity of cooperation between neighboring upper and lower riparian countries to minimize some of the climate change-induced vulnerability such as flood, as well as to maintain dry season flow for irrigation, navigability, domestic uses and demands for preserving ecological integrity.

Inundation levels over landmass

Given that surface water distribution in Bangladesh is dependent on highly uneven seasonal distribution of precipitation and Himalayan snowmelt as well as being highly uneven in itself, flooding in certain times of the year is very likely. Apart from inundating settlements and destroying infrastructure, these floods also regulate, and sometimes wreak havoc with, agricultural production.

Fig. 2.10 shows a flood regime land-type map of Bangladesh. The choice of the cropping pattern in an area depends generally on the area's normal flooding depth. Some varieties are grown on flooded land, while others are on basically flood-free land (whether naturally flood-free or made flood-free by construction of flood protection embankments). "Normal" flood depth thus serves as a regulator of the agricultural rhythm. Land use type in the country largely depends on the "inundation land type," which indicates the topographic position of land in accordance to monsoon season inundation. The classification of cultivable land by flood depth is given in Table 2.2, developed from categories of land types that rely on "normal: seasonal flooding (Brammer, 2002). This classification is used in water resources planning.

Groundwater

The Bengal delta, formed with alluvial soil, contains a large groundwater aquifer. The storage coefficient of the alluvial aquifer varies from 1 to 15 percent, where the transmission rate is in a range of 500 to 3000 m^3per day per meter width.

Given high surface water flow and high levels of rainfall during parts of the year, groundwater thus is a significant natural resource of Bangladesh, used in the domestic, industrial and agricultural sectors. In most parts of the country, the very shallow aquifers are found at 6-15 m below the surface, whereas deep aquifers are found at a depth of 60-120 m.

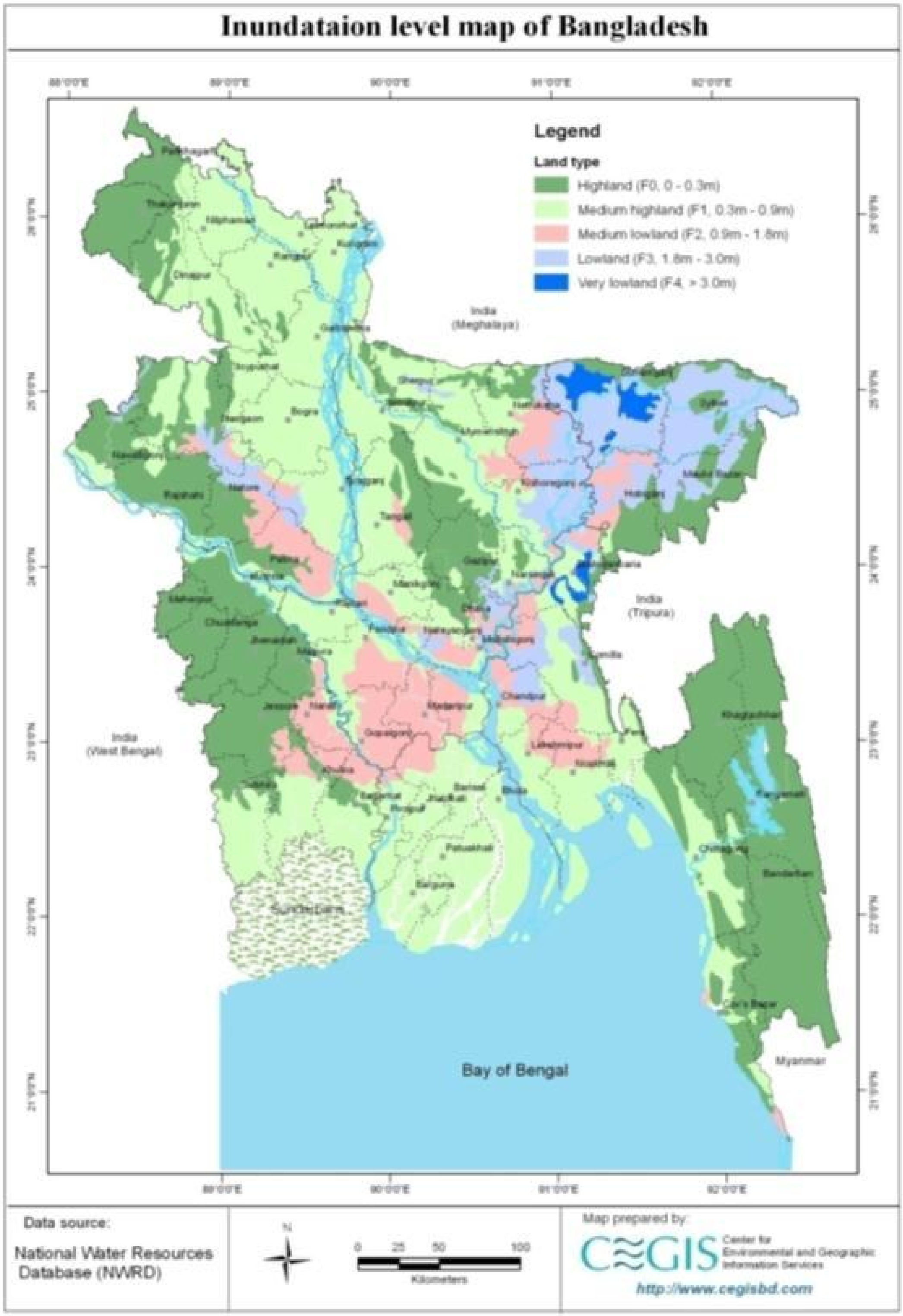


Fig. 2.10: Inundation land level map of Bangladesh

Table 2.2: Classification of cultivable land by flood depth

Land type	Flood depth (cm)	Land elevation description	Area (Mha)	%
F0	0-30	High land	4.20	29
F1	30-90	Medium high land	5.04	35
F2	90-180	Medium low land	1.18	12
F3	180-300	Lowland	1.10	8
F4	Over 300	Very lowland	0.19	1

Note: Settlements and water bodies cover 15per cent, Source: Harza, 1984.

2.2.8 Forest Resources

Officially, forest land occupies around 17 percent of Bangladesh's area. . However, it is not known how much crown cover is included. The Forest Department manages 1.52 million ha out of 2.52 million ha of forest land. Table 2.3 shows the division of forest land under the Forest Department.

Table 2.3: Types of forest managed by Forest Department

Types of Forest	Area (mn ha)	Percentage
Natural mangrove forests and plantations	0.73	4.95
Tropical evergreen and semi-evergreen forests	0.67	4.54
Tropical moist deciduous forests	0.12	0.81
Total	**1.52**	**10.3**

Source:http://www.bforest.gov.bd/type.php#green

The Ministry of Land controls 0.73 million ha as Unclassified State Forest (USF). Homestead or village forests, covering 0.27 million ha, are considered the most productive source of floral resource in Bangladesh. Hill forests comprise a significant class of Bangladesh forests, covering 670,000 ha(44 percent of forests managed by the Forest Department and 4.54 percent of the total country area).

The Sundarbans represent the world's largest contiguous natural mangrove forest, covering 6,017 sq.km. or 4.07 percent of Bangladesh's total area. The Sundarbans area includes three wildlife sanctuaries comprising 139,700 ha declared as a UNESCO World Heritage Site in 1997.

Major mangrove species in the Sundarbans are Sundri (Heritiera fomes), Gewa (Excoecaria agallocha), Keora (Sonneratia apetala), Baen (Avecennia officinalis), Dhundul (Xylocarpus granatum), and Passur (Xylocarpus mekongensis). Together, these account for 12.26 million m³of timber. Some non-wood valuable forest products exist, including golpata (Nypa fruticans), honey, wax, fish and crab.

The Sundarbans is a unique habitat for a number of wildlife, including the Bengal tiger (*Panthera tigris*), the Gangetic dolphin (*Platanista gangetica*), monkeys (*Macaca mulatta*), the Indian fishing cat (*Felis viverrina*), the Indian otter (*Lutra perspicillata*), and the spotted deer (*Axis axis*). Reptiles like the estuarine crocodile (*Crocodylus porosus*), the monitor lizard

(*Varanus salvator*), the rock python (*Python molurus*) and the green turtle (*Chelonia mydas*) also are found here.

The Sundarbans provides many livelihood and environmental services in Bangladesh, including its role as the crucible of biodiversity. In fact, when the powerful Cyclone Sidr hit Bangladesh in 2007, the Sundarbans served as a giant windbreak, thus saving many lives, homesteads and properties. Sea level rise as a consequence of climate change is likely to threaten the existence of the Sundarbans and thus becomes a major issue in understanding the country's vulnerability to climate change and adaptation.

While the Sundarbans is a natural forest, foresters in Bangladesh also have created mangrove plantations along the southern coastal belt. Several coastal afforestation projects planted mangrove species on 142,835 ha of land between 1960-61 and 1999-2000; however, some areas have been damaged by natural disasters. . Coastal afforestation is an example of mitigation (growing trees are carbon sinks) as well as adaptation (these trees act as buffers against cyclonic storm surges).

Hill forests are rich in biodiversity and have been managed as plantations since the late 19trh Century. These forests supply 2,393 million $m^3$of forest products and are home to a diverse array of plant and animal life. Teak is a major product from these forests, along with other important timber from other plants.

The plain land sal forest is spread over several districts and covers 120,000 ha, or 0.81 percent of total land area and 7.8 percent of forest area. The dominant species is sal (*Shorea robusta*), associated with koroi (*Albizzia procera*) and others. These are fragmented into patches thatare intensively mixed with nearby settlements. According to a recent survey, wood supply from these forests is around 3.75 million m^3. Participatory forestry programmes are currently implemented here under social forestry initiatives.

Lastly, village or homestead forests cover 270,000 ha, supplying the bulk of fuel wood for cooking and other purposes. A recent survey revealed that the village forests yield a total of 54.7 million $m^3$of forest products.

Overall, forests are important natural and managed resources of the country, although their degraded quality renders this area insufficient to meet national demands. At the same time, major scope for improvement exists under mitigation measures such as REDD+.

2.2.9 Livestock and Fisheries

Livestock

Livestock is considered an important part of a country's wealth. In 2007-2008, the total number of livestock in Bangladesh stood at some 48 million, with half being large ruminants (cattle and buffalo) and the other half small ruminants (goats and sheep). Of the total of 24.16 million large ruminants, nearly 23 million were cattle and the rest buffalo. Among small ruminants, most are goats. Cattle and buffalo provide draught services as well as various products such as hides and skins for further processing. In fiscal 2007-2008 the estimated share of the livestock sub-sector in GDP was 2.79 percent.

Livestock are important from a climate change point of view since they are a major source of methane directly (enteric fermentation) as well as indirectly (manure management). Livestock number and their management thus are important issues in climate change management. Of particular interest is the fact that nearly 70 percent of cattle are owned by small farmers operating no more than 1 ha of land; any required mitigation measures therefore mustfit into this widely dispersed ownership pattern.

Fisheries

Fish represents 80 percent of total animal protein consumed in the country. On the other hand, Bangladesh ranks third among top inland fish-producing and inland aquaculture production countries. The fisheries resources of Bangladesh comprise a wide range of fishes, prawns, lobsters, crustaceans, molluscs, turtles and other fish resources that occupy the country's widespread marine and inland open waters. Seasonally inundated floodplains, rivers and their tributaries, *beels, haors* and *baors*, along with the estuarine and brackish waters in the south, provide a hospitable ground for rich fishery resources. The total area under inland open and closed water bodies is about 4.6 million ha, of which 91 percent is inland open water body and the remaining 9 percent closed water body.

The aquatic ecosystem of Bangladesh is diverse and divided into three categories: freshwater, estuarine and marine. In the freshwater, 264 species of finfish, 4 species of crabs, 10 species of shrimps/prawns and 20 species of turtles have been recorded.

The estuaries are similarly rich in biodiversity, with 149 species of finfish and 19 species of shrimp/prawns. In the marine water, 475 marine fish species are found at different depths. Among these, 56 are cartilaginous fishes and 386 are bony fishes. A total of 11 species of marine crabs also have been identified.

In fiscal 2006-2007, the total production of fish was more than 2.3.million metric tons. Community-based fish culture, as well as use of modern technology and different programmes implemented by the Department of Fisheries (DoF) at field level, has raised inland fish production. DoF programmes include community-based fish culture, stocking of fingerlings, restoration of habitats, establishment of sanctuaries, enforcement of different fish conservation laws and floodplain aquaculture.

The sustainability of fish resources, the dependence of livelihoods of a very large group of fishermen and related occupation-holders, and the nutrition of the general population will all be critically dependent in the future on how climate change affects the fish habitat, the quality of the aquatic environment and technology. Thus, it will be essential to clearly understand how fishery resources will be affected by climate change, although currently only limited understanding of this exists, as will be discussed below.

2.2.10 *Biodiversity*

Bangladesh is rich in biodiversity. There are 266 indigenous fish species (belonging to 55 families) in inland water bodies, 56 species of prawns, more than 20 species of molluscs and 150 species of birds. The marine ecosystem has 442 species of fish, at least 36 species of marine shrimp, and about 336 species of molluscs, representing 151 genera. Several species of crabs and 31 species of turtles and tortoises, of which 24 live in freshwater, are found.

Furthermore, the IUCN (2000) has identified 22 amphibians, 126 reptiles and 628 birds in total (388 resident and 240 migratory), 110 inland mammals, and 3 species of marine mammals in the country. Numerous invertebrates in Bangladesh are yet to be identified. The country supports about 50,000 species of angiosperms, among which 300 species are being cultivated. The list of medicinal plants is expected to include more than 500 species. Timber plants number 224, while 130 fibre plants have also been found. As noted above, the Sundarbans supports a very rich and diverse fish fauna of 400 species, more than 270 species of birds and more than 300 species of plants.

This biodiversity already is under threat as a result of the pressure of an increasing population and other factors. According to the Red List of IUCN, 54 species of inland fishes, 8 amphibians, 58 reptiles, 41 resident birds and 40 mammals are threatened, as are marine and migratory species (4 fishes, 5 reptiles, 6 birds and 3 mammals). The Bangladesh National Herbarium already lists 96 seed-bearing plant species as threatened.

To protect against such threats, there are 28 Protected Areas (PAs) in Bangladesh. PAs cover a total area of 2,68,961 ha, which accounts for almost 1.8 percent of total land area. PAs include 15 national parks and 13 wildlife sanctuaries. Among the Pas, eight are ecologically critical areas;some are located in areas that may be under threat due to impacts of climate change.

2.2.11 *Various Mineral Resources*

In Bangladesh, 5 coal fields have been discovered so far, namely Barapukuria, Khalaspir, Phulbari, Jamalgonj and Dighipara. Commercial production of barapukuria coal mine commenced from10 September 2005 with the targeted capacity of one million metric tonne per year. During FY 2009-2010, a total of 0.77 million metric ton of coal were extracted from the coal mine.

Madhyapara hard rock mine has been operating since 25 May 2007 with the targeted capacity of 16.50 lakh metric tons per year (5500 tonnes per year). Since it became operational up to June 2010, about 1316167 metric tones hard rock was extracted from this mine.

Other minerals found in the country include limestone, lignite, silica sand, white clay, peat and gravel deposits etc.(Source: Bangladesh Economic Review, and BBS,2010).

2.3 Population Size and Other Characteristics

Bangladesh's population rose from 87.1 million in 1981 to 124.3 million in 2001, and stands at 142.3 million according to preliminary results of the 2011 population census. In both the earlier years, males slightly outnumbered females. However, several key changes have occurred over the years: First, the population growth rate fell steadily, from 2.35 percent (1974-1981) to 2.17 percent (1981-1991) and then to 1.59 percent (1991-2001). Since then, it has fallen even further, to 1.34 percent. This has been made possible by a drastic decline in the total fertility rate by almost half in two decades, from 4.7 in 1986 to 2.4 in 2007.

At the same time, the country's average population density was 834 per sq.km. (BBS, 2011) in 2001 and increased to 964 by 2011, although the density is not the same everywhere (Fig. 2.11). If only net land area is considered, the population density will be much higher. Overall, population density is lower in the hilly areas and the coastal region, although there are major exceptions in Chittagong or Cox's Bazaar districts, where the density was 1,421 and 913 respectively(Asaduzzaman,M.et al.,2010a).

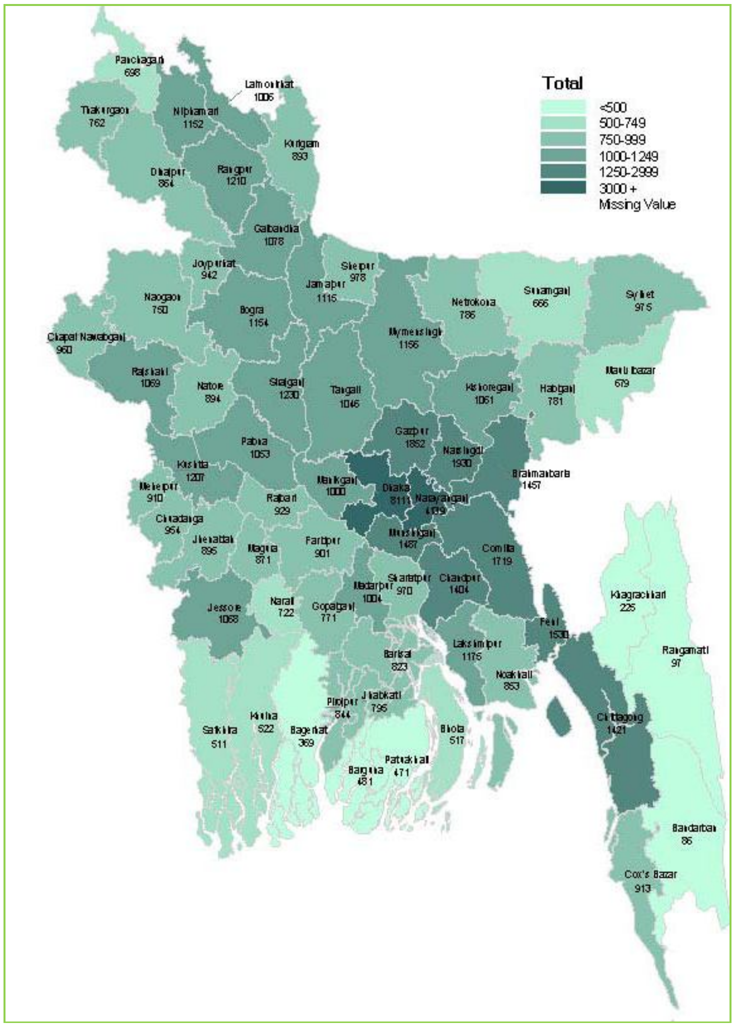


Fig. 2.11: Population density of Bangladesh 2011, Source: BBS, Statistical Year Book (SYB), 2011

Urban population has increased both in absolute and relative size, indicating a spatial change in distribution. In 1981, only about 15 percent of people were considered as urban, although by 2001 the proportion had increased to more than 25 percent. In absolute terms over the same period, the urban population increased from just above 14 million in 1981 to 31.0 million by 2001, implying a growth rate of around 3.5 percent annually. Given the declining rate of growth of the national population, the speed of urbanization has thus been phenomenal.

A change also has occurred in the age structure, with prime-age persons in the age groups 15-24 and 25-34 becoming more numerous both in absolute and relative terms. At the same time, the proportion of the very young has fallen. This means that the working-age population has increased as the total population size has grown.

The characteristics of population point to several implications in terms of vulnerability and adaptation. First, with 80 percent of land under active or old floodplain and home to much of the population, a very substantial group of people is exposed to river floods, cyclonic storms, and surges and salinity. With climate change, the risks that they face in the future are going to be even higher.Second, the fast pace of urbanization– with at least half the population by 2050 expected to be in cities and towns – calls for vulnerability assessments of, and adaptation measures in, the urban areas. (See Chapter 5, section on urban area vulnerability). A third and more positive change is the fact that the proportion of working-age people is increasing, which will lessen dependency. Even so, work will have to be found for all of them; if the rate of economic growth slows due to the impacts of climate change, this will be even more difficult than it already is(Asaduzzaman,M.et al.,2010a).

2.4 Economy, Livelihood and Related Issues

This section examines several issues: First, economic growth and development issues are examined, as well as the situation and performance in the key agriculture sector (including livestock, fisheries and forestry, industry and services). Second is an analysis of supporting activities such as energy, transport and infrastructure. The third sub-section considers livelihood issues such as poverty, employment, and achievements or shortfalls related to the Millennium Development Goals (MDGs), including those related to food security, health and nutrition. Education also is discussed here, although there is a separate section on human skills formation in general.

2.4.1 Economic Growth and Development

Record of growth

From 1998-1999 to 2010-2011, Bangladesh's economy has recorded a fairly strong growth rate of 5.7 percent annually. As Table 2.4 indicates, the main sources of growth have been manufacturing industries and services (with transport and trade being the two major items within this sector). Agriculture has grown at a comparatively lower rate, although sub-sectors such as livestock and forestry exhibited better performance. At the same time, long-term growth hides year-to-year fluctuations that sometime may be quite sharp, as Fig. 2.12 indicates.

Table 2.4: Exponential rates of growth of the economy and sectors

(Percent per annum between 1998-99 and 2010-11)

Sector	Percent/annum
GDP	5.7
Agriculture	3.6
Crops	3.3
Livestock	4.5
Fishery	3.1
Forestry	4.8
Industries	7.4
Services	6.3

Source: Estimated by consultant based on data in *Bangladesh Economic Review*, various years.

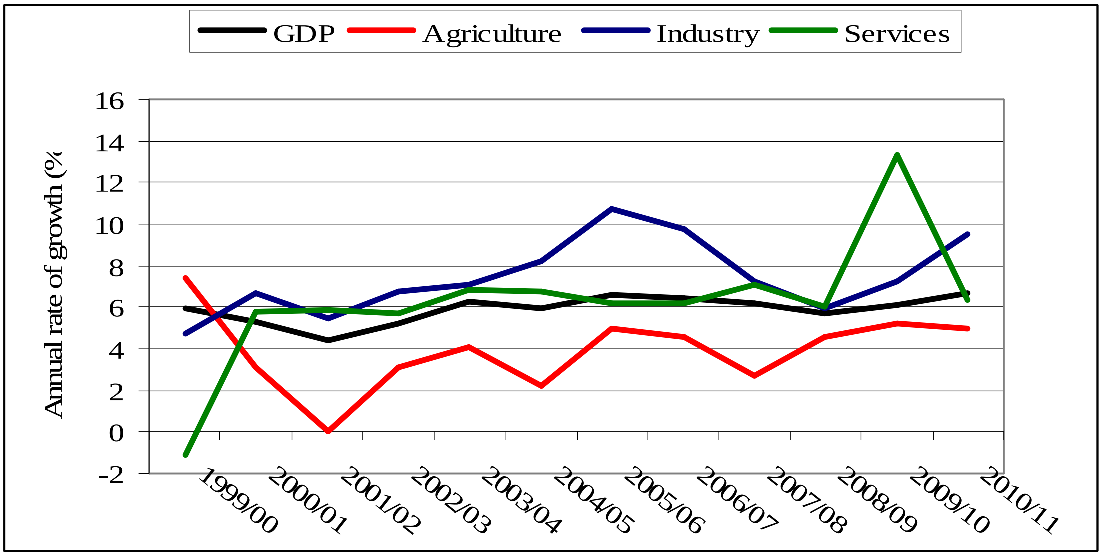


Fig. 2.12: Fluctuations in annual rates of growth of sectors, Source: BBS**,** SYB, 2001-2011

Sectoral shares

Sectoral shares have been changing over time. The share of agriculture has fallen from about a quarter to 19 percent, while that of industries has risen from 14 to 17 percent over the period 1998-1999 to 2010-2011. The rest has been accounted for by the category “all others,” basically services. While the fall in the share of agriculture may appear disconcerting, note, however, that this is the share in the aggregate value added. Despite the fall in this share, the actual value added in agriculture has risen from Taka 47 billion to slightly more than Taka 74 billion, implying a rise of more than 67 percent jump at constant prices (1995-96). Similarly, industrial value added has risen from Taka 29 billion to Taka 69 billion, an increase of 138 percent in 13 years at constant prices of 1995-1996.

External economy

Here we examine briefly external economic links and their implications for Bangladesh. This may also serve as an indicator of how the country may fare as and when substantial funding becomes available for managing climate change and its impacts.

Bangladesh’s balance of trade remained negative for the last one decade, continuing earlier trends. In 2008-2009, the payments for imports were US$20.2 billion versusUS$15.6 billion in exports, leaving a negative trade balance of US$4.7 billion. On services and income items too, there were net negative balances. Yet the current balance is positive, at US$2.42 billion, mainly because of remittances from outside workers. Since 2000, remittances have experienced explosive growth, rising from US$1.8 billion to slightly under US$11 billion by 2009-2010. At the same time, exports, particularly of readymade garments and knitwear, have risen from US$4.8 billion to US$12.4 billion. This belies the common belief that Bangladesh exports mostly primary commodities; in 2009-10, for example, only US$884 million of primary goods was exported, compared to US$15.3 billion in manufactured goods.

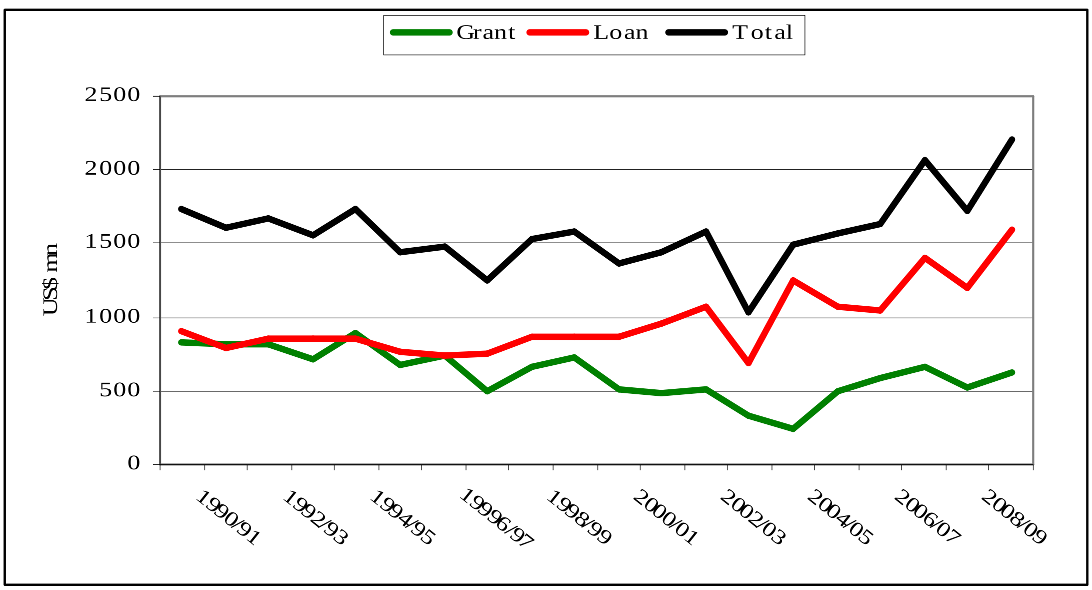
The situation related to imports was somewhat different, however. In this case, Bangladesh imported food both as a primary good (rice, wheat and oilseed) and processed food (such as edible oil). In 2009-10, US$23.74 billion worth of goods was imported, with the bulk of it (US$14.3 billion, or 60 percent) being consumer goods. Food constituted just US$2.0 billion, while the import of capital machineries and intermediate goods for processing was slightly more than 23 percent of total imports.

What the above situation shows is that Bangladesh is already handling a very substantial amount of money every year, and that so far this has not disturbed the macroeconomic balance as such. If climate change funding is obtained in the coming years, it is unlikely to create a significant macroeconomic "ripple."

ODA and private foreign investment

For the last 15 years, Bangladesh has received an average of around US$1.5 billion per yearin Official Development Assistance (ODA), although in recent years it has gone up to US$2 billion or more (Fig. 2.13). Compared to export earnings including remittances, this figure remains relatively small. The ODA grant element has been falling, while the loan element has mostly remained steady except during recent years. By 2009-10 Bangladesh had accumulated a foreign debt of more than US$21 billion, but its debt service liability (as a percentage of export earnings) had persistently fallen and stood at just 3 percent that year.

Of the total money disbursed under ODA, much has been as project aid. Food aid particularly has been of low significance, primarily hovering at between 3 and 4 percent of total disbursement. The highest amount in recent years was at the height of the global food crisis in 2007-2008, at US$111 million, but even then it constituted only around 6 percent of total aid disbursed.



Source: Based on MoF, *Bangladesh Economic Review*, 2010

Fig. 2.13; ODA flow into Bangladesh

Foreign private investment in Bangladesh has been low compared to other countries in Asia. The highest such investment, US$1.1 billion, was in 2008.

2.4.2 Agriculture in Bangladesh and Its Performance

Growth of agriculture and sub-sectors

As Fig. 2.14 shows, the agricultural sub-sectors have exhibited variable performance similar to the case of the full sectors of the economy. Of particular note is that the crop sub-sector, the largest among all sub-sectors, has shown the most fluctuation from year to year. This has occurred because it is highly dependent on the weather and timely, adequate rainfall as well as availability of inputs such as fertilizer and fuel for irrigation machines.

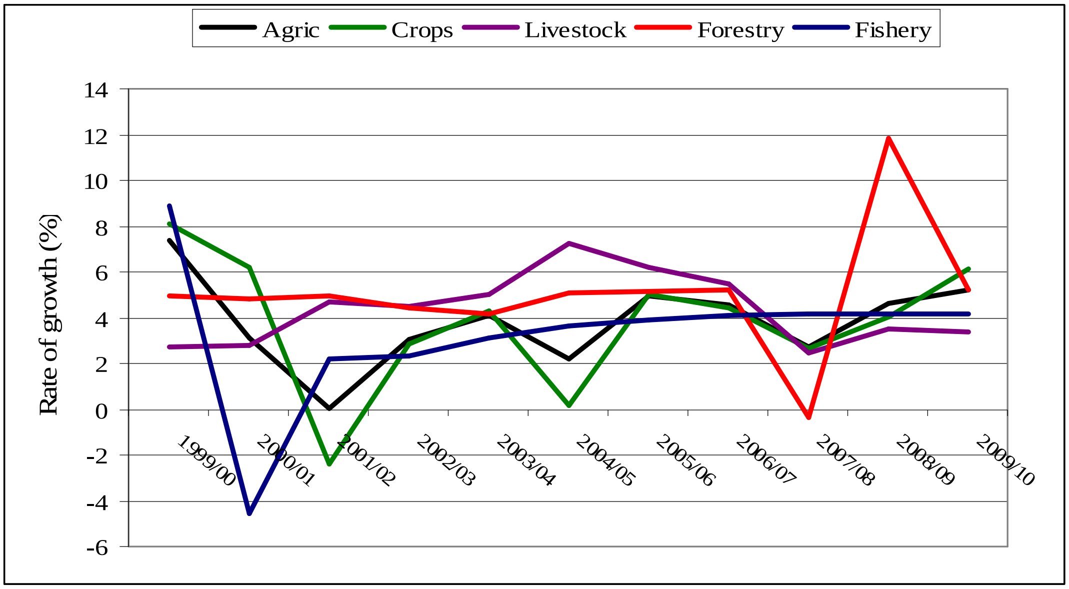


Fig. 2.14: Fluctuations in annual rates of growth in agriculture, Source: BBS, SYB 2001-2010

Shares of sub-sectors

Shares of the specific sub-sectors in the overall agricultural GDP have remained by and large invariant over time. Crops have accounted for 56 to 57 percent of the agricultural value added since the late 1990s. The share of fisheries also has remained constant, at 22 to 23 percent, whereas those of livestock and forestry have remained invariant at 12 to 13 percent and 7 to 9 percent respectively.

Characteristics of the crop subs-sector[1]

The crop sub-sector has several characteristics worthy of note, including:

i. First, rice dominates all crops, both in terms of value added as well as area. It accounts for more than 62 percent of the crop sub-sector value added, although this figure was even higher (68 percent) early in the decade. In terms of area, the the share of rice/paddy has increased (Fig. 2.15);only potato has to an extent also shown a similar trend. In contrast, the area under pulses, a source of vegetable protein and also nitrogen-fixing in soil, has fallen, as has that of wheat. The relative area under oilseeds likewise has fallen, with adverse nutritional implications. Throughout these years, total gross area remained basically unchanged at around 33,000 acres.

[1]This sub-section draws heavily from Asaduzzaman, M.et al.,2010

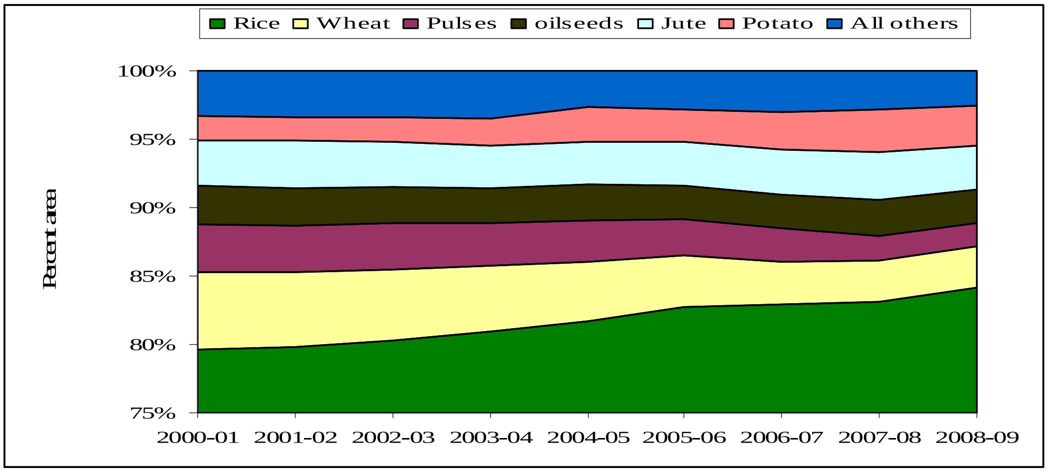


Fig. 2.15: Percentage share of various crops in gross cropped area, Source: BBS, 2002-2009

ii. Land is continuously transforming from agricultural to non-agricultural uses because of population pressure, expansion of area under settlement, urbanization, and infrastructure building. Given that increasing population also means a higher demand for food, the available land for crop cultivation must be intensively used; in Bangladesh, land use intensity has been rising steadily and now stands at 180 percent.

iii. There are three types of rice and rice growing seasons. *Aman* rice is basically rain-fed, but may need supplementary irrigation. It is also susceptible to natural hazards such as floods, cyclones in coastal areas, and drought. This was historically the main rice produced and has held on to its absolute area over time (Fig. 2.16). *Aus* is wholly rain-fed rice, grown on high land to avoid the impacts of flood; it has, however, more or less lost out to *boro*, which is practically wholly irrigated.

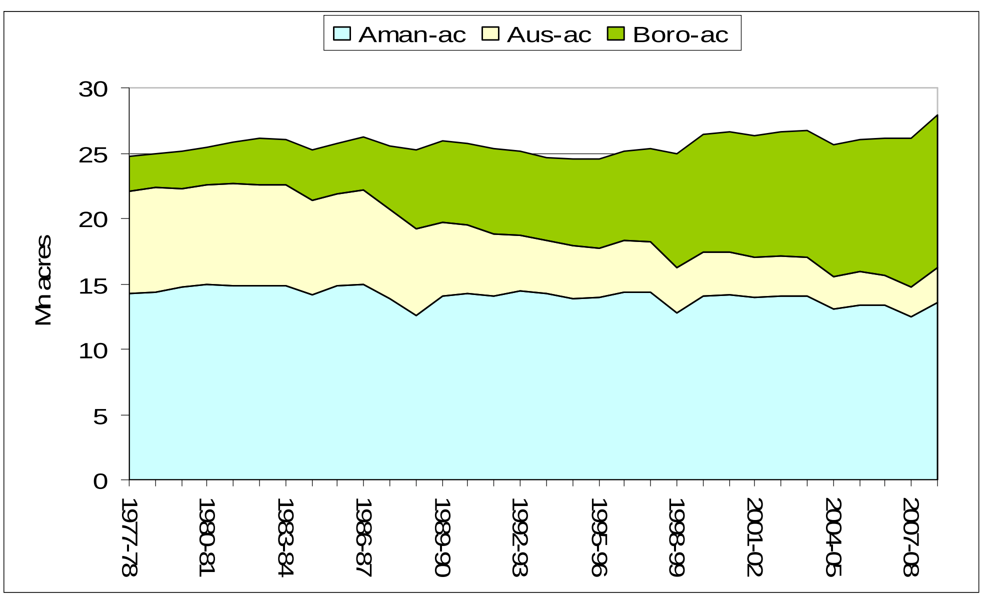


Fig. 2.16: Distribution of rice acreage under different seasons, Source: BBS, Various years

iv. High-yielding varieties (HYVs) which are fertilizer- and water management-intensive have largely replaced local varieties in terms of area (Fig. 2.17). In fact, *boro* is almost wholly HYV, while *aman* also is grown with HYV seeds wherever there are flood protection embankments. This is because HYV yields, although input-intensive, are much higher than the those of local varieties. Given that there has been large-scale switching from local varieties to HYVs, this has raised overall yield. This trend has been most prominent for the irrigated *boro* rice, which now accounts for some 69 percent of the country's total rice output (Fig. 2.18).

v. Crop agriculture has become far more energy-intensive, directly and indirectly, because of the higher application of fertilizer, including nitrogenous fertilizer; mechanized irrigation run with diesel and electricity; use of power tillers and tractors for land preparation; and use of mechanized power and diesel-driven threshers. At the same time, rice is usually eaten parboiled, which uses a lot of energy from biomass (rice husks), while milling is mechanized to a considerable extent.

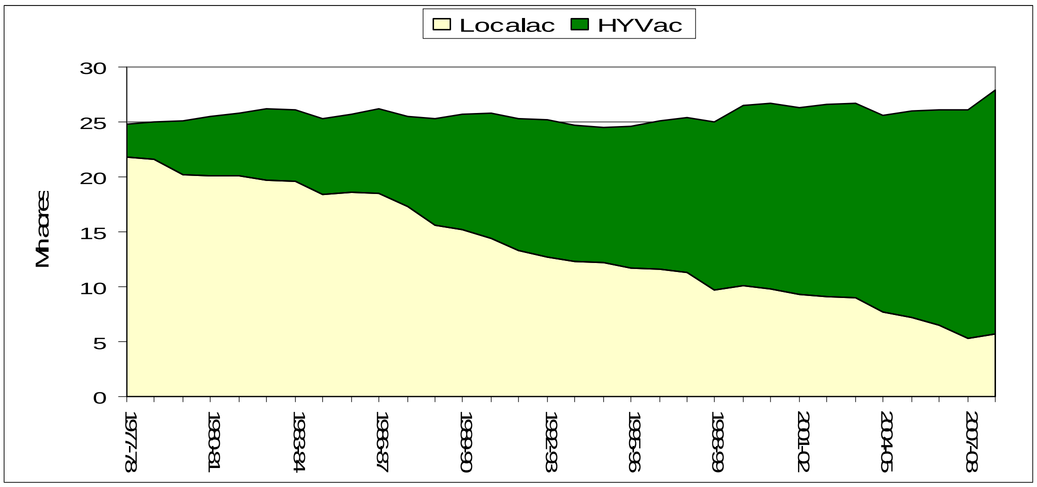


Fig. 2.17: Distribution of rice land by variety, Source: BBS, Various years

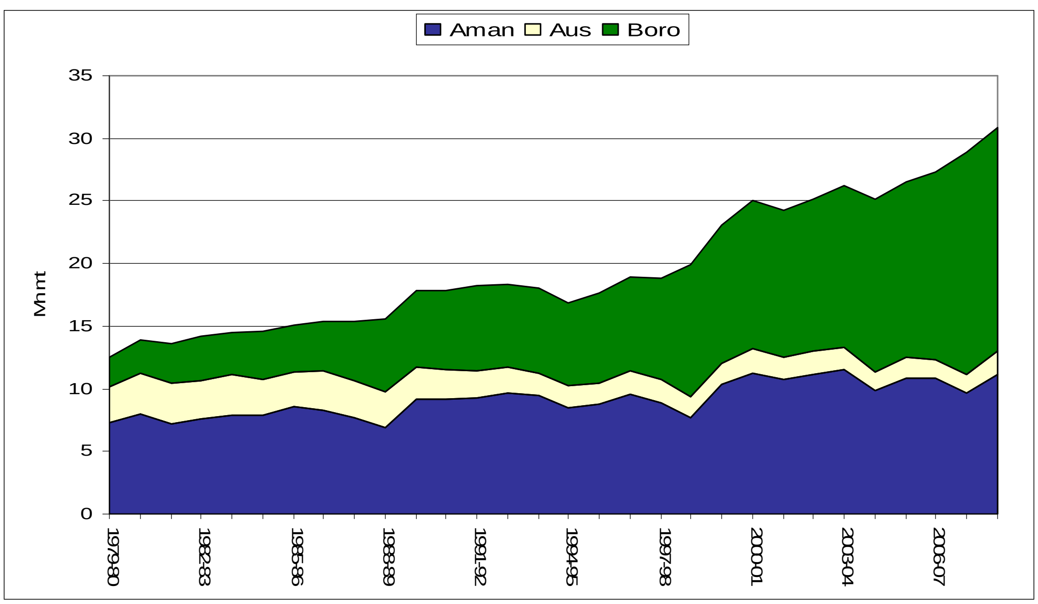
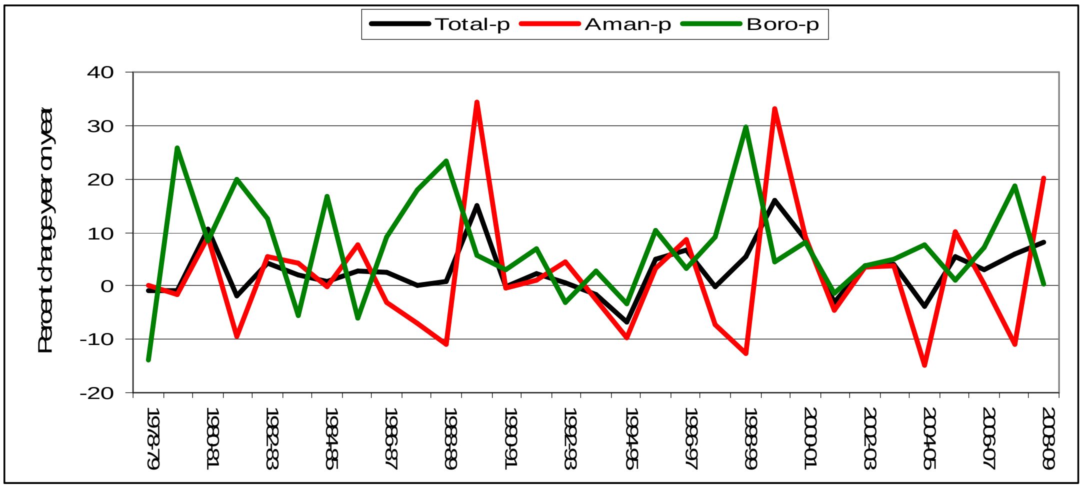


Fig. 2.18: Output trends of rice by season, Source: BBS, SYB, Various years

vi. Although water management and energy intensity have increased overall, there has not been much of a concomitant rise in productivity of either water or energy in rice production. In the case of potato, where cold storage uses a substantial amount of electrical energy, efficiency likewise is not high.

vii. Because of the use of energy-intensive inputs, particularly water management practices in rice fields and heavy application of nitrogenous fertilizer, agriculture now emits a substantial amount of GHGs (carbon dioxide, methane and nitrous oxide). A life cycle analysis done recently indicates that Bangladesh's agriculture may be emitting 12.7 million mt of CO_2, 2.99 million mt of methane and 0.05 million mt of nitrous oxide (Asaduzzaman,M. et al.,2011). In terms of global warming potentials (GWP) over 100 years, this is equivalent to nearly 90 million mt of carbon dioxide. For direct emission estimates, see Chapter 3.

viii. With regard to vulnerability, agriculture heavily suffers from weather variability and associated phenomena. As a result, there is high volatility in the year-on-year rate of growth of output (Fig. 2.19). Not surprisingly while both *boro* and *aman* rice output are volatile, the aman output actually shows negative growth in some years.



Source: Asaduzzaman (2010).

Fig. 2.19: Volatility of rice output

Note: *Total-p*: total production; *aman-p*: aman production; *boro-p*: boro production

ix. The production of crops is organized primarily in marginal and small landholding farms. The 2008 Agricultural Census found that 84 percent of farms hold no more than 2.5 acres (about 1 ha). On the other end of the scale are large farms holding at least 7.5 acres (3 ha), which accounted for 1.54 percent of farms. Thus, anything adverse agricultural occurrence in Bangladesh will negatively and heavily affect small and marginal farmers.

2.4.3 Industrial Performance

Manufacturing industries are categorized as small, medium or large. Medium and large enterprises account for the bulk of the value added by manufacturing industries (70 to 71 percent). The ratio appears to have remained invariant over the past decade or so. The quantum index of industrial production has increased over time from around 200 to around 400 (1988-

89 base=100). The industry with the most explosive growth has been readymade garments, with a quantum index that has shot up from around 800 in the year 2000 to more than 1600 now. Other industries that have experienced good growth include beverages, pharmaceuticals and cement. Agro-processing industries in general have not performed well. The quantum indices of jute, sugar, paper and fertilizer all have more or less fallen over time.

2.5 Production-Supporting Sectors

As indicated above, the discussion here will focus specifically on three sectors that provide outputs of goods and services used in production processes in the three broad sectors of the economy. These are energy, transport and other infrastructure.

2.5.1 Energy Resources: Consumption and Supply

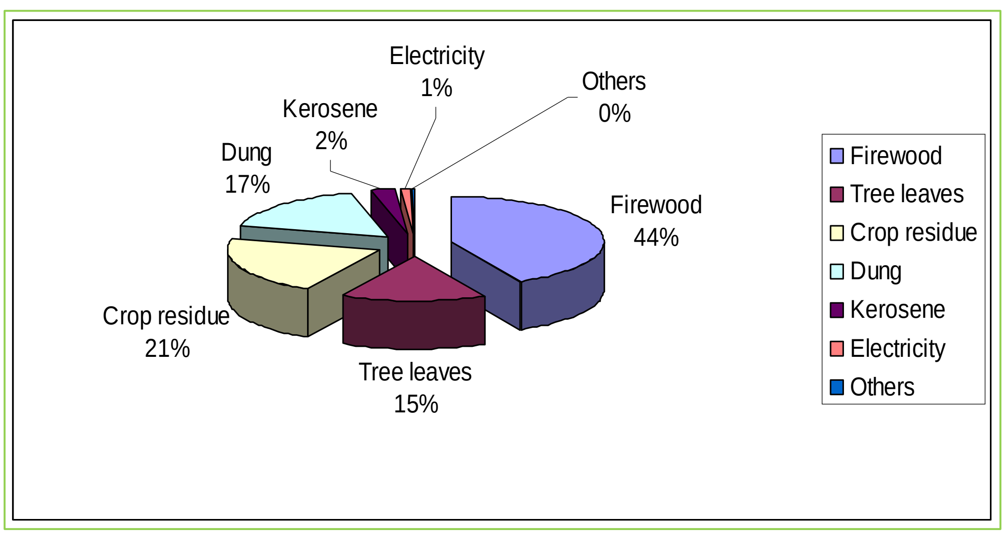
<u>Overall situation</u>

The overall energy situation in the country, in terms of total supply, clearly indicates the overwhelming contribution of biomass (see below for more details). Nonetheless, compared to other countries Bangladesh does not possess much indigenous supply of primary fuels. International Energy Association estimates show that in 2009 Bangladesh had a total primary supply of energy equivalent to only 29.6 million mt of oil equivalent (mtoe). On a per-capita basis this was only 0.18 mt of oil equivalent. Both India and Pakistan had much higher primary supply of energy per capita, of 0.58 and 0.50 mtoe respectively.

In the rest of this sub-section we treat biomass and other sources of energy separately.

<u>Biomass</u>

The energy resources consumed in Bangladesh include biomass (plant and animal residues) used mainly for cooking, parboiling of paddy and curing of tobacco, as well as various kinds of fossil fuels for lighting, transport, generation of power and non-energy purposes. Biomass is the main source of energy in rural areas (Fig. 2.20).



Source: Asaduzzaman, M. et al., 2009

Fig. 2.20: Distribution of sources of energy in energy units in rural households

No clear information for recent years exists on physical consumption of various forms of energy. For 2003, data from a large survey show that while biomass predominates in rural areas, it may come in various forms (Table 2.5), and that not all forms of energy are used for similar energy services. Biomass is used almost entirely for cooking and parboiling, for example, while kerosene is used almost solely for lighting. Electricity is used for all kinds of activities.

Table 2.5: Consumption of energy in domestic activities: rural
(per household/year)

Type of energy	All uses	Heating			Cooling	Lighting	Amusement
		Cooking	Parboiling	Other			
Firewood (kg)	1186.21	1064.84	28.60	92.77			
Tree leaves (kg)	501.51	470.67	29.99	0.85	-	-	-
Crop residue (kg)	708.18	538.86	164.41	2.72	-	-	-
Dung cake/stick (kg)	523.90	503.68	16.07	4.16	-	-	-
Sawdust (kg)	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 (Tk.)	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	-	-	-	-	-	...

Source: Asaduzzaman and Latif, 2005

Table 2.6 shows that depending on the type of biomass, it may be used either from own sources, purchased or gathered. Firewood comes both from gathering and market, while gathering is a major activity to obtain tree leaves. Crop residues and dung come mainly from own sources.

Table 2.6: Percent of households by source of supply of biomass

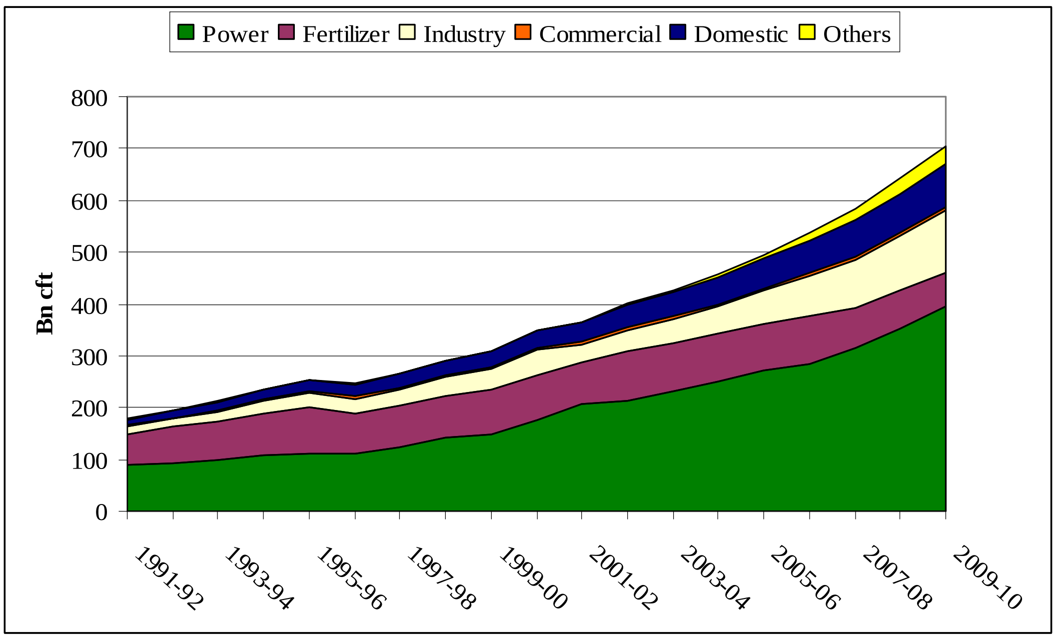
Type of biomass	Own production	Gathered	Purchased
Firewood	11.0	49.8	39.3
Tree leaves	52.2	46.3	1.4
Crop residue	68.5	24.7	6.8
Dung cake/stick	72.2	5.3	22.5

Source: Asaduzzaman, M. et al., 2009

The other issue that may be pointed out is that biomass is not necessarily easily accessible to the poor, as there exists a clear positive relationship between income and the level of consumption of biomass. This is true for firewood, crop residues and dung. For firewood, for example, those at the lowest level of income consume just under 600 kg/household/year, while the figure for the highest level of income is nearly 1,800 kg/household/year.

Natural gas

Among exhaustible primary energy resources, only natural gas and coal are available in the country in modest quantity. There are four main uses of natural gas, as primary fuel for power generation (including captive generation), as feed stock for production of urea, as fuel for heating in industries, and for cooking in domestic households. Relative movement over time of these four uses is shown in Fig. 2.21; the figure indicates that on the whole there has been a tripling of total sales/consumption over the last two decades, while power and fertilizer are the main gas-consuming sectors. Gas consumption in industries and residential households has also been rising rather fast, while that for fertilizer has been either falling or static. Though small, the growth in the "others" category, which include sales of compressed natural gas as fuel for transport, has also been gaining ground.



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Source: Constructed by Asaduzzaman,M

Fig. 2.21: Trend in consumption of natural gas by sector

As already noted, the reserve of natural gas in the country is modest, including recoverable reserves of 11.174 trillion cubic feet (cft) in 23 gas fields. The rate at which demand is increasing will be difficult to meet in the near future, and it is feared that unless new fields are discovered or new reserve assessments are made, existing gas will be able to meet demand only up to about 2030.[2] In fact, a shortage of gas already exists, and the Government has tried to ration gas by restricting the timing of sale of CNG and suspending gas connections to newly built houses. Such a state of affairs is likely to encompass a very disturbing situation with regard to climate change.

As natural gas becomes increasingly scarce, the country may have to depend on other less clean fuels such as coal, imported furnace oil or diesel. Apart from being costly, such fuels

[2] In recent months there have been new and additional supplies from old gas fields and fields that were previously not put in production.

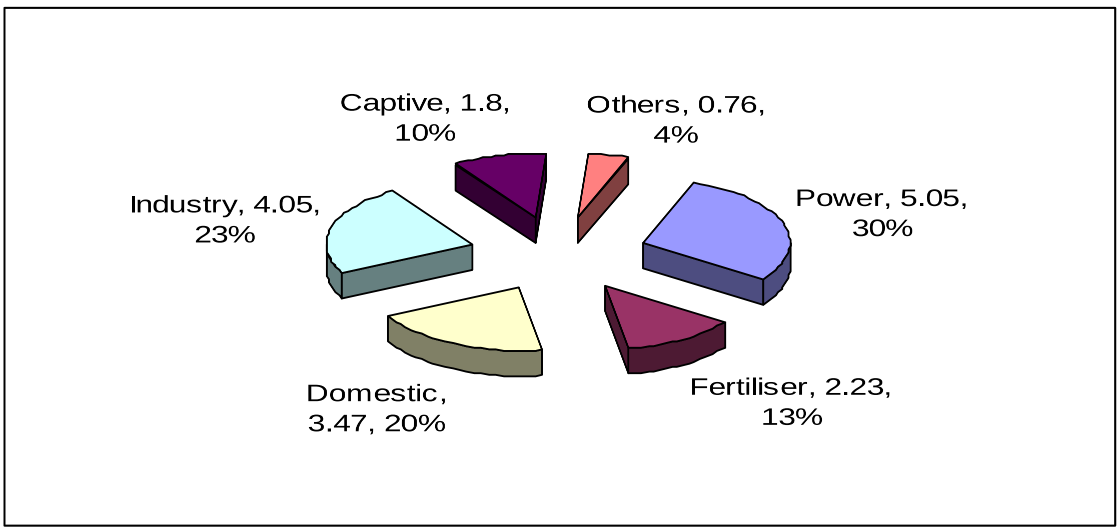
also are much more GHG emission-intensive. Therefore, in the future fuel switching is likely to raise Bangladesh's emissions more than any growth in aggregate energy demand.

Analyses have been conducted on the consumption trend of natural gas in various sectors, with econometric estimations of their significance (Asaduzzaman and Billah: 2009). The demand for natural gas is actually a derived demand in the sense that it is used for production of fertilizer or non-fertilizer industrial goods, for power and for satisfying domestic demand mainly in urban areas. In the fertilizer industry, for example, the demand for fertilizer, and consequently its production, drives the demand for natural gas in the sector.[3] Similarly, the production of power leads to demand for gas at power stations. In fact, the demand for generation of power has largely driven the demand for gas so far.

The estimated elasticity of demand for gas for power production is 1.16, while for the domestic and fertilizer sectors this is around 0.5. For non-fertilizer industrial production, it stands more or less at unity, i.e., for every 1 percentage point rise in the production level of non-fertilizer industries, the demand for natural gas rises by 1 percentage point as well.

Given the nature of demand, what could be the demand for natural gas in the future? Several estimates have been conducted. For example, the cumulative demand up to 2025 may vary from 17.36 trillion cubic feet (TCF) to 22.37 TCF, depending upon assumptions under various scenarios (Asaduzzaman and Billah, 2009). In projecting such demand, Asaduzzaman and Billah (2009) have found that, over time, first the industrial and then domestic demand increases fast – and consequently the shares of these two sectors may become much larger. This is illustrated by Fig. 2.22.

Fig. 2.22: Cumulative projected consumption of gas (base case), Source:Asaduzzaman&Billah,2009



Note: The first numerical figure is the projected total consumption in TCF, while the second refers to the percentage of the aggregate of all sectors.

Can this demand be met? There are large question marks over a positive prospect. Reports indicate that the shortages of gas may become evident even now, and certainly within

[3]Strictly speaking, it should be the demand for nitrogenous fertilizer. However, practically the whole of domestic production of fertilizer is of urea, so that production of fertilizer and production of urea are almost synonymous.

the next decade. So far the doomsayers have not proved much off the mark, as new industries with export potential cannot begin production while gas connections remain restricted and other rationing systems are put in place.

The above has grave implications for Bangladesh, first in terms of growth prospects. The shortage of power and the consequential slowdown of growth or costlier path of growth as fuel switching takes place has already happened, and thus is likely to limit the country's competitiveness. Secondly, this will also mean higher emission than before for every unit of GDP.

Coal

Coal has been discovered in Bangladesh in rather small quantities, although the quality is good compared to elsewhere. The total reserve may be between 2 to 3 billion mt, but not all may be recoverable. So far only one mine has been worked up, with a rated capacity of 1 million mt/year, although the actual production appears to be far less. The coal is used for a power plant with 2x125 MW units.

A little peat is available in the country, of some 170 million mt. However, it is overlain with prime agricultural land, and so far little has been extracted or used.

Petroleum and petroleum products

Refined petroleum products are partly imported and partly produced in the country based on imports of crude petroleum. Fig. 2.23 shows the trend of imports in recent years. A few points are clear: First, the imports of crude are roughly on the order of 1.2 million mt, which very likely is determined by processing capacity within the country. In fact, figures on industrial production show that except for a year in 2005-06, the output of petroleum products generally has been between 12 to 13 hundred thousand mt. Second, the import of refined oil shows an upward trend, although because of a lack of disaggregated figures it is not clear which type of refined oil is showing this rising tendency. Anecdotal evidence indicates that it is likely to be octane, petrol and diesel; in fact, diesel already has the largest single share in total refined oil imports.

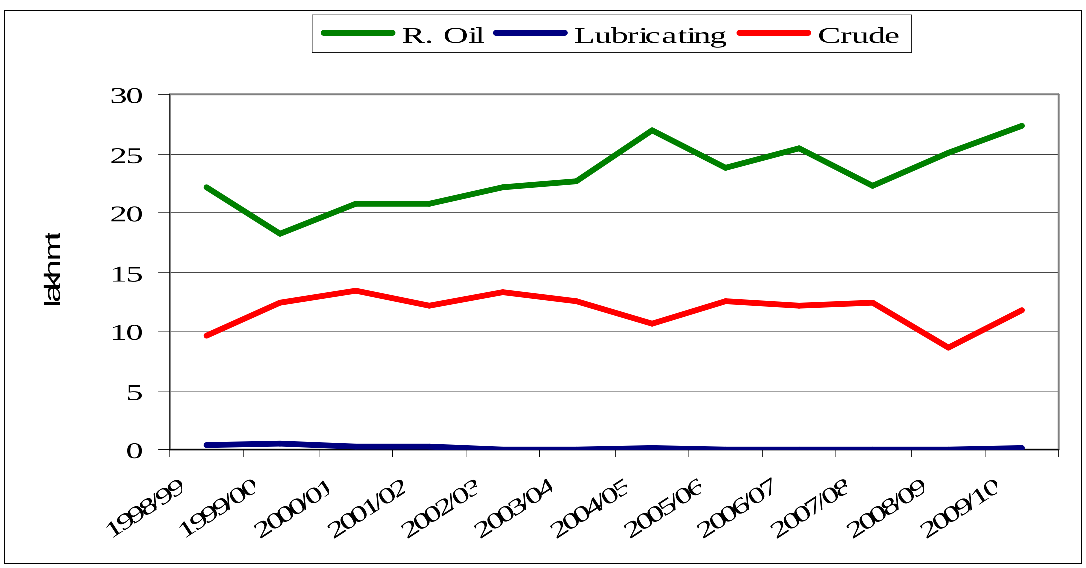


Fig. 2.23: Imports of petroleum products, Source: BBS, SYB, Various years

Among petroleum products, diesel is used both for transport (buses and trucks) as well as for mechanized irrigation, in which case it is the main source of energy. Energy efficiency in transport and in water lifting for irrigation are therefore important for lowering consumption of energy as well as lessening wasteful GHG emission. Literature on water use efficiency indicates that this has not occurred (Alauddin and Sharma, 2008; Chowdhury, 2010).

Kerosene is used mainly for lighting where electricity is not available. In terms of lighting efficiency, kerosene lamps are in general not so good because lumens per unit of energy are low.

A very small oil field was discovered in 1986. Daily production from one well had been 600 to700 barrels per day. This is refined in the country but has no discernible impact on consumption of petroleum products.

About 1.133 million litres of condensate is produced daily from the 17 gas fields in the country. From them, on average, 127,500 litres of petrol and 151,000 litres of diesel are produced daily in the condensate fractionation plants at different gas fields. Some are later further processed in a refinery.

<u>Electricity</u>

Several points related to electricity consumption, future demand and supply are worthy of note. First, in terms of consumption, Bangladesh is a low power-consuming country. Even compared to other countries in SAARC, Bangladesh ranks below every country except Nepal (World Development Indicator, World Bank, 2008).

Second, only two types of consumers are prominent in power consumption, residential and industrial (Fig, 2.24), but industrial consumption is growing at a very slow pace of only 2.4 percent per annum. In contrast, domestic consumption is growing at a rate of 7.9 percent annually. Both commercial and “other” category are also rising fast (7.2 percent and 6.8 percent respectively), although their shares remain relatively small (Asaduzzaman and Ahamed, 2011).

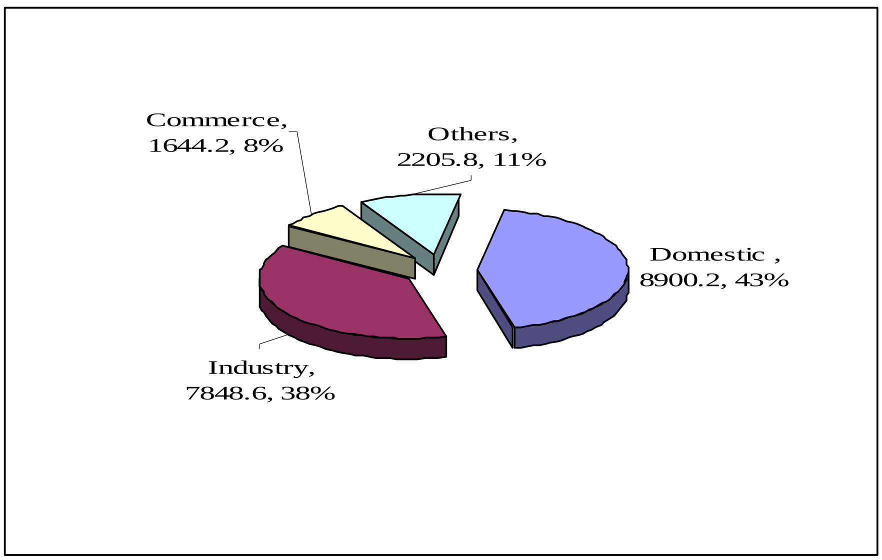


Fig. 2.24: Shares of sectors in power consumption, Source: BBS, SYB, Various years

(Average million kwh over 2004-2005 to 2008-2009)

Why industrial power consumption does not rise faster is not obvious, but it is likely that power shortages and frequent power cuts may have led industrial entrepreneurs to invest in captive generation, making them less dependent on supply from the grid. In any case, overall power consumption is rising at a rate of 5.6 percent. It is further important to understand the relationship between electricity use and growth of output or income.

Asaduzzaman and Billah (2009) and Asaduzzaman and Ahmed (2011) have elaborately discussed and tried to analyze the relationship between growth of the economy and consumption of power. Others who have done so recently include Paul and Salahuddin (2011).Asaduzzaman and Ahmed (2011) particularly note the short-run relationship between electricity and output (proxied by GDP), but not the reverse causation. On the other hand, no such electricity-to-output relationship is confirmed in the long run. This long-run relationship, if it exists, appears to run from output to electricity, as has been found by Paul and Salahuddin (2011). More interestingly, if industrial manufacturing output (proxied by industrial GDP) is considered, there is no short- or long- run relationship between power consumption and output, but the causality is seen to run from output to electricity. Relevant literature also usually has given similar mixed results in the case of other countries.

The question now is how the situation will unfold in the future. Several estimates are available for the future demand for electricity (for details in one place, see Asaduzzaman and Ahmed, 2011). Note, however, that these estimates actually underestimate the rate of growth of the economy, which currently may be around 6.8 percent. Even the latest estimates by Asaduzzaman and Ahmed (2011) assumed a rate of growth no more than 6 percent for 2010-2011. Yet the forecast electricity demand was around 40 Twh; for 2008-2009, this was actually 30 Twh. Clearly, however, actual generation fell far short.

The main culprit in all of this appears to have been the lack of a clear understanding at policy level of the need for power generation, compounded by apathy on the part of multilateral development partners for funding such investments. Accordingly, certain policy reforms were attempted in the electricity sector, but these did not yield the desired results. While details of these governance issues are not appropriate here, the ultimate result was that power shortages assumed critical dimensions (Asaduzzaman,M.,2008). As a result, the Government has been forced to allow quick rental of power plants by the private sector, using furnace or diesel oil. In turn, this has led to much higher costs of production – meaning more subsidies or higher prices of energy – as well as higher GHG emissions than would have been necessary with timely action.

As indicated earlier, natural gas shortages are forcing the Government to rely more on carbon-dense fuels. At present, the distribution of electricity production from various primary fuels shows that 83 percent of installed capacity is based on natural gas, while 89 percent of actual generation depends on it (Fig. 2.25). Shares of other fuels are comparatively small.

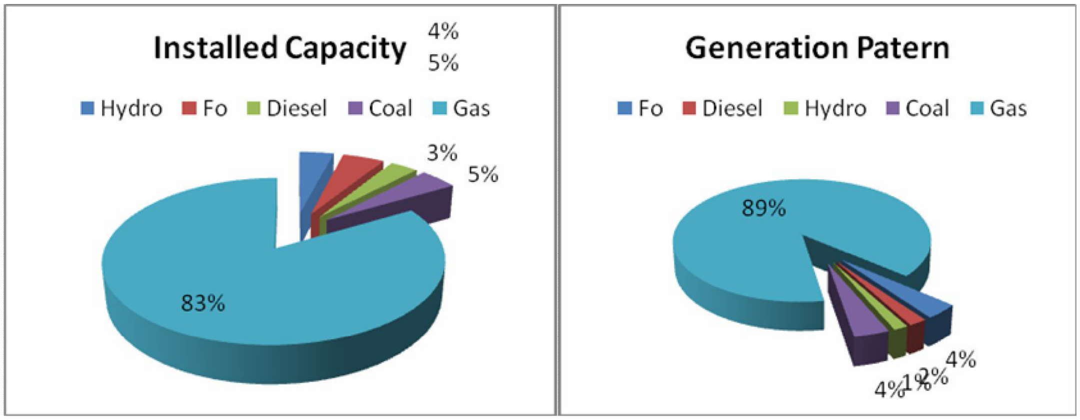


Fig. 2.25: Distribution of capacity and generation by fuel, Source: Bangladesh Economic Review,2009

Another issue that relates to capacity and generation is whether these are in the public or private sector domain. As Fig. 2.26 shows, the shares of the public sector are high on both counts, but the private sector generates more electricty. It is likely that given the present emphasis on quick rental plants, private sector shares both in capacity and generation will increase. The present pattern also indicates that the private sector is more efficient than the public sector in generating power from the same installed capacity. Yet this is not universally true, and cases are not infrequent when the genration cost of BPDB plants are lower than those of private sector plants (Asaduzzaman and Ahmed, 2011)

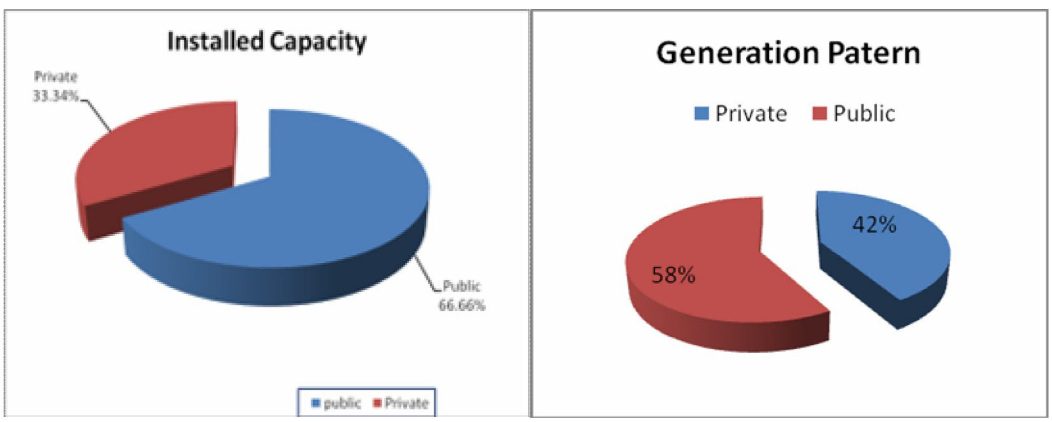


Fig. 2.26: Distribution of capacity and generation by plant ownership, Source: BBS, SYB, Various years

Electricity from renewable and other sources

Electricity can be produced from renewable sources such as sunshine, wind, waves and moving water. Among these, the last one (hydroelectricity) contributes 4 percent to installed capacity but only 1 percent to actual generation. The picture related to other renewable is not bright, except for solar power. In the case of wind energy, there is generation in only two places in the country, with a total of 2 MW capacity. In the case of solar, there had been a vigorous installation programme conducted, and by January 2010 some 454,000 households and institutions had been electrified with solar panels, with a total capacity of 21 MW. By 2012 1 million homes were expected to have solar panels.

The Government plans to generate electricity from nuclear fuel. While a Memorandum of Understanding has been signed with a Russian organization in this regard, the process remains in its infancy.

Other renewable sources: Biogas

Major prospects exist for biogas production in the country from the manure of livestock, particularly large ruminants. So far, however, there have been only sporadic attempts to achieve this.

On the whole, Bangladesh can be considered a country deficient in modern energy, whatever natural gas it has is going to run out within the foreseeable future, unless major new discoveries are made. The country has been unable to utilize well whatever coal it has. At the same time, progress in using renewable energy has been rather limited. Most important, whatever resources the country has are being used comparatively inefficiently.

2.5.2 Infrastructure

In this sub-section, we discuss the situation regarding the physical infrastructure in the country. The energy infrastructure already has been discussed and analyzed above. Here four additional types of infrastructure are discussed, including transport and communication; water management; market and growth centres; and habitation including housing.

Transport and communication

There are four types of transport system in the country, including roads and highways, railways, waterways and airways. According to the Roads and Highways Department, in 2008 there were 20,995 kilometres of highways, excluding the roads constructed and maintained by district councils, municipalities and other local bodies. Of this, 3,478 kilometres were national highways, 4,004 kilometres were regional and the rest (13,513 kilometres) was Feeder Type A roads. The Feeder Type A roads connect to the national and regional highways, which are all-weather roads. Of the total Feeder Type A roads, slightly more than 50 percent are paved roads of variable quality. Bangladesh has one of the highest road densities in the world when all types of roads, including *kutcha* (dirt) roads constructed under various works programmes, are included. However, the quality of such roads is subject to question. For example, these roads have often also been thought responsible for water logging in many areas due to lack of proper alignment with respect to local hydrological factors such as direction of surface water flow.

Bangladesh has a Bridge Division in the Ministry of Transport and Communications that looks after the construction and maintenance of bridges with lengths of 1,500 m and above. The country has one major river bridge on the Jamuna. The bridge, 11th-longest in the world, has an actual bridge span of 4.8 kms. The Government is in the process of constructing another long bridge to span the Padma River.

Bangladesh Railway has a total network of 2,835 route kilometres (broad gauge, 659.3 km; dual gauge, 375 km; and metre gauge, 1,801 km). In 2009-2010, the railway system carried 7.3 billion passenger km and 641 million tons km of freight.

In the case of water transport, services cater either to inland navigation along the rivers or to marine transport, where ports feature prominently. The inland navigation takes place over 6,000 km of waterways during the monsoon and 3,800 km during the dry season. Both state-owned and private water vessels ply these routes. To keep rivers navigable throughout the year, the Government has undertaken a project for capital dredging of 53 rivers.

Bangladesh has two ports, Chittagong and Mongla, with about 2,000 ships passing through the Chittagong port every year. Storage capacity in the ports is 359,000 tons. Most exports and imports also are routed through the Chittagong port. The Mongla port handles about 8 percent of maritime cargo. In 2009-2010, 1,500 thousand mt of import cargo and 148,000 mt of export cargo passed through this port. The country has three international airports and several domestic airports, although not all of the latter are in operation.

Information and communication infrastructure

Transport and communication includes communication facilities such as television, radios, mobile phones, IT-based communications such as Internet, and the postal services. Of these, the postal services are the oldest and least dependent on modern technology. There is one state-owned television company and several private television channels. Similarly, there is a state-owned radio facility that operates several radio stations, while several radio stations are operated by private companies. ICT-based communication systems, particularly cell phones, have spread quickly. The country now has five mobile telephone companies, with a combined subscription of nearly 81 million by September 2011. The number of Internet users is not known definitively but is considered likely to stand at just around 1 million, or 0.6 percent of population, concentrated in the capital city and a few other centres. On the other hand, the Government's declared policy is to digitalize all day-to-day and routine operations using ICT. Several projects have been taken up for this purpose, while facilities such as e-tendering have already begun. Nonetheless, the full legal architecture for a digital economy has not yet been put in place.

Water management infrastructure

As already discussed, floods are a regular phenomenon and the use of water in crop production, particularly for the cultivation of irrigated rice, represents a major issue of water management. The use of water and its regulation has been made possible by constructing an array of flood control, drainage and irrigation infrastructure, both inland and along the coast. The Bangladesh Water Development Board (BWDB) has so far constructed and maintained 24 flood control projects benefiting 248,000 ha; 46 submersible embankments covering 290,000 ha; 241 flood control and drainage projects covering 2,360,000 ha; and 104 drainage projects with a benefited area of 770,000 ha. Some projects combine several water management features.

Similarly, the BWDB has constructed polders and embankments in the coastal areas for protection from salinity and storm surges during cyclones. Around 1,850,000 ha are protected by 82 flood control and drainage projects. Of these, the Coastal Embankment Project, constituting 141 polders, is the largest and covers 1,050,000 ha.

The irrigation infrastructure includes gravity flow irrigation systems as well as mechanized irrigation using deep and shallow tube wells and low lift pumps. Irrigation by different mechanized and manual means is shown for the year 2008-2009 in Fig. 2.27.

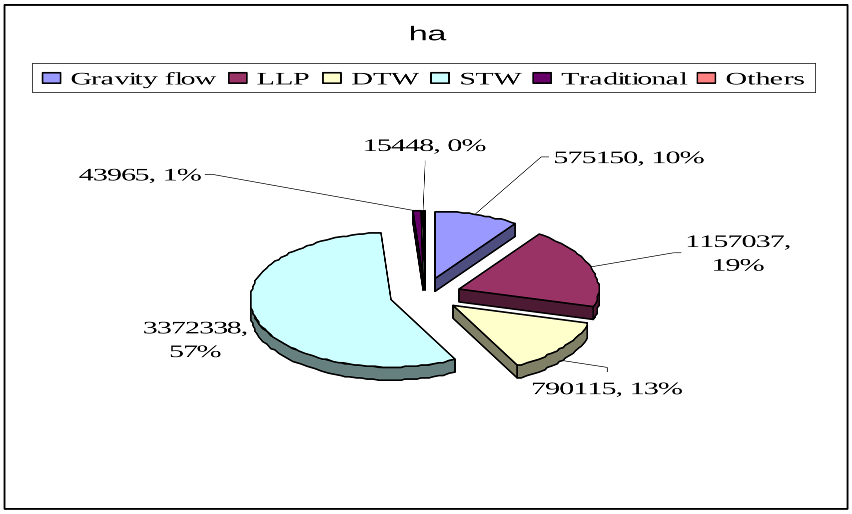


Fig. 2.27: Irrigation by various means (2008-2009), Source: Bangladesh Economic Review, 2011

Cyclone shelters are a major infrastructure in the coastal areas. These are constructed to provide refuge to exposed populations during cyclones and storm surges and are also intended for multi-purpose use as school and community centres. Presently there are more than 2,100 shelters (PDO-ICZMP, 2004a) in 15 of the 19 coastal districts, although these can accommodate only 27 percent of the people at risk (WARPO, 2001a). The National Water Management Plan (NWMP) has proposed 775 multi-purpose shelters for 1.72 million people and 1,369 *killas* (raised earth mounds) for livestock over the next 15 years (WARPO, 2001a). The Government's "safe haven" medium-term goals are based on providing protection against a 1 in 30-year cyclone surge event, while the long- term goals aim at providing 1 in 100-year protection. The population served would be typically 2,000 per shelter, 900 animals per *killa* and about 22 per *bari*-level shelters (PDO-ICZMP, 2004a).

Market and growth centres

The marketplaces and growth centres play a very crucial role in the overall marketing system in the country. In fact, rural roads usually connect villages to marketplaces. On average, there are 1.5 growth centres per 100 sq.km. in the country. Some regional variation is found in such density, with the highest being in Chittagong district, at almost 6 centres per sq.km.

Habitation and housing

The structure of the main dwelling unit in a residence may be examined from the materials for the roof and for the wall. Several types of materials are used, which may be divided into durable (brick, cement, concrete), semi-durable (wood, CI sheet), and limited durable (hay, straw, bamboo and mud). Twenty percent of houses had durable walls in 2005, while only 8 percent had durable roofs. A total of 27 percent had least durable walls in 2005, while the proportion was 8 percent for roofs. Thus, most households had either semi-durable walls or roofs. By 2010, these proportions had risen for durable walls and roofs, while the proportions for the least durable had fallen for both; even so, the semi-durable category remained as the most numerous.

Not surprisingly, for both years the proportions of durable walls or roofs were higher in urban areas than in rural areas.

2.6 Livelihood, Poverty, Human Development and Quality of Life

This sub-section examines various indicators of human well-being, including factors such as disasters that create sudden downturns in such well-being. This can be started with information on per-capita income.

2.6.1. Income, Livelihood and Employment

Per-capita income growth

Per-capita income has risen at a slower pace than GDP because of the growth in population. Around 1999-2000, it stood just short of Taka 16,000per year (at 1995-1996 prices). By 2009-2010, it had risen to more than Taka 24,000, i.e., by slightly more than 50 percent. In dollar terms this rise has been somewhat higher, however. In 1999-2000, the dollar value of that year's per-capita GDP (at current prices) had been $367; by 2009-2010, it had risen by 86 percent, to $684.

Livelihood

Most people in the country are dependent on either agriculture or wage labourers in rural and urban areas. Consequently, such sectors dominate in terms of providing livelihoods. Recent information on livelihood sources is lacking, but earlier information indicated that marginal and small farm holders, as well as wage earners, accounted for more than 70 percent of all households (Fig. 2.28). The situation is unlikely to have changed much.

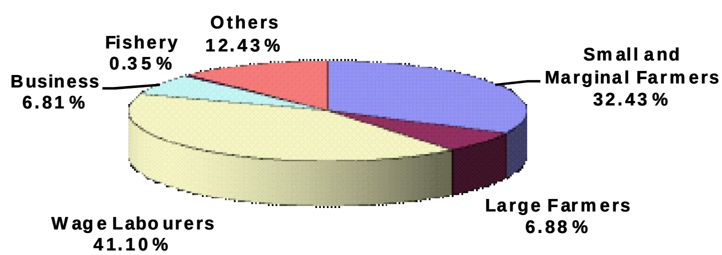


Fig. 2.28: Shares of households in livelihood groups, Source: BBS, SYB, 2005

However, the above may be a simplification of a more complex reality in which people depend on more than one source of income for their livelihood, as found by Asaduzzaman and Islam (2009). Their results show that only about 20per cent of all rural households depend on agriculture as the sole source of income. The respective percentages for non-agricultural activities and wage labour are 20 and 13per cent. That means 47 per cent of households depend on a mix of occupations. In fact, the highest percentage of households (27per cent) depends partly on agriculture and partly on non-agricultural activities. In all, agriculture remains the sole or partial source of livelihood for some 60per cent of all households. The employment situation more or less mirrors this.

Employment

The latest Labour Force Survey of Bangladesh, in 2005-2006, showed that in that year 47.4 million men and women above 15 years of age (respectively, 36.1 million and 11.3 million) were involved in various employment. Of the total labour force, 48.10 percent was employed in agriculture. The second highest-ranking sector was commercial activities, including catering businesses, employing 16.5 percent of labour. The third highest was manufacturing, employing 11 percent. By 2009, the total employed labour force stood at 53.7 million (38.5 million men and 12.5 million women). Agriculture remained the most important sector, employing 43.5 percent. The shares of commerce/catering and manufacturing stood at 15.3 percent and 13.5 percent. These two broad sectors are rather heterogeneous.

Income generation and social safety net programmes

The country has numerous income generation and social safety net programmes for the poor,in addition to programmes offering various kinds of support to the agriculture, industry and service sectors. These latter help in raising and stabilizing output, employment and income of those employed in these sectors. Support to the poor is provided both through the public and private channels, particularly in case of providing microcredit. In 2009 alone, the total microcredit disbursed was Taka 38.1 billion (US$5.5 billion), of which Taka 37.0 billion was by non-Government organizations (NGOs), including Grameen Bank.

Apart from this huge support to the poor, many other social safety net programmes under various categories were allocated during 2009-2010, including:

Cash transfer programmes Taka 12.3 billion

Food security programmes Taka 5.1 billion

This was equivalent to nearly US$2.4 billion. Thus, Bangladesh has allocated or disbursed an equivalent of US$7.9 billion in one year alone in 2009-2010.

The Household Income and Expenditure Survey, conducted in 2010, has reported in its preliminary findings that while around 13 percent of households in 2005 had access to at least one such programme during the 12 months prior to the survey, this proportion had risen in 2010 to about 24.5 percent (BBS, 2011). Admittedly, even this may not be enough compared to the need and may not be entirely properly targeted (BBS, 2011), but that the country is trying to ensure equitable livelihood prospects for all against many odds must be appreciated.

2.6.2 Food Security

Food security has three elements, including food availability (basically from domestic production and imports), food access (created mainly through increased income and purchasing power as well as safety net programmes, particularly for the very disadvantaged groups in society), and food utilization (leading to proper nutrition). Among these three elements, the domestic production aspects of the main staple, rice, have already been discussed and analyzed, This we found to be broadly adequate. Imports are small by standards of many developing countries and Least Developed Countries (LDCs). But Bangladesh has paid a price for ensuring rice availability, as production of most other types of food is not adequate and imports are necessary for those commodities. These include pulses, which are a major source of vegetable protein for the people and also culturally demanded as part of any frugal meal.

On the access side, purchasing power is conditioned by growth in income per capita, which has been discussed earlier and found to be growing at a rather slow pace, mainly due to inadequate rate of growth of GDP. A much higher rate of growth, possibly of 8 to 9 percent per annum, is needed for faster poverty eradication. For those who are not able to fend for themselves, various kinds of safety net programmes exist, but as noted above, even this is inadequate. The issue of nutrition will be discussed shortly in the sub-section under health.

On the whole, the overall food security policy so far has revolved around raising production of staples, leaving other aspects less attended to. But over time, this situation is being amended. The Government has prepared a US$7.8 billion Food Security Investment Plan with far more attention to the access and utilization aspects, including the impacts of climate change, as a sequel to the G20 L'Aquila initiative in 2008. The contribution of foreign aid assistance is expected to be US$5.1 billion, of which US$3.4 billion has been identified as first-priority requirements (GoB, 2011).

2.6.3 Poverty and Human Development

Poverty has fallen in Bangladesh over time (Fig. 2.29). The incidence of poverty based on an upper poverty line (estimated as cost of basic needs, including minimum acceptable calorie intake) has fallen from nearly 60 percent in 1991-1992 to 31.5 percent by 2010. The incidence of poverty based on a lower poverty line has also fallen similarly. Poverty has fallen apparently faster in urban areas compared to rural areas. The present incidence of poverty in rural areas appears similar to that found in urban areas in 2000.

A more comprehensive concept of poverty and quality of life is given by the Human Development Index (HDI). The HDI indicates a composite measure of three dimensions of human development: living a long and healthy life (measured by life expectancy); being

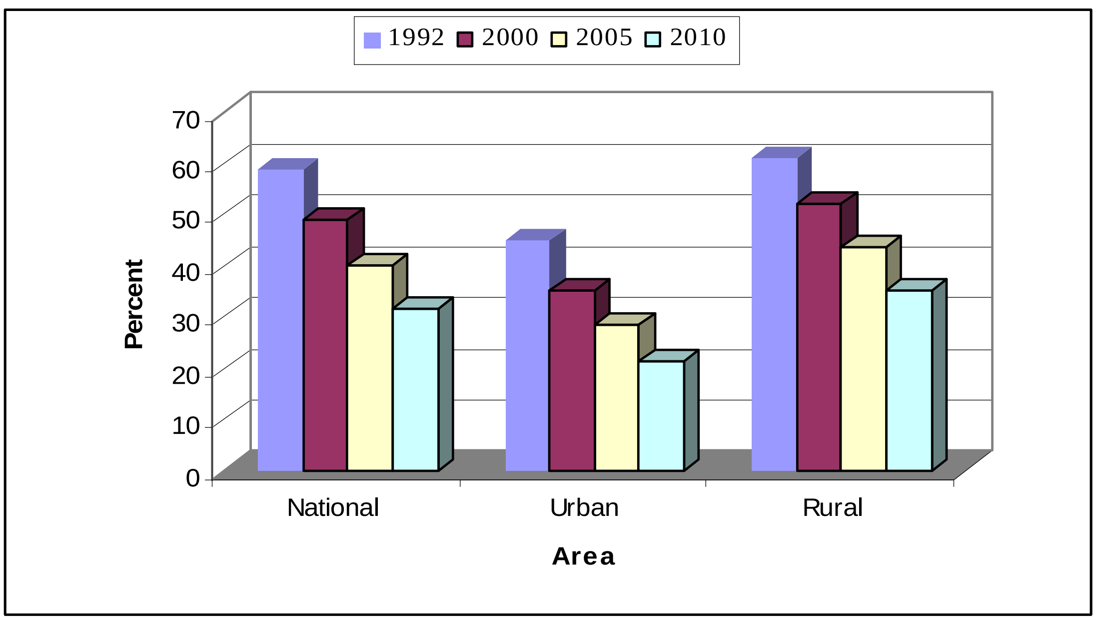


Fig. 2.29: Trend in head count incidence of poverty, Source: BBS, Household Income and Expenditure Survey, Various years

educated(measured by adult literacy and gross enrolment in primary education); and having a decent standard of living (measured by purchasing power parity, or PPP, income). It provides a broadened prism for viewing human progress and the complex relationship between income and well-being. The HDI for Bangladesh has risen from 0.328 to 0.543 during 1980 to 2007 (UN, 2009).

The Human Poverty Index (HPI) is similar to the HDI but stems from an opposite concept. In 2007, the HPI for Bangladesh was 0.36. Both the HDI and HPI put Bangladesh rather low in ranking among nations. In 2007, Bangladesh was ranked 146th out of 182 in HDI and 112th out of 135 in HPI. These figures clearly indicate the low level of socioeconomic well-being of the people in Bangladesh.

Despite positive trends in recent years, hunger and malnutrition particularly still remain to be banished altogether. This issue will be discussed under health issues.

2.6.4 Human Resource Development

Two types of indicators have been used to understand social well-being in terms of education and health. First, education

Education

The literacy rate in Bangladesh for the population 7 years of age or over has increased from 51.9 to 57.9 percent between 2005 and 2010. It is lower in rural areas (53.4 percent) compared to urban areas (70.4 percent). The country has achieved parity in enrollment of boys and girls. The number of children enrolled, however, either remained static or has fallen (MoF, 2010), at around 16.5 to 17.5 million. On the other hand, there was growth in the number of primary schools, including religious facilities, from below 50,000 in 1991 to almost 83,000 in 2010. The number of public primary schools has remained unchanged, meaning that growth has been in the number of privately run schools.

The secondary education system is basically run by the private sector, in many cases by organizations initially established as charities. There are more than 18,000, secondary schools, of which only 317 are in run by the Government. Similarly, out of 3,160 post-secondary colleges, only 61 are in the public sector. In the case of secondary schools, the Government provides the basic salaries of teachers through subventions.

For the future growth of Bangladesh, the main manpower needs are going to be fulfilled through those coming out of the universities, both general and technical. There are 26 public-run and 56 privately-run universities. The public universities are, however, much bigger than the private ones; this is reflected in the number of students, which were 115,000 in public institutions and 92,000 in privately run ones in recent years. Technical educational institutions of various types, 115 in different trades, are all in the public sector. Medical education was previously in the public sector, but major inroads have been made by the private sector. Agricultural training schools are in the public sector.

Given the size of the population and the expected rates of growth of the economy in the medium term, the education system is not at all commensurate with the demand already arising. Questions remain with regard to quality in general and at privately run institutions in particular, although there are a few centres of excellence as well.

Health, nutrition, water and sanitation

In the case of health, several issues merit attention. First, the status of health may be indicated by morbidity and mortality (including infant, child and maternal mortality), as well as by burden of disease. Second, it is necessary to know the nutritional status of people. This may be understood through various indicators such as hunger index, child malnutrition, malnutrition at early stage of life, and the health infrastructure (physical facilities such as those related to water and sanitation, human resources, health care institutions, quality, and access). Finally, reproductive health must be discussed separately, given that it may be a major issue under climate change. These are all involved exercises, so what will be provided is a brief exposure to the overall situation. The crude death rate in Bangladesh stands at around 6 per 1,000 population. The urban rate is about 5 per 1,000, while that in rural areas is higher, at about 6.5 (MoF, 2010). National, urban and rural rates all appear to have risen somewhat over time; reasons for this are not yet clear. One could speculate that the population structure is changing, with the share of the old people rising, although this is not borne out by an examination of the age patterns over successive population, as found during censuses (Asaduzzaman, 2010a). Other theories of the cause focus on a potentially rising burden of disease. Although it is difficult to conduct a trend analysis given a lack of a long time series, Table 2.7 indicates the present burden already may be quite onerous. These also include some indications of the burden of disease.

Table 2.7: Health care situation in Bangladesh

Health status indicators	Value
Infant mortality rate (per 1000 live births)	52
Maternal mortality ratio (per 1000 live births)	3.2-3.4
Neonatal mortality rate (per 1000 live births)	31-37
Under five mortality rate (per 1000 live births)	60-65
Percent of population using safe drinking water (tap and tube well)	98.8
Percent of population using (water seal) latrine	54.2
Prevalence of night blindness among preschool children	0.04
Percent births attended by skilled personnel	17.8
Percent women received at least one antenatal care visit	51.7
Percent mother received postnatal care from a trained provider within 42 days of delivery	21.3
Malaria slide positivity rate (positive per 100 slides examined)	8.47
Malaria incidence rate per 1000 population	0.63
TB incidence rate per 100000 population	99
Percent of smear-positive pulmonary TB cases detected put under DOTS	72
Percent of smear-positive pulmonary TB cases detected cured under DOTS	92
Percent of urban population access to improved sanitation	77.1
Percent of <5 children with diarrhoea treated with ORT(ORS or homemade solution)	81.2
Percent of <5 children with symptoms of ARI seeking care from trained provider	28.13

Source: Health Bulletin, 2009, Website of Health Ministry.

The indicators are symptomatic of a quite unhealthy situation. These indicate not only a high burden of killer and debilitating diseases such as malaria and tuberculosis, but also high child, infant and neonatal mortality as well as an unsatisfactory maternal health situation. The only apparent positive indicator was the availability of safe drinking water, but here too the high prevalence of arsenic in groundwater in many cases is a major cause of concern.

In 2007 a main cause of death was found in dengue fever (nearly 45 per 1,000 deaths). An even more important cause was respiratory disease (114.1 per 1,000), while heart and related diseases were responsible for the deaths of 88.3 persons per 1,000. Dengue, respiratory diseases and malaria prevalence all may become higher with climate change impacts (see also Chapter 5).

Some ideas related to morbidity may be developed from reports provided by hospitals in the country. These indicate that waterborne diseases such as diarrhea are a major cause of death, particularly in the case of children in rural areas.

Infant, child and maternal mortality are still high despite improvements in recent years. Infant mortality has fallen from 58 to 42 per 1,000 live births between 2000 and 2009, while child mortality has been lowered from 4.2 to 3.1 per 1,000during 2000-2008 (MoF, 2010). The fall in maternal mortality has been far less impressive, however, moving from 3.2 to 2.9 per 1,000 live births. The immediate causes of such mortality have been linked to malnutrition among children and pregnant or lactating mothers. It will thus be instructive here to refer to some recent discoveries related to diseases and their prevalence during childhood and adult life, which can be linked with the nutritional status of mothers and children during conception and up to 2 years after birth.

<u>The Hunger Index</u>

In recent years various global hunger indices have been proposed. The hunger index of IFPRI is an equally weighted average of three proportions, including the proportion of population who are undernourished, i.e., who have insufficient calorie intake; proportion of underweight children under age 5 (underweight meaning low weight for age); and mortality rate of children under age 5. The index has a range from zero to 100.

Certain results may be quoted from those estimated by IFPRI for Bangladesh on its comparative position over time (Fig. 2.30),(Asaduzzaman, M. et al.,2010b). The figure shows that while Bangladesh had the worst hunger index compared to other selected countries in Asia, over time the situation has improved. Nonetheless, the country still fares worse compared to most others except India.

Why is child malnutrition so important? The basic reason is that it has been scientifically proven that (Victora *et al* , 2010):

•Poor foetal growth or stunting in the first 2 years of life leads to irreversible damage, including shorter adult height, lower attained schooling, reduced adult income, and decreased offspring birth weight

• Children who are undernourished in the first 2 years of life and who put on weight rapidly later in childhood and in adolescence are at high risk of chronic diseases related to nutrition

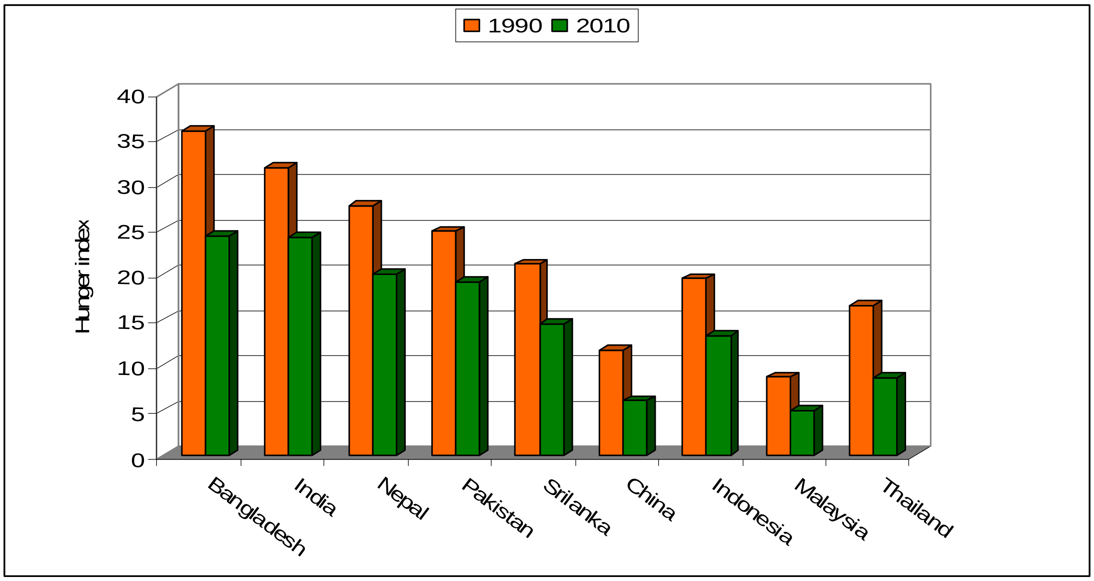


Fig. 2.30: Change in hunger prevalence in some Asian countries, Source: Asaduzzaman, 2010b

Thus, the inter-generational propagation of under nutrition can be observed. While under nutrition is strongly associated with shorter adult height, less schooling, reduced economic productivity and, for women, lower offspring birth weight, increased size at birth and in childhood was positively associated with adult body-mass index. Children in South Asia in general, and in Bangladesh in particular, are highly prone to malnutrition, as noted earlier. The Hunger Index, and consequently child malnutrition, is affected by many factors, including average food production or per-capita availability; access to food; income; education, particularly women's education; and other factors. More specifically, the adequate access to food and nutrition during the time from conception to 2 years after birth, for child and mother alike, is absolutely essential to prevent the potential intergenerational propagation of lack of nutrition and morbidity. Such capacity is likely to be severely compromised in the case of major adverse impacts of climate change.

Water and sanitation issues are important in influencing the health status of people, particularly children who are susceptible to diarrhoea and other gastroenteric diseases. As indicated above, apparently water for drinking is safe water in most cases. There is, however, the problem of arsenic contamination in a high percentage of tube-wells. People in 59 out of 64 districts spread over126,134 sq.km. in Bangladesh are at risk of or suffering from arsenic contamination of drinking water. A total of 75 million people are at risk, and 24 million are potentially already exposed to arsenic contamination.

The availability of safe drinking water is especially poor for coastal communities, as fresh groundwater is only available at great depths if at all. Inadequate access to safe water contributes to a high incidence of diarrhoeal diseases. Pre-monsoon diarrhoea outbreaks are common in the coastal belt. The arsenic problem is also prevalent in this area. On the other hand, the highland population in the eastern hilly region is subject to the severe scarcity of domestic water.

The sanitation situation likewise is not satisfactory. Nationally, according to a survey conducted by Department of Public Health (www.dphe.gov.bd, accessed on 6 October 2011), 42 percent of households had no definitive place for defecating. Of the 58 percent who had such access, only 33 percentage points had hygienic toilet facilities, while for 25 percentage points lived in unsanitary condition. Thus, 67 percent of households had either no toilet or access to a poor-quality toilet. The percentage having hygienic toilets was higher in urban areas (60 percent) than in rural areas (29 percent), where 47 percent had no toilet facility whatsoever. The lack of cash was given as the most important cause for not having a toilet facility (77 percent), while lack of space (11 percent) and of awareness were cited as other major reasons.

The health care facilities are basically in the hands of private practitioners and in public and private clinics and hospitals. Table 2.8 shows some relevant indicators of such facilities.

Table 2.8: Health care facilities, Source: BBS, Statistical Year Book, 2009

Facility indicator	Number
Hospitals *	2,860
Hospital beds	74,415
Persons per hospital bed	1,860
Registered physicians	49,994
Persons per physician	2,860

Reproductive health

It has been discussed earlier that the movement of the maternal mortality rate has been downward, but not significantly so, in part because of the continued limited access of mothers or mothers-to-be to maternal health care. In fact, this is but a coalescing of the lifetime deprivation in terms of food and health care that girls suffer from beginning in childhood. A tragic consequence of such a dismal situation is that three-quarters of children born to these women die within the first week of their lives. Details would require a far more in-depth discussion, but interested readers may consult WHO (2003).[4]

2.7 Disaster and Climate Vulnerability

2.7.1 Types of Natural Hazard

Natural hazards are regular phenomena in Bangladesh because of the country's unique geographical location, its climate, and the interplay of coastal dynamics. Floods are a normal feature in any given year, while drought is not infrequent. Coastal cyclones and storm surges occur from time to time. There are also apprehensions of non-climatic hazards such as earthquakes, the frequency of which appears to be rising. The impact of these events is almost always attended to in limited ways before another similar event occurs, creating a downward spiral in the development process. The costs of development become greater than if the events had been less frequent. Climate change will add to these woes, possibly by several orders of magnitude. It is not simply that the development process will be hampered, but also that human lives and property will be lost. In this section we try to briefly narrate the present situation. More details on vulnerability and adaptation will be given in Chapter 5.

2.7.2 Floods

Floods are the most often recurring natural hazard in Bangladesh, occurring almost every year and occasionally become devastating. In Bangladesh floods can be categorized into three classes: (i) monsoon floods, which occur in floodplains and are seasonal, with waters rising and receding slowly, inundating vast areas and causing huge loss of life and property; (ii) flash

[4]WHO, *Country Profile on Reproductive Health in Bangladesh*, 2003.

floods, which are seen in hilly and adjacent areas, with waters rising and receding suddenly; and (iii) tidal floods, which are of short durations and occur in coastal areas.

Normal floods inundate roughly 20 to 25 percent of the total land area every year. Lands along the major rivers are often not protected by flood embankments but are essential for the regular rhythm of agriculture, and are considered a blessing for Bangladesh because they provide moisture and fertility to the soil through alluvial silt deposition during floods. However, when large areas are inundated, causing extensive damage to crops and properties and disruption to communication, it becomes a matter of great concern. In 1998, more than 65 percent of the land area of Bangladesh was inundated and crop loss was enormous. A map of the degree of flood vulnerability of the country is shown in Figure 2.31.

The principal sources of floods are the major river system, the GBM, in the monsoon months. A large area of land adjacent to the rivers is subjected to this type of flood. Although the fluctuations in the water levels of major rivers are rarely dependent on local rainfall, the long duration of local rainfalls often can lead to drainage congestion and cause localized flood-type situations.

The northern and northeastern trans-boundary hilly areas are vulnerable to flash floods in the pre-monsoon (April and May). Flash floods in these regions cause damage to infrastructures as well as dry-season *boro* rice crops at the time of, or just before, harvesting.

The southwest region, the central part of the south, and the adjacent areas of estuaries and tidal rivers become normally inundated twice a day by natural tide from the Bay of Bengal. During April to June and September to November, about 12,000 sq.km.of coastal land is affected by occasional cyclonic stormsurges due to tropical cyclones in the Bay of Bengal.

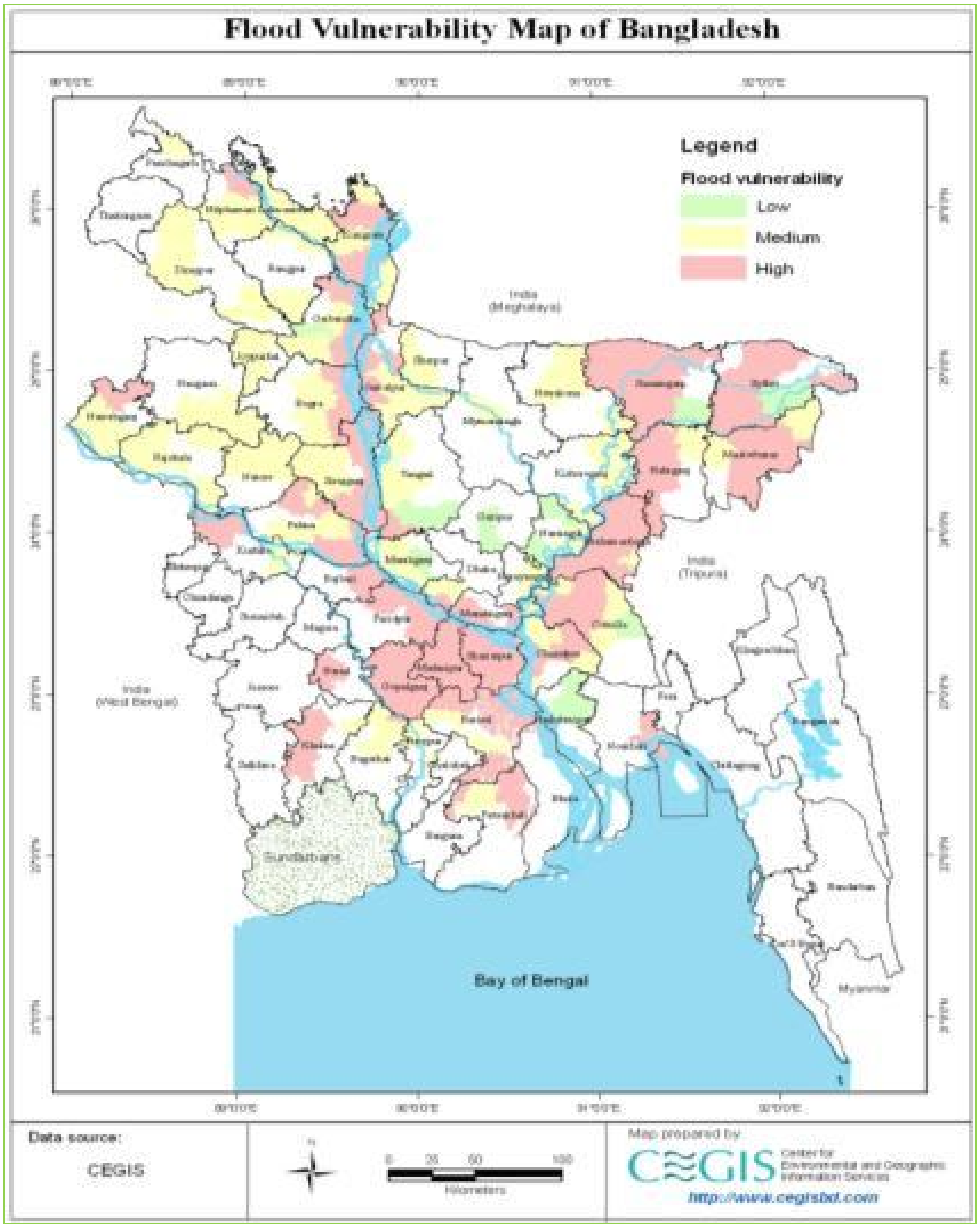


Fig. 2.31: Flood vulnerability map of Bangladesh

2.7.3 Erosion

Riverbank, *char* (river and deltaic islands), and coastal erosion are the important secondary consequences of floods or high water levels having dynamic energy. These are localized processes, but during times of floods and cyclones the processes tend to accelerate and become more severe. The erosion-prone zones of Bangladesh, not surprisingly, are by and large along the major rivers of the country.

Riverbank erosion makes millions of people landless. A study by WARPO (2005) concluded that in 1991, 100 out of the 462 administrative units in the country were subject to some form of riverbank erosion, of which 35 were serious; about 1 million people were affected on a yearly basis. On average, about 87 sq.km. of mainland are lost each year due to erosion by the major rivers. On the other hand, during 1984 to 1993 about 50 sq.km. of land accreted each year (ISPAN, 1993). Based on an analysis of the 240-km-long stretch of Brahmaputra-Jamuna between the Indian border and the confluence with the Ganges for the period 1973 to 1996, a study by EGIS (1997b) concluded that the river has been shifting at an average rate of about 130 m/year. This corresponds to a loss of about 70,000 ha in 23 years, while only 11,000 ha had been accreted.

2.7.4 Drought

Drought refers to a condition when the moisture availability at the root zone of plants is less than adequate. It is often observed when there is an extremely high rate of evapotranspiration or high index of aridity. Long spells of rainless days, ranging upwards from two weeks, can cause droughts, even though the country experiences high average rainfall.

Every year 3 to 4 million ha of land are affected by droughts of different magnitudes. Between 1949 and 1991, droughts occurred in Bangladesh 24 times. The situation may aggravate to the detriment of crop production as well as drinking water availability under climate change (see Chapter 5 on vulnerability and adaptation)

2.7.5 Salinity Ingress

The coastal region of Bangladesh covers almost 29,000 sq.km. and more than 30 percent of the cultivable lands of the country. During monsoon, there is abundant freshwater due to high rainfall as well as surface flow along the rivers from the north, keeping the saline water from the sea in check. During the rainless winter, however, the freshwater flow from the north in the rivers recedes; saline water from the south, in the Bay of Bengal, intrudes inland and makes it unfit for human consumption as well for crop agriculture. About 53 percent of the coastal area is thus affected by salinity.

Rahman and Ahsan (2001) estimated that a total of 1.65 million ha of land in Khulna and Barisal divisions out of 2.34 million ha,or 70 percent, is affected by different degrees of soil salinity. Of these, 0.49 million ha are strongly saline. Salinity has traditionally restricted the cultivation of rice and dry season rabi crops. There is a seasonal salinity interface with the threshold limit for agriculture moving inland in May in the southern part of the coastal region(PDO-ICZMP, 2004a). In the southwestern region, surface water salinity has been aggravated by reduction in dry-season flows entering the Gorai distributaries following the diversion of the Ganges flow upstream of the border. Salinity now reaches as far as Khulna, creating problems to normal agricultural practices and affecting the supply of clean water for industrial use. Surface water salinity is also a problem for Chittagong when there are no releases from the Kaptai Lake as the saline front approaches the abstraction point for city water supply (PDO-ICZMP, 2004a). River water salinity also has important implications for the natural environment, such as functioning of the Sundarbans ecosystem, sedimentation rates in tidal rivers, and human health.

2.7.6 Cyclonic Storms and Surges

Tropical cyclones accompanied by storm surges are among the major disasters in Bangladesh. The Bay of Bengal is a favourable breeding ground for these cyclones. About 5.5 percent of cyclonic storms (with a wind speed of at least 62 km/hr) forming in the Bay of Bengal hit Bangladesh, as do about 1 percent of cyclonic storms of the global total (Ali, 1996, 1999a, 1999b). When minimum death tolls of over 5,000 are considered, it turns out that Bangladesh is the worst sufferer of all cyclonic casualties in the world, with a death toll of about 53 percent of the global total (Ali, 1999a). Around 500,000 people died in 1970 alone, with 140,000 killed in 1991. The high number of casualties in Bangladesh arises from the fact that cyclones are always associated with storm surges due to the peculiar physical features of the coastline. More than 5 million people living in High Risk Areas (HRA) of the coast are extremely vulnerable to cyclonic disaster. With rising sea surface temperature due to climate change, in the future cyclonic storms may be even more devastating. Cyclone Sidr may have been an example of such ferocity. However, death tolls were lower not only because of the path of the cyclone but also because of the use of cyclone shelters and early warning systems.

2.7.7 Earthquake

Bangladesh is extremely vulnerable to seismic activity, the nature and the level of which are yet to be defined. In Bangladesh complete earthquake monitoring facilities are not available. Nonetheless, the country faces a high risk of moderate to strong earthquakes or tsunamis that may result in widespread damage and loss of thousands of lives. Between 2006 and 2009 alone, 115 tremors of at least magnitude 4 on the Richter scale have been recorded. Another 10 earthquakes recorded a magnitude of over 5. The epicenter of 37 of these tremors was inside the country. These minor tremors indicate the possibility of much more powerful earthquakes hitting the country in the future.

2.7.8 Tornado

Tornadoes occasionally occur in Bangladesh during the pre-monsoon hot season, especially in April, when the temperature is the highest. A tornado is usually accompanied by thunder, lighting, terrifying roaring and heavy rain, and is a very short-lived weather anomaly. Although small in size, tornadoes leave complete destruction wherever they hit. They are more common in the central part of Bangladesh than in other areas.

2.8 Institutions

In this section we discuss mainly the general institutional framework in the country as well as issues of environmental governance. Institutional issues and policies related to adaptation, mitigation and related governance and research will be discussed in the relevant chapters below.

2.8.1 Administrative Structure

Bangladesh is a parliamentary democracy with a Cabinet of Ministers headed by a Prime Minister who is the head of the government. The President is the head of state. The judiciary, legislative and executive branches of the Government are separate from each other. Each Ministry has a Minister who provides political directions, while the Secretary is the chief executive of a Ministry. The secretary is assisted by a group of bureaucrats. Ministries may have one or more agencies, some of which are administrative and some research or field-oriented, depending on the mandate of the Ministry.

For administrative purposes, including security matters, the country is divided into seven divisions, 64 *zilas* (districts) and 483 *upazilas* (sub-districts). Ministries or their agencies often have their representative offices at the divisional, district and *upazila* levels. *Upazilas* are divided into unions, which are clusters of revenue villages). Each union is headed by an elected chairman and a few members. *Upazilas* are commonly headed by *upazila* chairmen and other members who also are directly elected. In theory, districts should also have a council headed by an elected chairman; however, this office has long been defunct in practice. Local government is thus effectively represented by the *upazilas* and the unions.

2.8.2 Environmental Governance

The administrative framework for environmental governance, which also includes the governance for climate change, is described below.

Ministry of Environment and Forests

The Ministry of Environment and Forests (MoEF) is the key institution to address the issues of environment and degradation occurring naturally and due to human interference. This is more an oversight and coordination Ministry, rather than having direct control over the agencies of other Ministries. The Department of Environment (DoE) under the MoEF deals with climate change issues nationally and internationally in addition to its normal administrative and regulatory functions oriented toward the environment. The MoEF is further tasked with the implementation of the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2009, which is elaborated in later chapters.

Climate Change Unit (CCU)

A National Steering Committee on Climate Change has been established to coordinate and facilitate national actions on climate change. The National Steering Committee reports to the National Environment Committee, which is headed by the Prime Minister. A Climate Change Unit has been set up under the MoEF to support the National Steering Committee on climate change and coordinate with other Ministries and departments implementing projects under BCCSAP. Climate change cells have also been established in different Ministries.

National Environmental Committee

The National Environmental Committee is headed by the Prime Minister and ensures a strategic overview of environmental issues as well as determines environmental policies

National Steering Committee on Climate Change:

Immediately after the Bali Conference (COP13), the Government formed the National Steering Committee on Climate Change. It is headed by the Minister of the MoEF and comprises of secretaries of all relevant Ministries as well as civil society representatives and represents the focal point for developing and overseeing implementation of the BCCSAP . Five functional working groups were also constituted on adaptation, mitigation, technology transfer, financing and public awareness.

Climate Change Cell

The Climate Change Cell was established in the Department of Environment in 2004 under the Comprehensive Disaster Management Program (CDMP) of the Government. The Cell provides the central focus for the Government's climate change-related work, operating as a unit of the DoE under MoEF, and provides different services related to affairs on climate change, including support for international negotiations.

The National Disaster Management Council (NDMC)

The NDMC, headed by the Prime Minister, is the highest forum for the formulation and review of disaster management policies. It has two committees to implement its disaster management policies and decisions:

- The Inter-Ministerial Disaster Management Committee
- The National Disaster Management Advisory Committee

Disaster Management Bureau

The Ministry of Food and Disaster Management is the focal Ministry for disaster management. Its Disaster Management Bureau (DMB) is the apex organization responsible for coordinating national disaster management interventions across all agencies. It is a technical arm of the Ministry of Food and Disaster Management. It oversees and coordinates all activities related to disaster management at national and local levels.

Chapter 3

Emission of Greenhouse Gases: An Inventory for Bangladesh

3.1 GHG Inventory as a Core Issue for National Communication

In Chapter 1 the GHG emission inventory has been singled out as a major component of the National Communication, because unless periodic reporting is made on GHG emissions, it will be very difficult to know how urgently the international community will have to act to avoid dangerous climate change, and what kind of activities should get priority. So, SNC envisages preparing a comprehensive GHG emission inventory by sources and removals by sinks for the base year 2005 using comparable methodologies (IPCC 1996/2006).

3.2 Objectives and Scope of GHG Inventory

3.2.1 Objectives

The main objective of the GHG inventory is to estimate the quantum of various GHGs that are emitted by the country and assess their current status in Bangladesh by sector and gases. As part of the overall exercise, an emission baseline and a GHG database management system will also be established.

3.2.2 Scope of Work

GHG emission can take place in various sectors and activities. Five major activities will be covered under the inventory, which include:

a) Energy (including biomass burning, transport sector, etc.)
b) Industry (cement manufacturing, fertilizer, pulp and paper, etc.)
c) Agriculture (ruminant livestock, livestock and manure management, wet rice cultivation, etc.)
d) Waste and refuge management (municipal waste, wastewater treatment/management, etc.)
e) Land use change and forestry (change in forest cover and woody biomass, change in forest land use, etc.)

All activities refer to national-level data. All the major GHGs have been covered, namely, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Others such as CO, NOx, NMVOC, Sox, HFCs, PFC or SF_6, have been given little or no attention because of a general paucity of data and the likelihood these are not significant in Bangladesh. The MoEF is trying to archive data used for the inventory purposes along with the source details so that in the future such exercises, including biennial updating, may be carried out more routinely.

3.2.3 Specific Issues in Energy Sector GHG Emission Estimation

In the case of emission from energy activities, the fuels that have been considered are described below, along with data problems that have been faced and the manner in which the problems were resolved.

Natural gas:

Natural gas is the most important primary fuel among fossil fuels and is used for electricity generation, industrial process heating, industrial captive generation, household cooking and heating, and in the transportation sector in the form of CNG. The consumption of natural gas by each sector is found in a relatively complete state from Petrobangla and the distribution companies. CNG has been used only since 2005.

Diesel:

The next important fuel is diesel, which is used mostly in the transportation sector. In addition, diesel is used for irrigation as well as running of farm equipment and small-scale electricity generators in various industries, commercial entities and households. A detailed breakdown cannot be obtained; however, information from broad sectors such as railway, navigation, and agriculture were obtained. In the agriculture sector, 80 percent of diesel use is attributed to irrigation and the rest to farm equipment. It is not possible to estimate the amounts used for electricity generation by commercial entities and households because of a lack of data, which may only be generated through large-scale surveys in urban areas. So far, these have not been carried out.

Kerosene:

Kerosene is mostly used in the domestic sector for lighting and cooking purposes. Some is used in the agriculture sector for unspecified purposes.

Gasoline:

Petrol, octane, HOBC, MS and others are all grouped together as gasoline. This is used mostly in the transportation sector, and some in small generators. In the absence of detailed data, the amounts are attributed to the transportation sector as a whole, especially to cars.

Jet fuel:

Jet fuel is used exclusively in aviation. Data on domestic aviation and international bunkers are not available.

Lubricants:

Lubricants are not combusted directly; however, every type of engine in different sectors uses lubricants. Part of it is burned off through the process and thus contributes to emissions. However, a sector-wise breakdown is not available.

Furnace oil:

This is another major fuel used in electricity generation, furnaces in various industries, and navigation vessels.

LPG:

LPG is used for cooking in households and hotels/restaurants. In the absence of any detailed data, amounts are attributed to the residential sector.

Natural Gas Liquids:

Natural Gas Liquids (or condensate) production 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.

***Coal*:**

No reliable statistics on coal use in the country exist. However, because coal was consumed by a single industry category, i.e., brick making, its use can be estimated from the number of bricks produced. The estimation problem would have been straightforward had it been that all kilns had the same annual output and they all used only coal. However, an unknown number of brick kilns use varying amounts of firewood in place of coal, even though environmental regulations strictly forbid that. Thus, expert judgment had to be employed based on studies of the brick manufacturing industry conducted by BUET and the Department of Environment, MoEF. Coal consumption was estimated to be 1.7 million mt in 2001, and a consumption growth of 100,000 mt per year was assumed.

Biomass:

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, etc. The calorific values used in this report are the local values as reported by the BBS in its Statistical Yearbooks.

3.3 Energy Sector Emission Estimation Method

In the SNC, GHG inventory was performed by using two types of methods – a Reference Approach and a Sectoral Approach within an IPCC Tier 1 analytical framework. Under Tier 1, usually the global default values are used. For Tier 2 estimation, national values, if available, are used. In the present case, the basic method has been to use Tier 1 values for conversion and emission factors.

The first step was to identify all energy-consuming sectors in Bangladesh. The identification of fuels was the next step, followed by the identification of data sources. The fuel consumption by each sector was collected from relevant sources. These were then reorganized into the sub-sectors under the energy activities, as specified in the IPCC 2006 Guidelines. Only the relevant sectors were selected for reporting. A comparison of the Reference Approach and Sectoral Approach inventories has been given later.

There are no reliable national estimates of calorific values of different fuels. In addition, there are no data available on national emission factors. As a result, an IPCC Tier 2 methodology inventory could not be performed.

3.4 Fuel Supply and Consumption in Bangladesh

The fuel definitions, calorific values and carbon contents were obtained from the publication *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 2 (Energy)*. The local names of the fuels vary from the IPCC nomenclature. The local names of petroleum products were obtained from BPC and tallied with the IPCC names. The values for biomass were obtained from BBS publications. These names and values are presented in Table 3.1.

Table 3.1: Calorific values, carbon content and names of fuels used in Bangladesh

FUEL TYPES[2]			Local Name[1]	Unit	Calorific Value[3]	Unit	Carbon Content (TC/TJ)[4]
Liquid Fossil	Primary Fuels	Crude Oil	Crude Oil	KT	42.3	TJ/KT	20
		Natural Gas Liquids	Natural Gas Condensate	KT	46.34	TJ/KT	17.5
	Secondary Fuels	Gasoline	MS, HOBC, Octane	KT	44.3	TJ/KT	18.9
		Jet Kerosene	JP-1	KT	44.1	TJ/KT	19.5
		Other Kerosene	SKO	KT	43.8	TJ/KT	19.6
		Gas / Diesel Oil	HSD, LDO	KT	43	TJ/KT	20.2
		Residual Fuel Oil	FOHS	KT	40.4	TJ/KT	21.1
		LPG	LPG	KT	47.3	TJ/KT	17.2
		Naphtha	Naphtha	KT	44.5	TJ/KT	20
		Bitumen	Bitumen	KT	40.2	TJ/KT	22
		Lubricants	Lubricants	KT	40.2	TJ/KT	20
		Other Oil	SBP, MTT, JBO	KT	40.2	TJ/KT	20
Solid Fossil	Primary Fuels	Sub-bit. Coal	Sub-bit. Coal	KT	25.8	TJ/KT	26.2
Gaseous Fossil		Natural Gas (Dry)	Natural Gas	M^3	35	MJ/M^3	15.3
Biomass[5]		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

Sources: 1. BPC, 2010, 2. Table 1.1: Definitions of Fuel Types Used in the 2006 IPCC Guidelines3. Table 1.2: Default Net Calorific Values (NCVs) and Lower and Upper Limits of the 95% Confidence Intervals 4. Table 1.3: Default Values of Carbon Content5. BBS yearbook 2006-07

3.5 CO2 Emission from Fuel Combustion

3.5.1 Summary of Energy Sector CO_2 Inventory

The comparison of CO_2 emission, estimated by Reference and Sectoral Approaches, is presented in Table 3.2. The Reference Approach involved estimating the total consumption of each fuel only, not by sector. It can be seen that the inventories by the two approaches compare quite well, varying only between ± 1-3 percent.

Table 3.2: Summary of Energy Sector CO_2 Emission (k mt**)**

Year	2001	2002	2003	2004	2005
Sectoral Approach	30,210	31,484	33,115	35,764	37,920
Reference Approach	31,183	31,937	33,994	35,428	37,879
Difference	973	453	879	-336	-41
Percent difference	3	1	3	-1	0

Table 3.3 shows the year-wise summary of CO_2 emission by the different sub-sectors under the energy sector. Among the different fuel-consuming sectors, energy industries is the highest contributor to GHG emissions, followed by manufacturing and construction. Fig. 3.1 shows relative contribution of energy sub-sectors for the year 2005.

Table 3.3: Summary of Energy Sector CO_2 Emission (k mt)

Energy Sub-Sectors	2001	2002	2003	2004	2005
1. Energy industries	10,693	11,105	11,223	12,056	12,780
2. Manufacturing and construction	8,755	8,728	10,087	10,652	11,276
3. Transport	4,551	4,566	4,585	4,955	5,500
4. Residential	3,811	4,075	4,737	4,974	4,675
5. Agriculture	1,625	1,626	1,597	1,764	1,993
6. Non-specific	549	1,148	631	1,097	1,426
7. Commercial	226	236	255	266	270
Total Emission from Combustion Activities	*30,210*	*31,484*	*33,115*	*35,764*	*37,920*
Fugitive CO_2 Emission	*23*	*24*	*26*	*28*	*30*
Grand Total	**30,233**	**31,508**	**33,141**	**35,792**	**37,950**

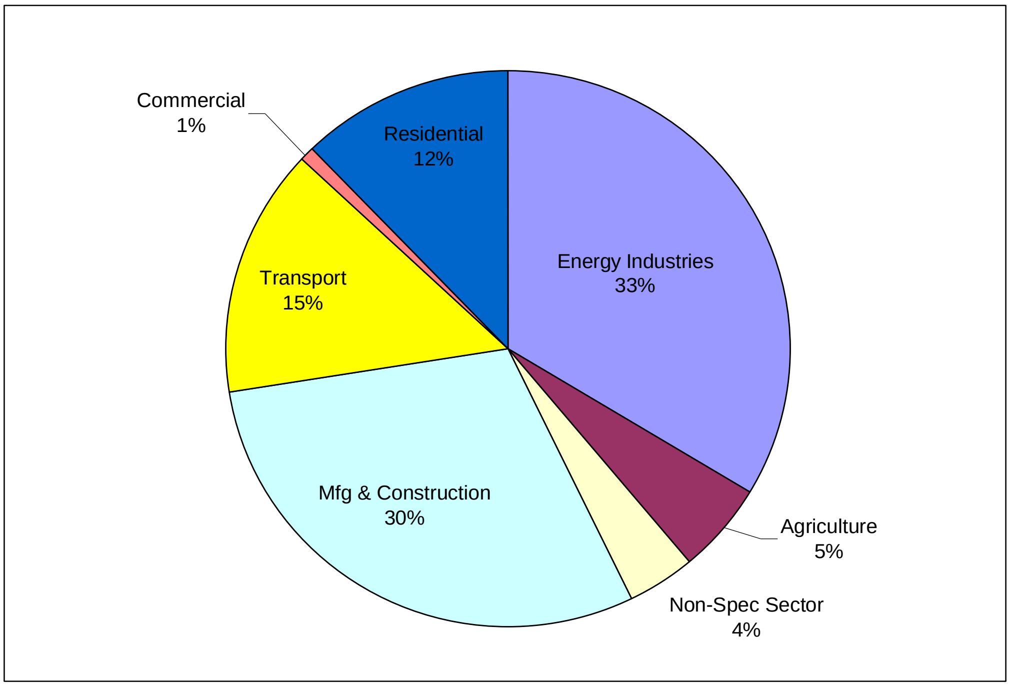


Fig. 3.1: Relative contributions to CO_2emissions by different energy sub-sectors (2005)

3.5.2 Analysis of Sub-Sectors

<u>Energy industries</u>

Electricity generation is the only significant source for emission of CO_2 in the energy industries category (Table 3.4). Some furnace oil is consumed for petroleum refining, but since there is only one petroleum refinery in the country of modest capacity, the emission from petroleum refining is likely to be negligible. Even if another refinery is constructed, the emission will remain small. The other energy industries category in the table includes energy consumption by the gas fields. Data for internal gas consumption for gas processing was found for six out of 15 gas fields. The reported amount was 0.1-0.15 percent of gas production. In the absence of other data, CO_2 emission for all other gas fields has been estimated by assuming that 0.1 percent of gas production is internally consumed.

Table 3.4: CO_2 emission from energy industries (k mt)

Energy Industries	2001	2002	2003	2004	2005
Power generation	10,629	11,042	11,152	11,988	12,713
Petroleum refining	44	41	47	43	41
Other energy industries	21	22	23	25	27
Total	**10,693**	**11,105**	**11,223**	**12,056**	**12,780**

Manufacturing

Figure 3.2 shows CO_2 emissions from the manufacturing and construction sector, disaggregated by some key industry categories. The figure shows the chemicals category to be the most important. This category includes the fertilizer industries, which account for the bulk of the emissions from the chemicals group. One interesting observation is that the textile and leather group, which appears to be second in importance to the chemicals group, is rising fast and may perhaps soon surpass the chemicals group if no new gas-based fertilizer industry is set up.

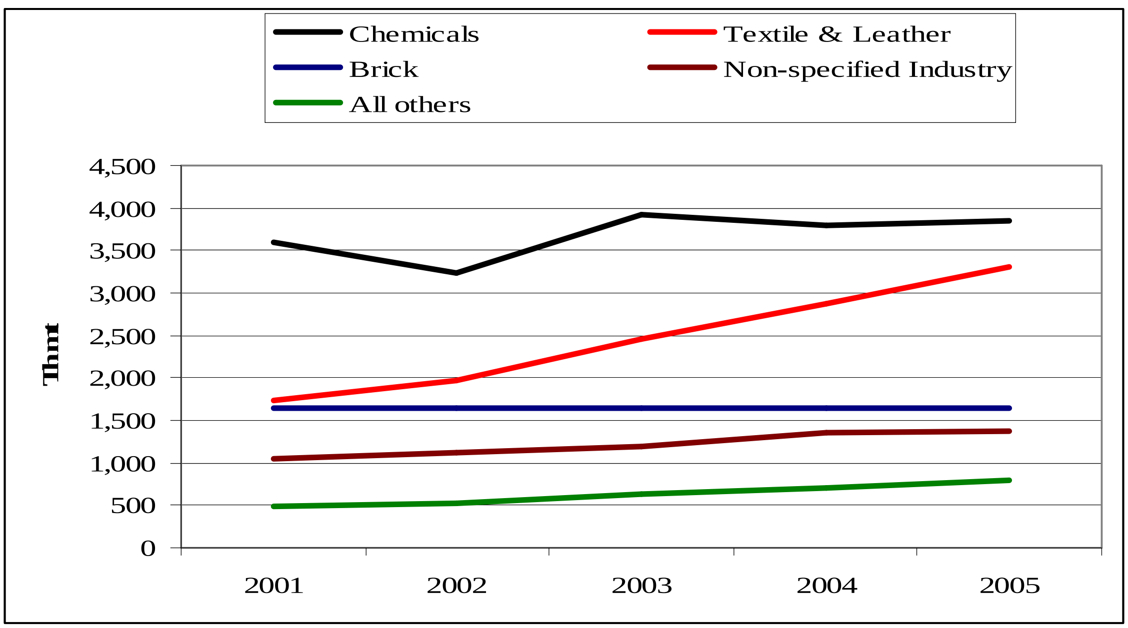


Fig. 3.2: Trend in CO2 emissions from manufacturing industries

For a better appreciation of the data presented in Figure 3.2, a pie diagram showing the relative contributions (in percent) of the different industry groups of the manufacturing sector for the year 2005 is presented in Fig. 3.3. It is worth noting that, out of the nine categories shown, brick, textile andleather, and chemicals (fertilizer) industries together contribute 77 percent of the total emissions of this sub-sector. Steel andiron, food, beverage andtobacco, and non-metallic minerals each have only a 3 percent share of total CO_2 emissions.

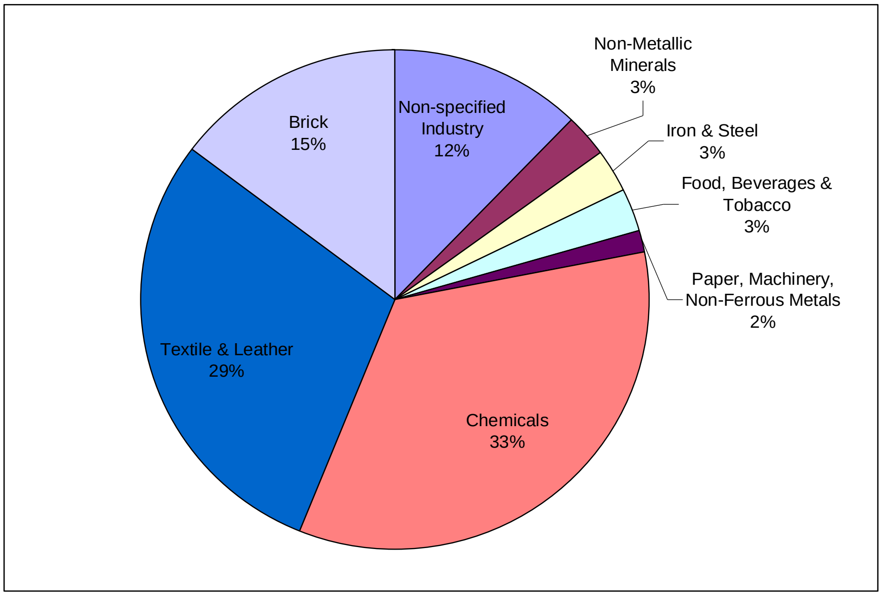


Fig.3.3: Emissions from the manufacturing sub-sectors (2005)

Transport

Figure 3.4 gives a breakdown of emissions from the transportation sector, while Figure 3.5 shows the relative contributions of the different transportation modes in 2005. It is observed that about two-thirds of emissions take place from trucks and buses.

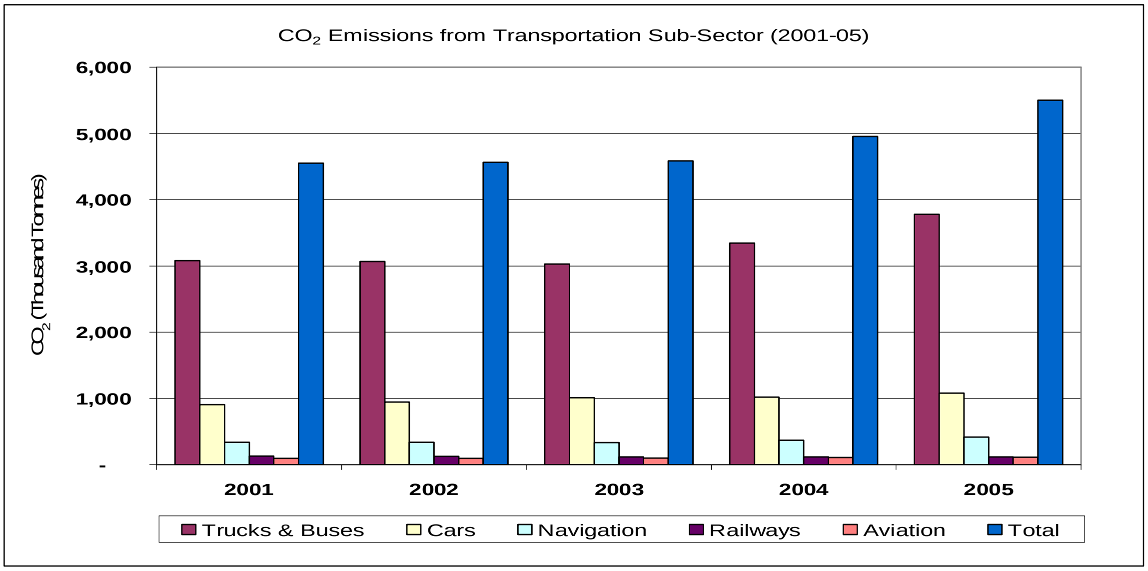


Fig. 3.4: CO_2 Emission by different types of transportation

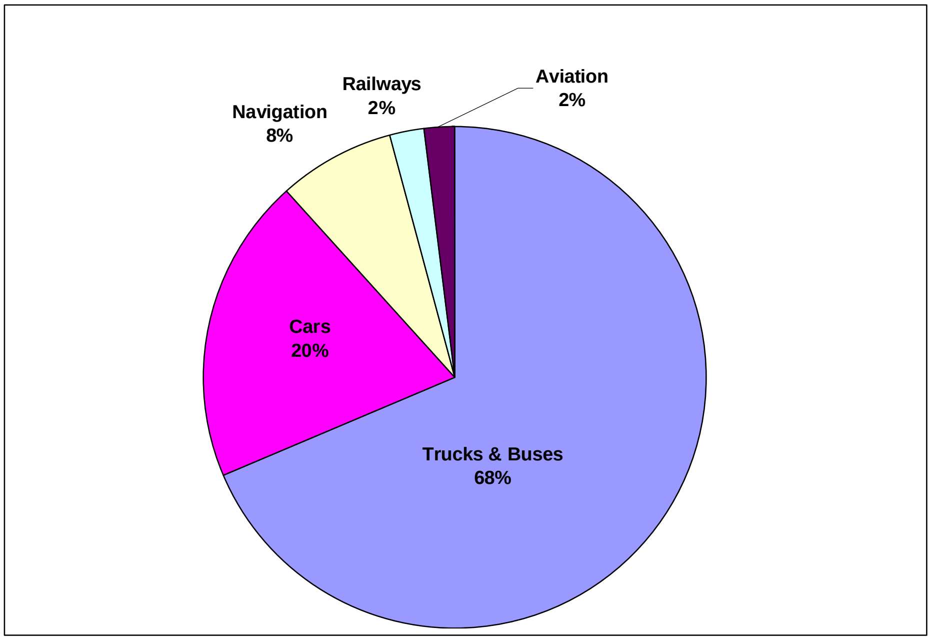


Fig.3.5: CO_2 Emission by different transportation modes (2005)

Residential and commercial

Table 3.5 shows that the commercial sector consumes only natural gas, while the residential sector consumes LPG, natural gas and kerosene. Natural gas and LPG are used mainly for cooking, while kerosene is mainly used by rural households for lighting. It is worth pointing out that both the commercial and the residential sector also consume very large quantities of biomass as cooking fuel or for other heating purposes. BecauseCO_2 emission of biomass is not counted in net emissions, it is reported separately.

Table 3.5: CO_2emission from residential and commercial sectors

Sector	Fuel	2001	2002	2003	2004	2005
Commercial/Institutional	Natural Gas	226	236	255	266	270
Residential	LPG	61	60	66	68	64
	Natural Gas	1,772	2,044	2,497	2,748	2,920
	Kerosene	1,978	1,971	2,174	2,158	1,691
	Total	3,811	4,075	4,737	4,974	4,675
All		4037	4411	4992	5240	4945

Agriculture

The main fuel-consuming activity in agriculture 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 requisite disaggregated data, it was assumed that 80 percent 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. The results are shown in Fig. 3.6.

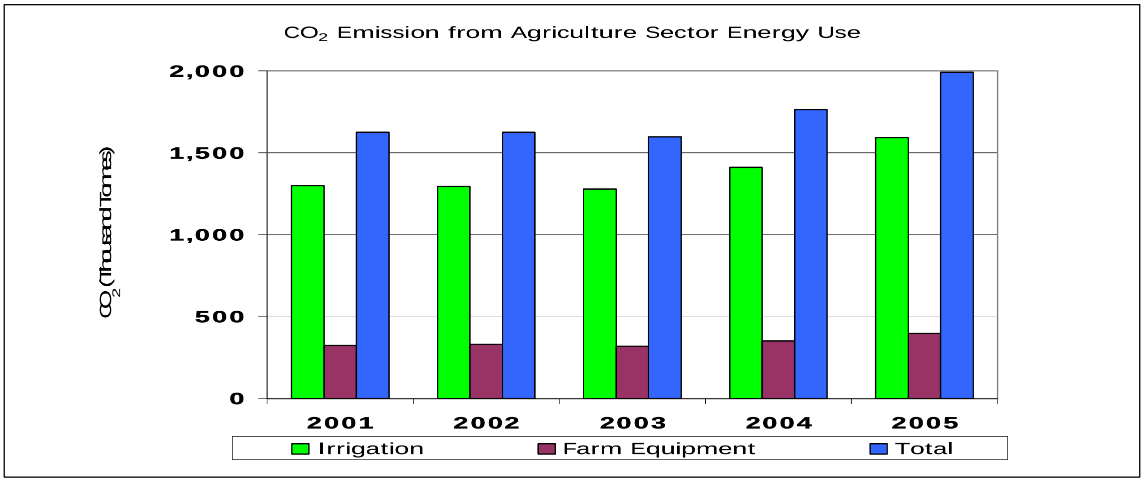


Fig. 3.6: CO_2emissions from agriculture sector energy use

Non-specified sectors

The unaccounted-for gas (UFG) and other fuels that were consumed, but in no specific activities that could be identified, were placed in this group. In reality this is not a sector, but for accounting purpose this is convenient because otherwise the inventory would be incomplete. Table 3.3 and Fig. 3.1 earlier have shown the estimated emissions from the non-specified group. A substantial quantity of gas, assumed to be oxidized, is considered here. It may be noted that the contribution of this group is more than the commercial sector, and in the year 2005 the emission from this sector was comparable to that of the agriculture sector as well.

3.5.3 Analysis by Fuel Type

Solid, liquid and gas

Figure 3.7 and Fig. 3.8 respectively show the CO_2 emissions from solid, liquid and gaseous fuels and by primary and secondary fuels. Since natural gas is the predominant fuel in Bangladesh, it is not surprising that the highest CO_2 emission also is from natural gas. The second-highest CO_2-emitting fuel is now diesel. Kerosene also is a significant emitter. The drop in the use of kerosene over time is probably related to the expansion of rural electrification and the dissemination of Solar Home Systems (SHS).

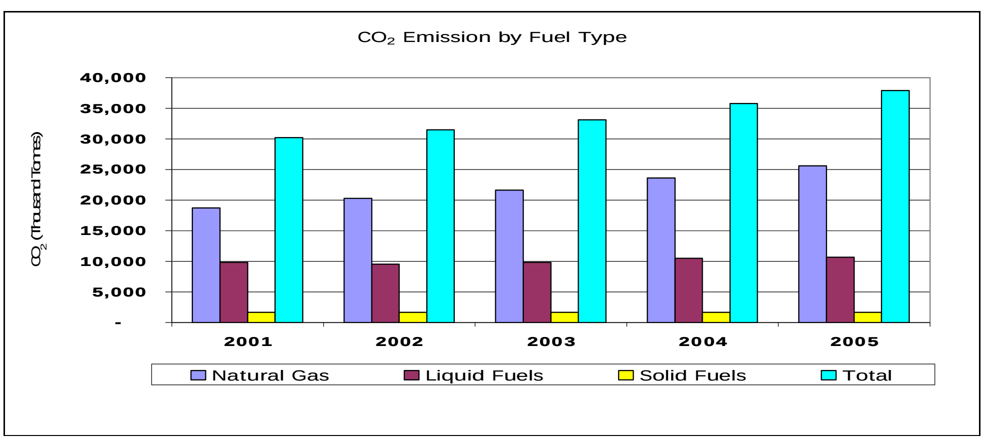


Fig.3.7: CO_2emissions by fuel type

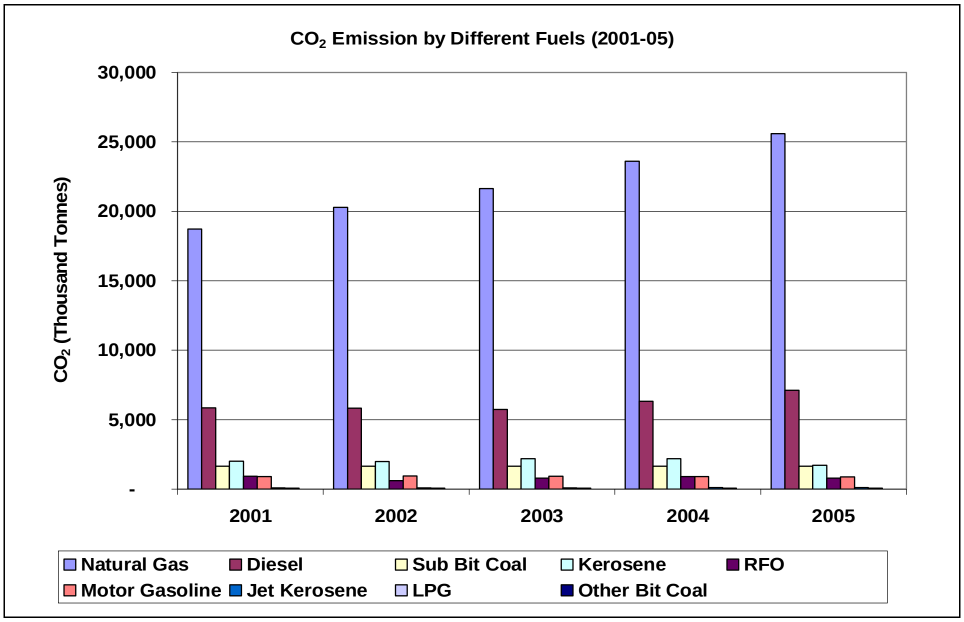


Fig. 3.8: CO_2emissions from primary and secondary fuels

Figure 3.9 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 to correctly account for emissions occurring within the borders of Bangladesh, as per the IPCC guidelines.

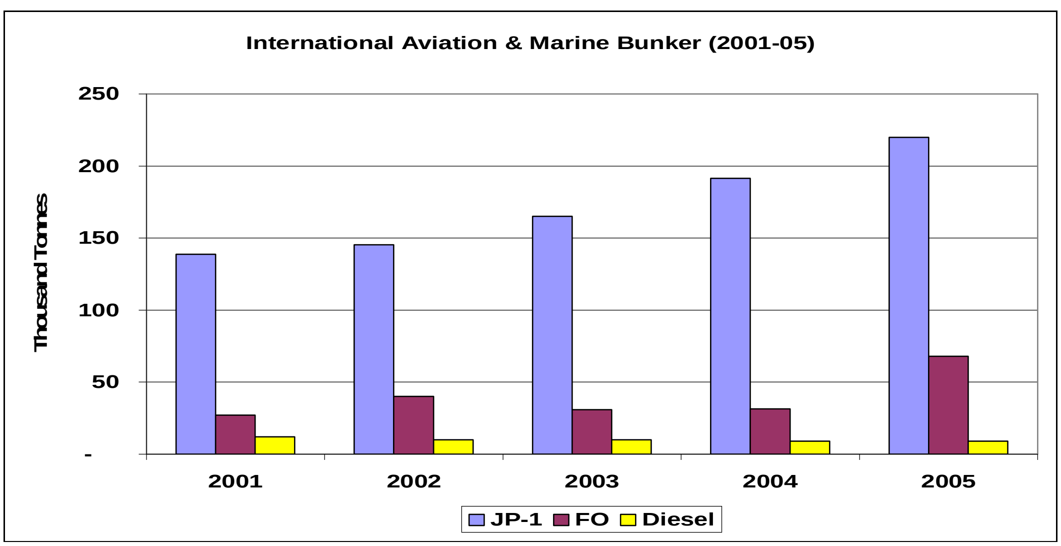


Fig. 3.9: International aviation and marine bunkers

Biomass

Table 3.6 shows the quantity of different types of biomass in million mt (MT) and the CO_2 emissions in kilo mt (KT). BBS reports seven categories of biomass; however, as noted above, only four categories are shown by lumping similar items based on their calorific values. As required by the IPCC methodology, these are reported but not added to the national GHG inventory. The calorific values used for the different types of biomass are country- specific values as reported by BBS.

Table 3.6: CO_2emissions from the combustion of biomass fuels

Year	Cow dung (MT)	CO_2, KT	Firewood (MT)	CO_2, KT	Agri. Waste (MT)	CO_2, KT	Other Waste (MT)	CO_2, KT	Total (MT)	Energy in TJ	CO_2, KT
2001	8.2	7,088	6.2	9,415	28.65	15,885	5.90	8,242	48.95	411,771	40,629
2002	8.2	7,088	6.4	9,719	28.69	16,155	6.00	8,368	49.29	418,863	41,329
2003	8.2	7,088	6.6	10,022	28.8	16,179	6.20	8,646	49.80	425,002	41,935
2004	8.3	7,174	7.2	10,933	28.7	16,003	6.30	8,772	50.50	434,601	42,882
2005	8.4	7,261	7.8	11,845	28.5	15,855	6.50	9,050	51.20	446,033	44,010

3.5.4 Fugitive and Non-CO_2 Emissions

Tables 3.7 and 3.8 present the N_2O emission from combustion activities and CH_4 emissions from both combustion activities and fugitive sources such as leakage for two years, 2001 and 2005. The CO_2 equivalent emissions are also presented in the two tables. 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 industrial burners, could not be accounted for due to a lack of data.

Table 3.7: CH_4 and N_2O emissions from the energy sector (Gg), (2001 and 2005)

Categories	2001			2005		
	CH_4	N_2O	CO_2 eq	CH_4	N_2O	CO_2 eq
Energy	19.88	0.41	544	26.04	0.48	694
Fuel combustion activities	2.10	0.41	170	2.76	0.48	206
Fugitive emissions from fuels	17.78	-	374	23.27	-	491

Table 3.8: Fugitive CH_4 and CO_2emissions from energy sector (Gg),(2001 and 2005)

Categories	2001			2005		
	CO2	CH4	Eq. CO2	CO2	CH4	Eq. CO2
Flaring	22.67		23	29.64		30
Distribution		17.8	374		23.27	491
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 3.9 gives the summarized results in CO_2 equivalent units of the emissions of the three GHGs that were estimated for the energy sector and sub-sectors, and their relative contributions for the years 2001 and 2005. As can be clearly seen, the non-CO_2 gases contribute a negligible amount to the overall emissions, and are less than 2 percent. However, it is important to point out that the uncertainties in the estimation of the non-CO_2 gases are very high.

Table 3.9: Summary of GHG emissions from fuel combustion in energy sector (2001 and 2005)

Gas	GWPs	2001			2005		
		Emission (Gg)	CO_2 Eqiv. Gg	Percent of total eq emission	Emission (Gg)	CO_2 eqiv. Gg	Percent of total eq emission
CO_2	1	30,210	30,210	98.37	37,920	37,920	98.20
CH_4	21	17.8	374	1.22	26.04	547	1.42
N_2O	310	0.4	127	0.41	0.48	149	0.39
Total		30,228	30,711	100	37,946	38,616	100

3.5.6 Trend in Emission Growth

The trend in emission growth is best illustrated by comparing with the last two GHG inventories. Figure 3.10 presents the SNC inventories along with the ALGAS inventory for 1990 and the INC inventory for 1994. As can be seen from Figure 3.10, there has been a threefold increase in GHG emissions in the intervening period. This is consistent with both observed economic growth and the growth in fossil fuel consumption in the country.

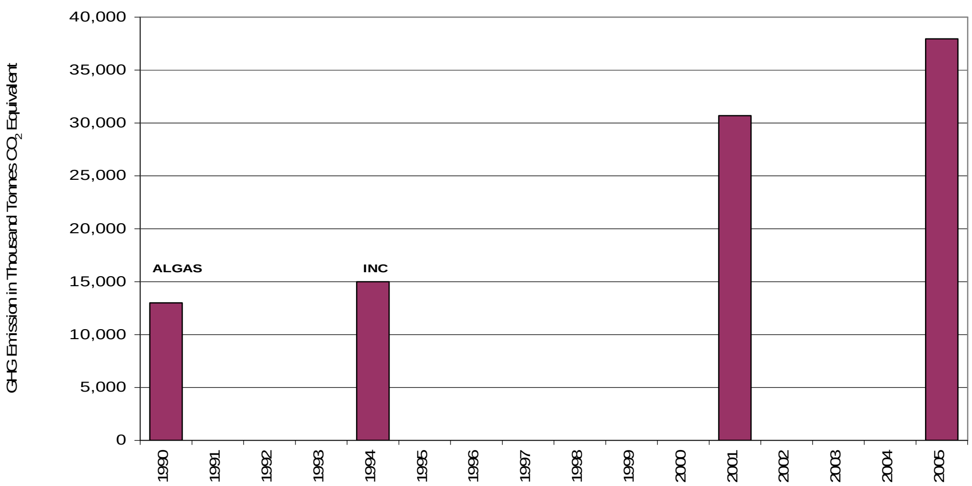


Fig. 3.10: Growth in GHG emissions from 1990 to 2005

3.5.7 Uncertainties

Uncertainties of the CO_2 emissions from fuel combustion were estimated in accordance with IPCC guidelines. Since the emission factors used were IPCC default values, the IPCC default uncertainties apply. Expert judgments were used for 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. Problems arose when that had to be disaggregated into user categories or end-uses. Table 3.10 shows the estimates of uncertainties of activity data and emission factors for the eight energy sub-sectors.

Table 3.10: Uncertainty estimates for GHG emissions in the energy sector

Energy Sub-Sectors	Activity Data	Emission Factor
Energy industries	10%	5%
Manufacturing	20%	5%
Transport	25%	5%
Residential	15%	5%
Agriculture	15%	5%
Non-specified	30%	10%
Commercial	20%	10%

However, for the following cases more elaboration is needed:

- 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 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 5,000 kcal/kg to 7,000 kcal/kg. Therefore, the IPCC default value was used.

The total quantity of diesel supplied is known reliably, but its use in different sectors and end-uses is not known. Diesel is used in a variety of applications. Even though sales points for different sectors are designated, diesel is sold for many other uses for consumption in other sectors. For example, filling stations for vehicles sell diesel to standby generators, and oil depots for agricultural applications sell diesel to mechanized county boats. The most uncertain data item is the use of diesel in small generators.

The system loss of natural gas, which is a euphemism for 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 much of the rest is consumed. Since the gas is combusted, it was allocated into the non-specified sector and appears in the inventory as CO_2 emissions.

Data on biomass have been taken from the Government-published Statistical Yearbook of Bangladesh, although this is not a result of any survey or census data. It comes from a model developed in the mid-1980s under a project called the Bangladesh Energy Planning Project (BEPP). However, crosschecking with other sources and indirect calculations based on a number of rural households and industries led to the conclusion that the uncertainty is not more than +20 percent.

Uncertainties in the estimation of CH_4 and N_2O cannot be calculated because there are 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, 0.1percent of sales volume has been assumed, which is a negligible quantity; this value can easily exceed 0.25 percent. In that case, the uncertainty would be more than 200 percent.

3.5.8 Quality Control and Quality Assurance

Supply data on oil and gas in Bangladesh are very reliable, but estimates of coal and biomass are based on expert judgment and other indicators. With respect to gas and oil, no special quality control and quality assurance is required because data are available from very reliable Government sources. However, when it comes to a sectoral split, the data are far from being reliable. For quality control purposes the following 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 percent.
2. The quantity of gasoline and diesel consumed was crosschecked against the number of vehicles multiplied by the average annual passenger-kilometre for the case of cars and buses and freight-kilometre for 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 agreement was found to be good. The fact that the Sectoral Approach inventory matched the Reference Approach inventory to within ±2 percent lends support to the quality of the inventory.

3.5.9 Completeness

Data by activity and fuel types for different sectors are available 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 perhaps not so important because natural gas is by far the largest fuel source in Bangladesh. With respect to completeness of the GHG inventory of Bangladesh, the following comments can be made:

1. The difficulty with coal supply and consumption, as well as their calorific values, has been mentioned earlier. The estimation would have been easier had it been that all brick kilns, which use coal, had the same annual output and all used only coal. An unknown number of brick kilns use varying amounts of firewood in place of coal, even though environmental regulations strictly forbid that, as stated. Expert judgment based on studies of the brick manufacturing industry conducted by BUET and the Department of Environment, MoEFputs the figure at around 2 million mt of coal per year. According to Government statistics, however, less than 1 million mt of coal is imported annually. Without an accurate survey of all brick kilns using coal, it is impossible to ascertain this quantity; therefore, only the Government-published data for coal consumption was used in this inventory.
2. 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 is occurring in the transmission and distribution lines. The problem is aggravated by the fact that the reported system loss includes both leakage and UFG. Leakage has to be accounted as methane emission, while UFG is carbon dioxide emission. As a result, IPCC default procedures were followed.
3. Even though the total supplied diesel is shown as consumed in various sectors, it is alleged that between 100,000 and 300,000 mt of diesel are informally traded across the national border because of the price differential. The inventory could not account for this uncertain quantity.
4. The actual consumption at the consumer or device level could not be known for many fuel items. 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, gasoline use in small household generators, coal use in brick kilns and kerosene use for cooking all are not known.

5. The fraction oxidized for coal is not known because the combustion process takes place in a crude kiln; often, the unburned coal is sold to rural commercial establishments such as restaurants.
6. The quantity of furnace oil (FO) in different sectors is not known, but based on expert judgment, the predominant use appears to be in the industry sector. All FO was therefore allocated to that sector.
7. A certain quantity of FO enters the country as bunker fuel of end-of-life ships, imported to be broken down for steel scrap. This could not be accounted for.
8. Lack of reliable 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 likely to have been greatly affected.
9. Only the three main GHGs have been reported. As noted, the inventory has not dealt with other gases such as CO, NO_x, SO_2 ,NMVOC, SOx, HFCs, PFC and SF_6.

Table 3.11 presents a summary of CO_2 emissions, data sources, fuels used, and comments on the state of completeness or availability of data for the fuel combustion activities in different sectors as per IPCC grouping.

Table 3.11: Summary of CO_2 Emissions and Data Source and Fuel Type (2005)

Categories	Gg CO_2	Data Source	Fuel	Remarks
1 - Energy	**37,950**			
1.A - Fuel combustion	**37920**			
1.A.1 - Energy industries	**12,780**			
1.A.1.a.i - Electricity generation	12,713	BPDB, BPC, Petrobangla		NG, FO, diesel
1.A.1.b - Petroleum refining	40	ERL	FO	Private refining is not covered
1.A.1.c – Manufacture of solid fuels and other energy industries	27			Internal consumption of NG by the gas fields
1.A.2 - Manufacturing Industries	11,276	Petrobangla, BPC, BBS	NG, diesel, FO, Coal	Breakdown of fuel by industry type is available only for NG
1.A.2.a - Iron and steel	338		NG	
1.A.2.b - Non-ferrous metals	8		NG, Coal	Includes aluminum, copper and various molding shops
1.A.2.c - Chemicals	3,850		NG	Includes fertilizer
1.A.2.d - Pulp, paper and print	157		NG	
1.A.2.e - Food processing, beverages and tobacco	290		NG	Includes agro-products and seed, tea estates
1.A.2.f - Non-metallic minerals	1,952		NG, Coal	Includes brick, ceramic, glass
1.A.2.h - Machinery	8		NG	
1.A.2.l - Textile and leather	3,300		NG	
1.A.2.m - Non-specified industry	1,373		NG, Coal	
1.A.3 - Transport	**5,500**		MS, HOBC, diesel, FO, , JP, CNG	
1.A.3.a - Civil aviation		BPC, Padma	Jet Kerosene	
1.A.3.a.i - International aviation* (International bunkers)	693	BPC, Padma	Jet Kerosene	Not added to emission, for information only
1.A.3.a.ii - Domestic aviation	112	BPC	Jet Kerosene	
1.A.3.b - Road transportation		BPC, Petrobangla	MS, HOBC, diesel, CNG	
1.A.3.b.i - Cars	1,080			No further breakdown available
1.A.3.b.iii - Heavy-duty trucks and buses	3,777			
1.A.3.c - Railways	116	BR	Diesel	
1.A.3.d - Water-borne navigation		BPC	Diesel, FO,	
1.A.3.d.i - Water-borne navigation (International bunkers) *	213	Jamuna, BSC	Diesel, FO	Not added to emission, for information only
1.A.3.d.ii - Domestic water-borne navigation	415	BPC	Diesel, FO	
1.A.4 - Other sectors	**6,936**			
1.A.4.a – Commercial/institutional	270	Petrobangla	NG	
1.A.4.b - Residential	4,675	BPC, Petrobangla	kerosene, LPG, NG	Data for small generators run by liquid fuels not available
1.A.4.c – Agriculture		BPC	kerosene, diesel	
1.A.4.c.i - Stationary	1,593			Irrigation consumes 80% fuel
1.A.4.c.ii - Off-road vehicles and other machinery	398			20% fuel
1.A.5 - Non-specified	**1,426**			
1.A.5.a - Stationary	1,426			UFG is included here
1.B - Fugitive emissions from fuels	**30**			
1.B.2.b - Natural gas		BGFCL, SGFL, Chevron		
1.B.2.b.ii – Flaring	30			Only one gas field data available

*In accordance with the guidelines set out by the IPCC, CO_2emissions from International Bunkers are not included in the transport total.

3.6 Emission from Industry Sector

3.6.1 Introduction

The industrial processes category accounts for emissions generated in the production and use of minerals, the production of metals, the chemical industry, certain processes such as paper production, foods and drinks, and finally, the production and consumption of halocarbons and sulphur hexafluoride. 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 CO, SO_2, NO_x and NMVOCs are also included in the IPCC Guidelines. In general terms, the main gas emitted in this category is CO_2. Note that in each case, we have already estimated the release of carbon dioxide and other gases, wherever applicable, from combustion of fossil fuels and biomass. In this section only the non-combustive processes will be discussed that give rise to release of GHGs. For the sake of clarity we will warn the reader where such double counting may occur.

3.6.2 Sub-Sectors of Industrial Sector

Emissions are often produced as a byproduct 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. Such production processes that emit CO_2 include cement production, lime production, soda ash production and use, and limestone consumption.

The Revised IPCC 1996 Guidelines have given a list of industrial processes which may give rise to emission of one or other GHGs. Among these, in Bangladesh we may identify the following for estimation of GHG emissions.

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 practice, however, among all these mainly cement and fertilizer production has been considered. In other cases, either the overall activities are comparatively small information on them is lacking, or the processes involve combustion of primary or secondary fuels considered under energy-related emissions.

3.6.3 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. CO_2 is emitted during clinker production rather than cement production itself. Emission estimates thus should be based on the lime content and production of clinker.

An indirect and significantly smaller source of CO_2 is from 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.

For estimation of carbon dioxide emission from calcinations, the following parameters have been used:

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

Emission factor (mt CO_2/mt clinker) = 0.5071 × (0.665/0.646) = 0.5218

(based on IPCC Guidelines)

The production of clinker and corresponding CO2 emissions over the years have been as shown in Table 3.12. Note that most cement in Bangladesh is imported from outside and during the time period shown in the table, only one cement factory had been operating. Two others came on stream in later years.

Table 3.12: Emission of GHGs from cement industry

Year	Clinker (mt)	CO_2 (Gg)
2000 – 2001	164564	85.87
2004 – 2005	158520	82.72

3.6.4 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 NO_X, NMVOC, CO and SO_2 may also occur during ammonia production.

In Bangladesh, ammonia is produced for manufacturing ammonium and urea fertilizer. There are six ammonia producing plants in the country with an installed capacity of 2,896,000mt of urea, and 150,000 mt of ammonia. The 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 to the atmosphere. The most accurate method of estimation will be based on the consumption of gas. However, due to the paucity of data, we have used the ammonia production method. The steps in the estimation are:

1. The quantity of ammonia produced in tons is estimated
2. The default emission factor of 1.5 t CO_2/t NH_3 is used to transform ammonia into equivalent CO2 emissions
3. The quantity of $NH_3$is multiplied by the emission factor to obtain CO_2 and transformed into Gg.

The resulting CO_2 emission from seven ammonia-urea complexes (2001, 2005) are* shown in Table 3.13.

Table 3.13: Emissions of CO2 from ammonia-fertliser complexes

Indicator▼ /Factory ►	NGFF	UFFL	ZFCL	PUFF	CUFL	JFCL	KAFCO
Ammonia Production (tons/year)	66,000	272,250	307,000	56,100	330,000	355,740	499,500
CO_2 emission (tons/year)**	99,000	408,375	460,500	84,240	495,000	533,610	749,250

Total yearly emission of CO_2 from ammonia-urea complexes = 2,829,975 tons

= 2,830 Gg

* As there was no addition or decommissioning of ammonia-urea complexes during 2001-2005, CO_2 emission from these complexes remained more or less the same over this period.

** As stated above, IPCC default emission factor of 1.5 tonne CO_2./tonne NH_3 was used, although some of the complexes (KAFCO) produce more NH_3 than needed for urea production

Source : Based on BCIC, Official Communication, 2010. www.kafco.com

http://teacher.buet.ac.bd/mahammad/ammoniaplant.pdf

3.6.5 Total Carbon Dioxide Emissions in Industry Sector

The total carbon dioxide emission from the cement and fertilizer industry is given in Table 3.14

Table 3.14: Non-energy emissions from industry

Year	Cement (Gg)	Fertilizer (Gg)	Total carbon dioxide emission (Gg)
2000-2001	85.87	2830	2915.87
2004-2005	82.72	2830	2912.72

3.7 Emissions from Agriculture Sector

3.7.1 Methane (CH_4) Emissions from Cultivated Rice Fields

Anaerobic decomposition of organic material in flooded rice fields produces methane (CH_4), which escapes to 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 from a paddy field is dependent on several factors, including weather, characteristics of soil and paddy, and agricultural practices, particularly water management

Methodology

Following IPCC Guidelines, CH_4 emissions are calculated using the formula

CH_4 emission = HA × SF × CF × SIEF

where

HA = Gross harvested area
SF = Scaling factor
CF = Correction factor for presence or application of organic matter
SIEF = Seasonally integrated emission factor

HA (Harvested area): While calculating harvested area, multiple cropping patterns were taken into consideration, i.e., the areas cultivated for each type of paddy during a year were added to get the value of HA.

SF (Scaling factor): In order to determine the SF, the total harvested area was divided into (i) upland, (ii) irrigated, (iii) flood-prone, and (iv) drought-prone areas. Following IPCC guidelines and using expert judgment, SFs (scaling factors)as given below, for different water regimes are used taking low carbon content and high salinity of soils into consideration:

Water management regime	SF
Upland	0
Irrigated area .with multiple aeration.......................	0.52
Rain fed (regular)………………	0.28
Flood-prone area	0.31
Drought-prone area	0.25

The division of the area under different seasonal rice is made as follows:

Local, hybrid and HYV *boro*: wholly irrigated with multiple aerations – SF: 0.52
Broadcast *aman*: deep-water rice in flood-prone area: SF: 0.31
Local transplanted *aman* rice: 10 percent irrigated (SF: 0.52); rest equally divided between drought-prone (SF: 0.25) and regular rain fed (SF: 0.28)
HYV *aman:* 20 percent irrigated (SF: 0.52); rest divided equally between drought-pone (SF: 0.25) and regular rain fed (0.28)
Local *aus*: 2.5 percent irrigated (SF: 0.52); rest upland (SF: 0)
HYV *aus:* 5 percent irrigated (SF: 0.52); rest upland (SF:0).
CF (Correction factor): According to IPCC guidelines, CF for harvested area without application of any organic fertilizer is 1.0.

In Bangladesh, organic matter content in most soils is less than the critical value of 2.0 percent. Moreover, the major portion of cattle dung is used as fuel because of the scarcity of cooking fuel in rural areas**.** In the absence of any value as to what fraction of cattle dung is applied to the rice field, a value of 1.0 is taken for CF in this estimation.

SIEF (Seasonally integrated emission factor): In India the values are reported to vary from 5 to 15 gms/m^2 for continuously flooded rice fields (Mitra et al. 1996, Parasher et al. 1996), with the mean value being 10g/m^2. This value is used in the present calculation.

<u>Methane estimation</u>

In Bangladesh, paddy is cultivated three times a year with different water regimes, as indicated earlier. During 2000-2001, a total of 10,887,130 ha was cultivated round the year, where the seasonal distribution of rice by variety and the water control regime are shown as in Table 3.15. The estimation on the basis of the water management practices of the methane released are shown in Table 3.16. Note that contrary to expectations, the release from flood-prone areas is not much because it is seldom observed that these areas are without any water management structure. It is only the broadcast *aman* area which is totally exposed to flood. Local *aman* is basically grown on lands which are not that flood-prone, and in many cases there are flood protection embankments. This is particularly true for HYV *aman*. But during *aman* season drought may occur part of the time; otherwise, it is basically rain fed and sometimes partly irrigated. The division of lands by water regime has been conducted based on information from a large-scale survey in 2008.

Table 3.15: Distribution of land by season, broad variety and associated water management (th ha)

Paddy type	Harvested area	Irrigated	Upland	Flood prone	Drought prone	Rain fed
			.	.		
Aus paddy						
Local	859.17	21.48	837.69	0	0	0
HYV	466.06	93.21	372.85	0	0	0
Sub-total	**1325.23**	**114.69**	**1210.54**	**0**	**0**	**0**
Aman paddy						
B. Aman local	769.87	0	0	769.87	0	0
T. Aman						
Local	2143.56	214.36	0	0	964.60	964.60
HYV	2796.63	559.33	0	0	1118.65	1118.65
Sub-total	**4940.19**	**773.69**	**0**	**0**	**2083.25**	**2083.25**
Total	5710.06	773.69	0	**769.87**	**2083.25**	**2083.25**
Boro paddy						
Local	201.74	201.74	0	0	0	0
HYV	3650.10	3650.1	0	0	0	0
Sub-total	**3851.84**	**3761.8**	**0**	**0**	**0**	**0**
TOTAL	***10887.13***	***4740.22***	***1210.54***	***769.87***	***2083.25***	***2083.25***

Source: BBS: Yearbook of Agricultural Statistics of Bangladesh 2005

Table 3.16: Estimation of methane emissions from paddy land in 2000-2001

Water management regime	(A) Harvested area ($m^2 \times 10^9$)	(B) Scaling factor	(C) Correction factor for organic matter	(D) Seasonally integrated emission factor	$E = A \times B \times C \times D$ CH_4 emission in Gg
Irrigated	47.40	0.52	1	10	246.48
Upland	12.10	0	1	10	0
Flood-prone	7.70	0.31	1	10	23.87
Drought-prone	20.83	0.25	1	10	52.07
Rain fed	20.83	0.28			58.32
All	**108.87**				**380.75**

The same exercise has been continued for the year 2004-2005 when a total of 10,368.39 thousand ha of land were cultivated for paddy with the divisions by season, broad variety and water regime, as shown under Table 3.17. The estimated emission of methane for the year is shown in Table 3.18.

Table 3.17: Distribution of land by season, broad variety and associated water management (th ha)

Paddy type	Harvested area	Irrigated	Upland	Flood prone	Drought prone	Rain fed
Aus paddy						
Local	573.69	14.34225	559.3478	0	0	0
HYV	450.99	22.5495	428.4405	0	0	0
Sub-total	**1024.68**	**36.89175**	**987.7883**	**0**	**0**	**0**
Aman paddy						
B. Aman local	494.05	0	0	494.05	0	0
T. Aman						
Local	1879.86	187.986	0	0	845.937	845.937
HYV	2906.01	581.202	0	0	1162.404	1162.404
Sub-total	**4785.87**	**769.188**	**0**	**0**	**2008.341**	**2008.341**
Total	**5279.92**	**769.188**	**0**	**494.05**	**2008.341**	**2008.341**
Boro paddy						
Local	187.95	187.95	0	0	0	0
HYV	3875.84	3875.84	0	0	0	0
Sub-total	**4062.79**	**4062.79**	**0**	**0**	**0**	**0**
TOTAL	**10367.39**	4868.87	987.7883	494.05	2008.341	2008.341

Source: BBS: Yearbook of Agricultural Statistics of Bangladesh 2005

Table 3.18: Estimation of methane emission from paddy land in 2004-2005

Water management regime	(A) Harvested area ($m^2 \times 10^9$)	(B) Scaling factor	(C) Correction factor for organic matter	(D) Seasonally integrated emission factor	$E = A \times B \times C \times D$ CH_4 emission in Gg
Irrigated area	48.69	0.52	1	10	253.19
Upland Area	9.88	0	1	10	0
Flood-prone area	4.94	0.31	1	10	15.31
Drought-prone area	20.08	0.25	1	10	50.02
Rain fed	20.08	0.28			56.22
All	103.67				**374.93**

The emission of methane is somewhere between 375-380 Gg over the period 2000-05. There appears to be a slight tendency for the emission to fall. This may have happened due to the lowering of the purely flood-prone zone without any anthropogenic water management regime. This may also be partly the reason why the emissions have fallen since the mid-1990s, when the emissions from rice fields stood at about 660 Gg. The other reason may be the use of different scaling factors than before.

3.7.2 Methane Emission due to Enteric Fermentation

Ruminant animals such as cattle, buffaloes, sheep and goats produce methane in their digestive tracts by bacteria as a byproduct of the fermentation process. When this is released by the animals, this adds to the GHG load in the atmosphere.

Methodology for estimation of methane production and release

The amount of methane produced by an individual animal depends on the type, age, sex,, body weight and volume as well as the nature of the feed intake. The information available on animal number and age-sex ratios are available for 1983-1984, which has been projected to estimate the number for the later years (Fattah, 2009). Data on live weight of livestock was available from the Bangladesh Livestock Research Institute (Savar, personal communication, 2010).

In the absence of primary data on parameters for methane estimation due to enteric fermentation of livestock, the emission factor developed in an Indian research work (Singhal et al, 2005) has been used. We have derived methane emission factor for Bangladesh livestock based on body weight of our livestock compared with livestock body weight and emission factor of India. The equation that has been used is:

Methane (CH_4) emission = CH_4/head/year (kg) × animal population (million)
= CH_4 million kg = CH_4 Gg

The estimated emissions are shown for two years, 2000-01 and 2004-05, in Tables 3.19 and 3.20.

Table 3.19: Methane emissions from different categories of livestock (2000-2001)

Livestock category	Population (in million)	Body weight (Bangladesh) kg	Body weight (Indian) kg	CH_4/head / year (kg) India	CH_4/head/Year (kg) Bangladesh (Derived)	Total CH_4 emission (Gg)
Cattle (Male)						
< 1 year	1.5404	68	79	7.6	6.54	10.0742
1-3 years	1.5815	133	174	16.36	12.50	19.7687
Others	8.0080	220	301	24.37	17.81	142.6225
Total (male)	11.1299					172.4654
Cattle (female)						
< 1 year	2.1990	63	82	7.39	5.67	12.4683
1-3 years	1.8185	123	179	15.39	10.57	19.2215
Milking cows	3.4714	205	326	35.97	22.62	78.5231
Cows dry	2.7271	210	326	29.38	18.93	51.6240
Others	1.0437	220	265	24.10	20.00	20.8740
Total (female)	11.2597					182.7109
Total cattle	22.3896					355.1763
Buffalo (male)						
< 1 year	0.03331	80	75	5.09	5.43	0.1808
1-3 years	0.04778	160	180	14.78	13.14	0.6278
>3 years	0.54857	300	475	60.61	38.28	20.9993
Total (male)	0.62966					21.8079
Buffalo (female)						
< 1 year	0.04218	90	90	6.06	6.06	0.2556
1-3 years	0.03858	175	197	17.35	15.41	0.5945
Milking buffalo	0.07003	400	458	76.65	66.94	4.6878
Buffalo dry	0.10127	400	458	56.28	49.15	4.9774
Others	0.03826	345	345	38.99	38.99	1.4917
Total (female)	0.29032					12.007
Total buffaloes	0.91998					33.8149
Goats	16.27	20	19	4.28	4.50	73.2150
Sheep	2.11	20	28	3.69	2.64	5.5704
Grand Total	**41.68958**					**467.77**

Table 3.20: Methane emissions from different categories of livestock (2004-2005)

Livestock category	Population (in million)	Body weight (Bangladesh) kg	Body weight (Indian) kg	CH_4/head/ year (kg) India	CH_4/head/ Year (kg) Bangladesh (Derived)	Total CH_4 emission (Gg)
Cattle (Male)						
< 1 year	1.559664	68	79	7.6	6.54	10.2002
1-3 years	1.601361	133	174	16.36	12.50	20.0170
Others	8.108230	220	301	24.37	17.81	144.4075
Total (male)	11.269255					174.6247
Cattle (female)						
< 1 year	2.226486	63	82	7.39	5.67	12.6241
1-3 years	1.841219	123	179	15.39	10.57	19.4617
Milking cows	3.514848	205	326	35.97	22.62	79.5058
Cows dry	2.761260	210	326	29.38	18.93	52.2706
Others	1.056849	220	265	24.10	20.00	21.1369
Total (female)	11.400662					184.9991
Total cattle	22.669917					359.6238
Buffalo (male)						
< 1 year	0.040187	80	75	5.09	5.43	0.2182
1-3 years	0.057659	160	180	14.78	13.14	0.7576
>3 years	0.661863	300	475	60.61	38.28	25.3361
Total (male)	0.759709					26.3119
Buffalo (female)						
< 1 year	0.050901	90	90	6.06	6.06	0.3084
1-3 years	0.046557	175	197	17.35	15.41	0.7174
Milking buffalo	0.084497	400	458	76.65	66.94	5.6562
Buffalo dry	0.122190	400	458	56.28	49.15	6.0056
Others	0.046169	345	345	38.99	38.99	1.8001
Total (female)	0.350314					14.4877
Total buffaloes	1.110023					40.7996
Goats	19.16	20	19	4.28	4.50	86.22
Sheep	2.47	20	28	3.69	2.64	6.5208
Grand Total	**45.40994**					**493.16**

On the whole, the emission levels have been around 465-470 Gg in 2000-2001 and more than 490 Gg in 2004-2005. The source of increased emissions appears to be the increased number of goats, as the number of cattle appears to have remained largely static.

3.7.3 Methane (CH_4) and Nitrous Oxide (N_2O) Emissions Due to Manure Management

Methane produced from manure management

There is little reliable national data on management of manure due to cattle/buffalo and other livestock droppings. Several types of information are necessary: first, the number of livestock by type, age and sex; second, the average quantity of droppings per day; third, the distribution of the manure by type of use, particularly how much of it is kept in anaerobic condition by season, and for how long; fourth, the average production of biogas due to keeping the manure in anaerobic condition and related other information on formation of methane. Some of this information is Bangladesh-specific, while other information is taken from IPCC's default values.

The information on livestock, particularly large ruminants, is available and has been used for estimating enteric fermentation. It can be assumed that only cattle and buffalo manure are partly kept in anaerobic condition in farm households. Poultry droppings are also kept in such conditions in some poultry farms. We use the related information on cattle and poultry. The next issue that needs to be resolved is the amount of droppings by livestock. Hossain (2003) reports that the average dung yield of cattle is 10 kg/head/day. Note, however, that if we take this figure to be for adult cattle, this dung rate should not be used for all types of cattle. Fortunately, for calculating enteric fermentation we have already estimated body weights of cattle and buffaloes. Taking the average yield of 10 kg/day/head for the cattle above 3 years, the rate of droppings has been calculated for all others in proportion to estimated body weights compared to adult cattle. The rate of droppings for buffaloes has also been estimated in the same manner. These rates – applied to the number of livestock by type, age and sex, as well as whether lactating or dry in case of adult female cattle and buffaloes – give us the total manure output. However, not all of this can be used to estimate methane emissions.

Limited available information indicates that only 61 percent of cattle dung is used as manure. Such droppings need to be decomposed before application in the crop field in pits that are usually 4-6 feet deep. These pits create anaerobic conditions to produce biogas, which is estimated to be 0.037 m^3 per kg of dung. Of this biogas, 60 percent is estimated to be methane. According to IPCC guidelines, one needs to correct this value by multiplying by a correction factor related to the depth of the pit. For those pits shallower than 5 metres, full decomposition may not take place and a correction factor of 0.4 should be used. Once the volume of methane in cubic metres is thus estimated, it is converted into weight by multiplying by 0.67. Thus, the estimate of methane is given by:

Manure quantity by weight x fraction kept in pit x biogas production (m^3 /kg) x CH_4 fraction in biogas x CH_4 correction factor x conversion factor

Apart from manure quantity, the parameters for the equation are respectively 0.6, 0.037, 0.6, 0.4 and 0.67.

For poultry, the rate of droppings per day is 0.1 kg/bird; biogas capacity is 0.07 m^3/kg, methane fraction in biogas is 0.6, and methane correction factor is 0.45.

Based on these values, and the number of cattle and buffalo by type, age, sex and lactation status, the methane emissions estimated for 2000-2001 and 2004-2005 from manure management are shown in Table 3.21. for cattle and Table 3.22 for poultry. There appears to be a slight rise in the methane emissions for large ruminants between 2000-2001 and 2004-2005. Methane emissions from poultry appear to be about a third of that from cattle and buffaloes.

Table 3.21: CH_4emissions from manure management

Livestock category	Dung mn kg		Fraction of dung dumped in pit	Bio-gas producing capacity m^3/kg	CH_4 fraction in bio-gas	CH_4 correction factor	Conversion factor kg/m^3	CH_4 emission Gg	
	2000-01	2004-05						2000-01	2004-05
Cattle	65530	66350	0.6	0.037	0.6	0.4	0.67	233.92	236.85
Buffalo	4423	5337	0.6	0.037	0.6	0.4	0.67	17.98	21.69
Total								**251.90**	**258.54**

Table 3.22: CH_4 emissions from poultry litter management (2004-05)

Population mn	Litter kg/head/year	Litter in pit	Bio-gas producing capacity m^3/kg	CH_4 fraction in bio-gas	CH_4 correction factor	Conversion factor kg/m^3	CH_4 emission kg	CH_4 emission Gg
183,450,000	36.50	0.60	0.07	0.60	0.450	0.67	84,790,498	84.79

Nitrous oxide (N_2O) emission from manure management

Nitrous oxide is produced as part of the nitrogen cycle through the nitrification and de-nitrification of the organic nitrogen in livestock manure and urine. The population of different categories of livestock is given in several tables earlier. Correction factors for cattle and buffalo are taken as 0.6 as used in CH_4 emission in manure management. Correction factors of goats, sheep and poultry were assumed high (close to 1) based on expert judgment.

Nitrous oxide emissions due to manure management of domestic livestock were thus calculated by using the formula:

N_2O emissions = $N_A \times E_F$;

***w**here*

N_A = Number of domestic animals

E_F = Emission factors

Although IPCC guidelines call for identifying the lactation status of cattle and buffalo, no such distinction is made here and the estimates use an average value of 50 kg N/animal/yr based on expert judgment for both cattle and buffalo.

Table 3.23: N_2O emissions from manure and poultry litter management

Livestock category	Number of animals (mn)		Nitrogen excretion (kg N/animal/yr)	Solid storage & dry lot fraction	Correction factor	Conversión factor, N_2O-N to N_2O (44/28)	CH4 emission (Gg)	
	2000-01	2004-05					2000-01	2004-05
Cattle	22.39	22.67	50	0.020	0.6	1.57	21.09	21.36
Buffalo	0.92	1.,10	50	0.020	0.6	1.57	0.87	1.05
Goats	16.27	19.16	12	0.020	1	1.57	6.13	7.22
Sheep	2.1	2.47	12	0.020	1	1.57	0.80	0.93
Poultry		183.45	0.6	0.020	0.95	1.57	-	3.28
Total							**28.88**	**33.83**

3.7.4 Nitrous Oxide (N_2O) Emissions Due to Nitrogenous Fertilizer Application

Emission of N_2O due to the application of nitrogenous fertilizer is given in the following equation:

N_2O – N emission (tons N_2O-N) = F × E
Where F = Nitrogenous fertilizer consumption (in tons of N)
E = Emission factor (tons N_2O-N released /tonne nitrogen applied

Estimated results are given in Table 3.24.

The table uses only urea consumption because it is the main nitrogenous fertilizer. Consumption of other nitrogenous fertilizer such as ammonium sulphate or di-ammonium phosphate or mixed fertilizer is rather small,

Table 3.24: Nitrous oxide emissions due to urea consumption

Item		**2001**	**2005**
Urea consumption (mt)	=	2121096	2523395
Applied N equivalent (mt)	=	975704.16	1160761.7
Emission factor (mt N_2O-N/mt N)	=	0.0125	0.0125
N_2ON emission (mt)	=	12196.3	14509.5
N_2O-N emission (Gg)	=	**12.20**	**14.51**
N_2O emission (Gg)	**=**	**19.17**	**22.80**

Source: Urea consumption figures are from *BBS: Yearbook of Agriculture Statistics of Bangladesh*

3.7.5 Emission of GHGs Due to Field Burning of Agricultural Residue

<u>Introduction</u>

Field burning of agricultural residues, which is a common practice in many countries releases, various GHGs such as carbon dioxide, methane, carbon monoxide, nitrous oxide and various nitrogen oxides. It is assumed that CO_2 released into the atmosphere is reabsorbed through regeneration. Therefore, although the amount of carbon dioxide emission has been estimated and reported here, we net it out while showing CO_2-equivalent emission. CH_4, N_2O, CO and NO_X have been taken into consideration excluding CO_2.

Method of estimation

In Bangladesh, field burning of crop residues is not widely practiced because these are used as fuel at home or also as mulch or cattle feed. Estimating the quantity of crop residues left in the field and subsequently burnt is a major issue. The method used to estimate may be shown as:

$R = P \times N \times D \times B \times F$

Here,

R = Total mass of crop residue burnt in the field
P = Crop production
N = Crop-specific residue-to- production ratio
D = Dry matter fraction
B = Fraction of dry matter residue that is burnt in the field
F = The crop specific burning efficiency (fraction)

GHG emission = R × EF

Here,

R = Total mass of crop residue burnt in the field
EF = Emission factor for particular GHG

The crop-specific residue and related parameters are shown in Table 3.25. These reflect, among other factors, that the proportion of residue left for burning on the field is comparatively small. The emission factors that are applied are from IPCC 2006 Revised Guidelines, Table 2.5. The amount of residues burnt is shown in Table 3.26. Note that of the total weight of the estimated crop residues burnt in the field, nearly 90 percent is due to paddy. Because paddy straw has many alternative uses, it is likely that much of it will be taken home rather than be burnt in the field. In that sense the proportion left to burn, 10 percent of dry matter, seems high. A possible alternative is to use a value of 5 percent. In any case, applying these onto the emission factors give the GHGs released; these are shown in Table 3.27.

Table 3.25: Crop-specific residue parameters used for GHG estimates from field burning

Crop	N	D	B	F
Paddy	1.76	0.85	0.10	0.89
Wheat	1.75	0.83	0.05	0.86
Maize	1.00	0.40	0.10	0.92
Minor cereals	1.75	0.85	0.10	0.89
Potato	0.20	0.71	0.05	0.68
Pulses	0.60	0.85	0.02	0.82
Oilseeds	0.60	0.85	0.02	0.82
Sugarcane	0.30	0.71	0.05	0.68

Source: Streets, D.G, *et al,Biomass burning in Asia: annual and seasonal estimates and atmospheric emissions,* revised manuscript, 23 May2003

Table 3.26: Total crop residues burnt in the field (mt)

Crops Name	2001	2005
Paddy	1,428.13	1,439.30
Wheat	100.23	45.93
Maize	2.37	19.19
Minor cereals	4.84	2.54
Potato	1.44	20.09
Pulses	2.86	2.34
Oilseeds	3.14	5.51
Sugarcane	47.09	46.64
Total	**1,590.17**	**1,581.54**

Table 3.27: GHG emissions from crop residue burning in Field(Gg)

Year	NOx	CO_2	CO	CH_4	N_2O
Estimated physical quantities (Gg)					
2001	3.98	2,409.11	146.30	4.29	0.11
2005	3.95	2,396.04	145.50	4.27	0.11
GWP (Gg) values of emission					
2001	35.42		277.97	90.09	32.78
2005	35.16		276.45	89.67	32.78

Based on the GWP values, CO_2 equivalent emissions for the above fournon-CO_2 gases were around 435-440 Gg in 2001 and 2005 respectively. These were, of course, much lower than the emissions elsewhere in agriculture, as discussed in the next section.

3.7.6 Aggregate GHG Emissions from Agriculture

The total emissions of CH_4 and N_2O from agriculture are shown in Table 3.28. It is seen that$CH_4$is the main GHG. On the other hand, several sources are almost equally important in methane release, although it must be said that there are many uncertainties in these estimates, particularly in emissions from manure management and field burning of agricultural residues.

Table 3.28: Methane and N_2O emissions in agriculture sector

Year	Rice Cultivation CH_4 (Gg)	Enteric Fermentation, CH_4 (Gg)	Manure & Poultry Litter Management (Gg)		Field Burning (Gg)		Total CH_4& N_2O Emission (Gg)	
			CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
2000-01	388.75	467.77	251.90*	28.88	4.29	0.11	1112.71	28.99
2004-05	374.93	493.16	343.33	33.83	4.27	0.11	1215.69	33.94

* Does not include GHG from poultry litter

3.8 Emissions from Land Use Change and Forest (LUCF)

3.8.1 Activities for Calculation of CO_2 from LUCF

The estimation of emissions from LULUCF focus upon four sub-sectors that are sources or sinks of carbon dioxide. These are:

a. Change in forest and other woody biomass stocks
b. Forest and grassland conversion
c. Abandonment of managed lands
d. Change in soil carbon

These GHG release and sinks have been estimated under each in turn. The details of the data and their characteristics are given in other companion reports but briefly discussed here as required.

3.8.2 Change in Forest and Other Woody Biomass Stocks

The base data on forest products of Bangladesh reported from 2003-2004 to 2007-2008 were collected from the Department of Forests' website (www.bforest.gov.bd). For the year 2001, harvesting data was collected from the head quarter of the Department of Forests. Carbon uptake and release were calculated using the IPCC method.

The IPCC method involves finding first the rate of annual change in forest and other woody biomass stock, initially by examining change in area of forest and consequent change in biomass and carbon release or uptake, and secondly reconciling that with commercial and unorganized logging and consequent release or uptake, taking care not to make a double counting. This exercise resulted in the following:

In 2000-2001, net release of carbon dioxide of 5,884.67 Gg
In 2004-2005, net uptake of carbon dioxide of 4,328.78 Gg

3.8.3 Forest and Grassland Conversion

Following the IPCC method, Worksheet 5-2 on Forest and Grassland Conversion was built up based on information on change in forest land, from which areas of forest clearing were selected. Such changes led to several others that cause GHG emissions. Part of the clearing is often done by burning biomass on-site, which releases CO_2. Add to this the part of biomass that is burnt off-site. Then again, some biomass is left to decay over a number of years, giving rise to the release of carbon dioxide.

Fractions of on-site and off-site burning were respectively chosen to be 0.1 and 0.9, based on expert judgment. Total carbon released from on-site and off-site burning was 1,279.79 Gg, equivalent to 1,279.79 x (44/12) = 4,692.56 Gg of CO_2.

CO_2 released by decay of the above-ground biomass was estimated assuming that 5 percent of the biomass cleared was left to decay. The estimated, average annual carbon release was 70.73 Gg, equivalent to $70.73/12 \times 44 = 259.34$ Gg of CO_2. Adding up CO_2 release from biomass decay to that from forest clearing, annual average CO_2 release was 4,951.91 Gg over the period 1996-2004.

3.8.4 Abandonment of Managed Lands

This category includes conversion of managed to abandoned lands. The categories are determined by the type of biomass that re-grows on the abandoned land. Pastures, plantation forests, or other managed lands which re-grow into their prior natural grassland or forest conditions are placed in this category. Due to population pressure and land scarcity, abandoned lands are rarely found in Bangladesh. Only in tea-growing areas are some plots found abandoned.

Estimation

Data were collected from statistics of the Bangladesh Tea Industry. Following IPCC 1996 Guidelines, carbon uptake was calculated. Area abandoned in 2001 was only 37.21 ha and in 2005 was 50.15 ha. The overall annualized area abandoned per year was 0.515 ha. To estimate the carbon uptake, the area was multiplied first by annual growth of aboveground biomass growth (taken to be 11 tons/dm) and then by carbon fraction of aboveground biomass (taken to be the IPCC default value of 0.5 tons). The multiplication resulted in a carbon uptake per year of 2.8325 tons. Converted into carbon dioxide, this was 0.01 Gg.

3.8.5 Soil Carbon

Estimation

The basic data for calculating soil carbon were collected from two sources. One source is the Reconnaissance Soil Survey under the Soil Survey Project of Pakistan, carried out from 1965 to 1975, before Bangladesh gained independence. Another is the Soil Series of Thana, surveyed by SRDI from 1990 to 2000. The Reconnaissance Soil Survey reports the percentage of soil carbon in different locations of districts. In soil series, the percentage of organic matter is given for different *upazilas*. For estimation, the mean value of carbon is taken for each district. In 2000 soil carbon data were not available. To estimate this, we used the relation

Soil carbon = soil organic matter / 1.72.

One ha of forest land was taken to contain 4,200 tons of soils, considering 30 cm depth (soil bulk density is taken to be 1.4 gm). The quantity of carbon is measured by multiplying the area by percentage of carbon for each district.

Following IPCC 1996 Guidelines, the level of soil carbon for each district in 1970 and 2000has been estimated and annualized the net change, which came to 2,399.7 Gg in aggregate for the total given area of the 30 districts for which basic data were available. Assuming that carbon emissions are approximately proportional to the area, the estimate is scaled up by the proportion of the country area to the area of the 30 districts data for which data are available. This translates into 4,795.2 Gg of carbon or 17,582.4 Gg of carbon dioxide for the entire country on an annual basis.

3.8.6 Summary of Total Carbon Dioxide Emissions Due to LULUCF

Table 3.29 shows the summary of results for the years 2000-2001 and 2004-2005. It is seen from the table that there is a decreasing trend in carbon dioxide emissions in the LUCF sector. As noted above, this may be attributed to the increase in social forestry as evidenced from the value in the 2nd column against 2004-2005.

Table 3.29: Carbon dioxide emissions (Gg) due to LULUCF

Year	Forest and other woody biomass	Forest and grassland conversion	Abandonment of managed lands	Soil carbon	Total carbon emission
2000-2001	5884.67	4951.91	+0.01	17582	28418.97
2004-2005	-4328.78	4951.91	+0.01	17582	18205.52

Note: “-”denotes uptake and “+” denotes emission

3.9 GHG Emissions from Solid Wastes and Waste Water Management

Issues

Solid waste (SW) and waste water, unless managed properly, may give rise to emission, particularly of methane. To estimate methane emission we need to know the quantity of waste generated, the management of the waste, the proportion of carbon that may be transformed into methane etc. In case, the garbage is incinerated, one needs to know the oxidation factor which would be zero if no incineration is done.

3.9.1 Estimation of Methane from Solid Waste Land Fills

Information available on waste generation pertains mainly to the main cities and specific industries. Given this, it may be noted that the average total solid waste generation varies from 4576 tons to 5903 tons per day over the period 2001 – 2005. On the other hand, the waste management is generally by landfills while much of it is scattered and do not give rise to GHG emission in that condition.

To calculate methane emission the following expression is used:

Methane = (A x B x C x D x E x F x G – R)(1-OX)

where,
A=Total SW generated (Gg)
B=Fraction of SW disposed at landfill sites (Gg)
C=Methane correction factor
D=Fraction of degradable organic carbon (DOC) in MSW
E=Fraction of degradable organic carbon (DOC) which actually degrades
F=Fraction of carbon (C) as methane
G=Conversion factor from carbon (C) to methane (CH_4)
R=Recovered methane (Gg/year - 0 in the present case)
OX=Oxidation factor (0 in the present case)

Methane generation has been calculated individually for six cities as the fraction of SW disposed at landfill sites are different for the six city corporations. According to the Conservancy Department, most of the landfill sites are unmanaged and less than five meters deep. The methane correction factor has been taken as 0.4 based on IPCC guidelines. The fraction of Degradable Organic Carbon (DOC) in SW is assumed as 0.15 (based on IPCC Guidelines). Also, the fraction of Degradable Organic Carbon (DOC) in MSW which actually degrades is 75% which value is close to that in other South Asian Countries. Fraction of Carbon (C) as methane has been considered 0.55 based on IPCC value (0.50-0.60). In Bangladesh, the recovered methane is zero. As there is no burning in any landfill site, oxidation factor is zero.

Based on these parameters and assumptions, the net annual methane emissions are:

For 2001 – 24.56 Gg; and for 2005 – 29.44 Gg.

The above estimates use IPCC default values. However, using Bangladesh-specific parameters based on landfill-related projects, for landfills in Bangladesh, methane emission factor is 0.0185. Given the SW generated and the fraction that is used for land filling, this results in a much lower value of methane release which are

For 2001: 13.76 Gg; and for 2005: 16.50 Gg

which means that it is roughly one-half of the estimates based on IPCC default values.

3.9.2 GHG Emission from Domestic and Industrial Waste Water

Domestic and industrial waste water often contains biodegradable organic matter and leads to release of methane and nitrous oxide. The release of methane depends on the organic content of water and the emission factor. In case of nitrous oxide, the presence of protein in waste water (for domestic it comes from human protein consumption) is the important factor. Much of the uncertainty is due to the quality and extent of necessary data that may be available. Given these factors, the results of the exercise are given below in Table 3.30.

Table 3.30: Emission from Waste Management

Year	Methane from SW (Gg)	Methane from domestic waste water (Gg)	Methane from selected industries (Gg)	N2O from waste water (Gg)
2001	13.76	544.67	0.87	3.85
2005	16.50	621.08	0.92	4.44

3.10 Projection of Greenhouse Gases

3.10.1 Introduction

In Energy Sector, GHG emissions from 2005 to 2030 were estimated using LEAP Model based on the IPCC Tier-1 emission factors under a baseline scenario. Emissions for industry, agriculture, LUCF and waste were estimated from 2005 to 2030 on the basis of previous trends. Based on total emissions of all sectors, yearly growth was 2.96%. The yearly growth in different sectors is shown in Table 3.31. It is seen that yearly growth rate was the highest in the energy sector (6.39%) and lowest in the industry sector (0.27%).

Table 3.31: Growth rate of emission from sectors(2001-05)

Sector	Yearly change (%)
Energy	6.39
Industry	0.27
Agriculture	3.29
LUCF	-1.38
Waste	3.52

3.10.2 Projection of Energy and Emission

Projection of Greenhouse Gas (GHG) emissions for Bangladesh has been performed for the period 2005 to 2030 using the LEAP modeling program. GHG emissions are projected based on the expected volumes of activity in the relevant sectors of the economy and the basic macroeconomic development scenario. GHG emissions are assessed based on the IPCC Tier 1 emission factors.

Fig. 3.11 shows the projection of energy in the different demand sectors (household, industry, commercial, transport, agriculture and public). A threefold increase in energy requirement is projected in the 25 years of the planning period. The corresponding emissions of GHGs from all energy related activities are shown in Fig. 3.12.

In the year 2005, the energy requirement by the demand sectors was 532 PJ, while the projected demand will be 1,692 PJ in 2030. As can be seen from Fig. 3.11 the industry sector had consumed 57% of the total energy in 2005 which will increase to 62 percent or thereabout by 2030.

Figure 3.12 indicates that as expected the industry and transport sector are the major emitters of CO_2 emissions amongst the demand sectors. It is interesting to note that the Household and Transport sectors are roughly equal in 2005, but in 2030 the Transport sector has more than doubled its share.

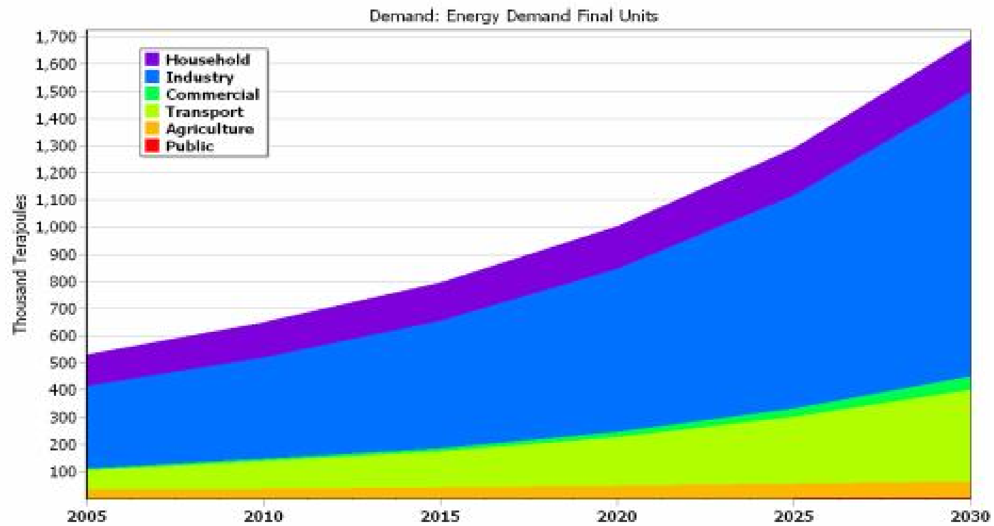


Fig. 3.11: Energy Use Projection of the Demand Sectors (2005 to 2030)

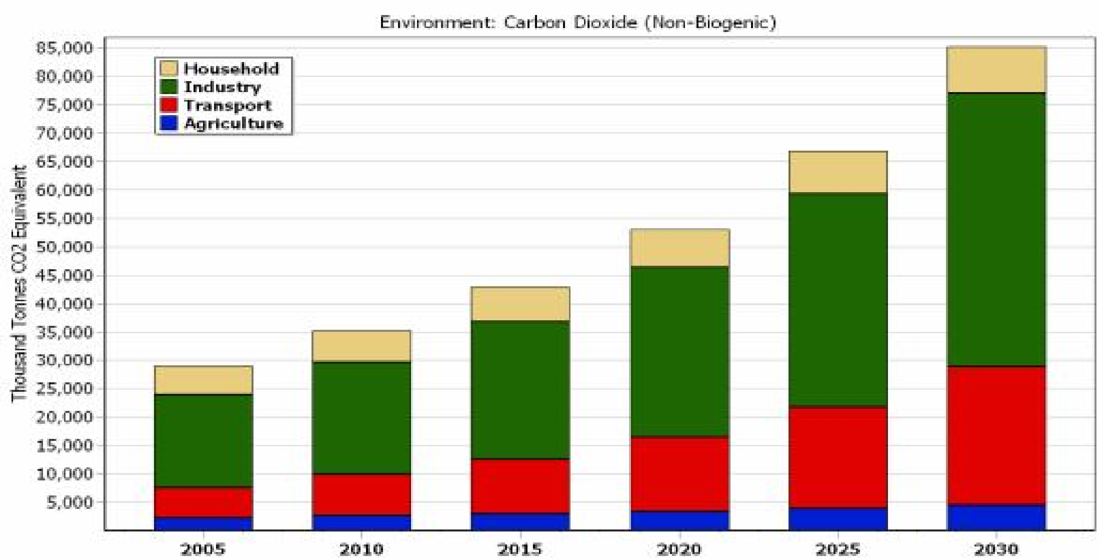


Fig. 3.12: CO_2 Emissions from Various Demand Sectors

Textile and leather, fertilizer and brick kilns are the major sources of CO_2 emissions from the industrial sector. In case of emission from transports, the share of road transport within the sub-sector increases from 88% in 2005 to 94% in 2030. CO_2 Emissions from energy transformation is mainly due to generation of power accounting for more than 95% of the emissions from this sector.

Steam Turbine (ST) power plants which dominate the 2005 generation capacity is fully retired by 2030 and replaced instead by CCGTs. This shift is expected to keep emissions down, and is a very good example of autonomous efficiency improvement. On the other hand, emissions from coal fired power plants increases dramatically over time consistent with government's future energy plans of constructing at least 10000 MW of coal fired power plants by 2030. The type of power plant chosen for this will determine in reality the level of emission as this will affect the energy efficiency and consequently the emission.

Other GHG (CH_4 and N_2O) emissions

Between 2005 and 2030, methane emission in terms of CO_2 equivalent rises from nearly 120 thousand mt to over 380 th mt. For nitrous oxide the CO_2 equivalent rises from nearly 100 th mt to just about 400 th mt. For methane the major sources by 2030 are transport and industry while for nitrous oxide it is electricity generation and industry.

Total GHG Emissions

Projection of aggregate GHG (CO_2, CH_4 and N_2O combined) emissions is presented in Fig. 3.13. In 2005, the total GHG emissions were 41,720 kton of CO_2 equivalent. This increases to 145,308 kton of CO_2 equivalent in year 2030 indicating an approximately 3.5 times increase over 2005 emissions. The contributions of the different sectors along with the total emissions are summarized in Table 3.32. In 2030, electricity generation and industry are the two main GHG emitters; both these sectors have recorded a 5 times increase.

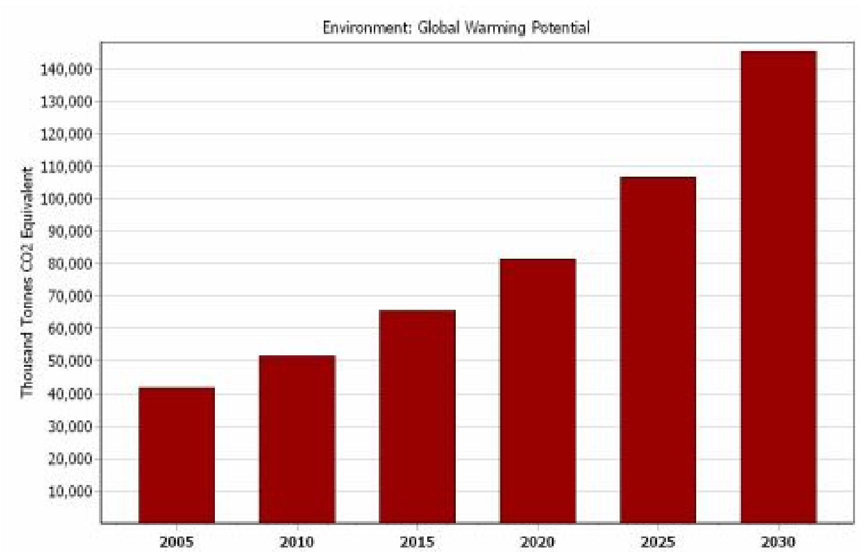


Fig. 3.13Total GHG emissions projection from energy activities (2005-2030)

Table 3.32: Summary of GHG Emissions Projection from Energy Activities

(Th mt CO_2 equivalent)

Sector	2005	2010	2015	2020	2025	2030
Agriculture	2293	2608	2977	3407	3911	4500
Household	5034	5558	6137	6775	7481	8259
Industry	16553	19929	24320	30108	37847	48341
Transport	5296	7325	9658	13105	17920	24577
Electricity Generation	11923	15619	22040	27520	38866	59168
Natural Gas Processing	514	557	639	734	919	1215
Oil Refining	107	36	48	64	86	115
Total	41720	51634	65819	81715	107028	146175

Table 3.33: Bangladesh Summary of GHG emissions year 2005

Greenhouse gas source and sink categories	CO_2 emissions (Gg)	CO_2 removals (Gg)	CH_4 emission (Gg)	N_2O emission (Gg)	CO emission (Gg)	NO_X emission (Gg)
Total national emission and removals	**59067.85**		**1879.30**	**38.85**	**145.50**	**4.00**
1. Energy	**37949.60**		**26.03**	**0.48**		
A. Fuel combustion (sectoral approach)			2.76	0.48		
1. Energy Industries	12780.00					
2. Manufacturing industries and construction	11276.00					
3. Transport	5500.00					
4. Residential	4675.00					
5. Agriculture	1993.00					
6. Commercial	270.00					
7. Other	1426.00					
B. Fugitive emissions from fuels	29.64		23.27			
1. Solid fuels						
2. Oil and Natural gas						
2. Industrial processes	**2912.72**					
A. Mineral products	82.72					
B. Chemical industry	2830					
C. Metal production						
D. Other production						
E. Production of halocarbons and sulphur hexafluoride						
F. Consumption of halocarbons and sulphur hexafluoride						
G. Other (please specify)						
3. Solvent and other product use	NE					
4. Agriculture			**1215.69**	**33.94**	**145.50**	**3.98**
A. Enteric fermentation			493.16			
B. Manure management			343.33	33.83		
C. Rice cultivation			374.93			
D. Agricultural soils						
E. Prescribed burning of savannahs						
F. Field burning of agricultural residues			4.27	0.11	145.50	3.98
G. Other (please specify) Poultry litter management			84.79	33.83		

Greenhouse gas source and sink categories	CO_2 emissions (Gg)	CO_2 removals (Gg)	CH_4 emission (Gg)	N_2O emission (Gg)	CO emission (Gg)	NO_X emission (Gg)
5. Land-use change and forestry	18205.52	0.01	**0.00**	**0.00**	**0.00**	**0.00**
A. Changes in forest and other woody biomass stocks	-4328.78					
B. Forest and grassland conversion	4951.91					
C. Abandonment of managed lands		0.01				
D. CO_2 emissions from soil	17582.40					
E. Other (please specify)						
6. Waste			**637.58**	**4.43**	**0.00**	**0.00**
A. Solid waste disposal on land			16.50			
B. Waste-water handling			621.08	4.43		
C. Waste incineration						
D. Other (please specify)						
7. Other (please specify)						
Memo items						
International bunkers*	**906.00**					
Aviation						
Marine						
CO_2 emissions from biomass	44010.00					

*In accordance with the guidelines set out by the IPCC, CO_2 emissions from International Bunkers and burning of biomass are not included in the national totals, but are reported separately as Memo Items in the Inventory.

The population of Bangladesh in 2005 was 137 million and the per capita carbon emission in 2005 was 0.23 ton per year.

Chapter 4

Mitigation of GHG Emission in Bangladesh: Options and Challenges

4.1 Introduction

Bangladesh is a least developed country (LDC). According to the UNFCCC, the LDC's are not obligated to mitigate i.e., take actions against emission of GHGs an inventory of which has been provided in Chapter 3 above. Given the gravity of the problems that climate change poses, the Conference of Parties in its Decision 1/CP 13 in Bali calls upon all developing countries to prepare and implement Nationally Appropriate Mitigation Actions (NAMA) on a voluntary basis for mitigating climate change. While exactly what would constitute NAMA and how far these will be supported financially and technologically and how far these actions will be monitored, reported and verified (MRVd) still remain to be completely decided, the thrust is unmistakable. Every country is expected to do its own bit of emission reduction, some (the developing countries) voluntarily and some (the developed countries) on a mandatory basis. In this milieu, the National Communications that all countries are expected to prepare periodically assume quite some importance as this becomes a major vehicle of reporting on not only climate related activities in general but more specifically on mitigation actions. In fact, the issue has become more important because there is now the discussion going on, although it is still to be finalized, regarding biennial updating of the mitigation actions by countries.

Bangladesh's Second National Communication which also includes ideas, policies and actions on mitigation and challenges to them thus has become extremely critical as a stepping stone to future such reporting but more importantly for real action on the ground. On the other hand, however, the Bali decision of COP 13 also upheld the right of developing countries to sustainable development. In its subsequent submission on the Bali Action Plan, Bangladesh defined its operational ideas about sustainable development which has become the cornerstone of Bangladesh's climate change related policies. This was also finally enshrined in the Bangladesh Climate Change Strategy and Action Plan, 2009 as 4 inviolate principles of ensuring security of food, energy, water and livelihood including right to health. The mitigation activities that Bangladesh has taken up or wishes to take up must obey these four security concerns.

4.2 Objectives

Based upon the above, the main objective of this chapter is to suggest domestic and, wherever necessary, regional programmes containing measures to mitigate climate change.Within this over-all objective, this chapter tries

- To assess programmes and measures that will mitigate climate change and are consistent with government's climate change strategy
- To provide policy makers with an evaluation of technologies and practices that can mitigate climate change and also contribute to national development objectives;
- To identify potential project/programme investments
- To understand the costs of the identified mitigation options

The discussion is national as well as regional in scope wherever necessary and considers only the energy production and use.

As discussed in Chapter 3 on GHG Inventory, various non-energy processes give rise to emission of carbon di-oxide, methane, nitrous oxide and other such gases and should ideally be considered for mitigation actions. However, the reduction of emission from non-energy processes is fraught with many difficulties. At the present state of knowledge, availability of information and data for specific processes, motivating economic agents who may sometime number millions (as happens in case of agriculture) may be quite difficult, while such mitigation measures may sometime conflict with other core development objectives such as food security. In case of agriculture mitigation and adaptation may be intertwined and thus becomes quite complex as well as conflict with each other. Non-energy processes therefore needs to be examined much more carefully than is possible in the present exercise. Mitigation in case of non-energy processes thus may be an issue for the future.

4.3 Mitigation Options in Energy Production and Consumption

4.3.1 Principles of Mitigation in Energy Activities

Given that energy security is an overriding concern and that for Bangladesh sustainable development and growth including poverty eradication is a priority target, the principle of mitigation should be not lowering energy consumption *per se* but raising energy efficiency so that the same required energy service can be obtained at the lowest usage of energy, whether in primary or processed form. Secondly, it may also include substitution of one energy source with another provided it is more cost-effective but satisfies the same demand for energy services. An example may be substitution of petrol or octane in transport vehicles with compressed natural gas.

Similarly, mitigation may also entail technological change such that the new technology may use the same quantity of primary or secondary fuel to produce more of the energy services or goods and other services. The sum and substance of all these is that either the same level of energy use must give rise to more of goods and services or the same level of goods and services must be produced with a lower level of energy. Thus GHG emission mitigation measures include (i) energy conservation, (ii) energy efficiency, and (iii) increased reliance on renewable energy which emits no GHGs on a net basis and associated technological changes.

4.3.2 Sectors for Mitigation

For the purpose of the Second National Communication (SNC) the following GHG mitigation areas of activity have been considered:

- Power generation, transmission and distribution
- Transport – road, rail and water
- Energy intensive industries – public and private
- Agricultural sector – water pumping for irrigation
- Residential/commercial – natural gas for cooking; buildings
- Cross-sectoral options (boilers; hollow bricks; DSM)
- Renewables (solar PV, biomass and wind)

It should be noted that the in each case, we must read the mitigation prospects along with the GHG emission situation that obtains in the sectors and sub-sectors. And we should identify those where one can fairly easily make changes and yet lower emission substantially. The efficiency of energy use in these sectors and sub-sectors are examined. The measures/options in these sectors/areas are discussed first in general terms and then from the various possible options the most suitable ones for Bangladesh are selected and analyzed in more detail.

Following the descriptions of the options, which include the present situation, the GHG reduction and the cost effectiveness of each unit of that option are calculated. From an assumed penetration rate, the total GHG reduction potential from 2010 to 2030 by that option is estimated, which is the mitigation scenario. In the GHG Inventory Projection the baseline scenario up to 2030 has been presented. The mitigation scenario is compared to the baseline scenario to provide an indication of the total GHG reduction potential up to 2030.

4.3.3 Power Sector

The power sector as discussed in the Chapter 3 above is largely based on the use of natural gas (Fig. 4.1) while the technology in use indicates a mix of various levels of efficiency (Fig. 4.2). Despite the fact that Bangladesh generates 82% of its electricity using natural gas, less than one-quarter of that power are generated in plants with combined cycle gas turbines (CCGTs). In Bangladesh CCGT plants usually have a heat rate of around 2000 Kilocalories per kwh of electricity produced. Steam turbines in contrast need 3000-3500 Kcal per kwh. The higher the heat rate, less efficient is the plant, the more is the consumption of fuel (gas, coal or oil), and higher is the level of emission per kwh of electricity produced.

Natural gas reserves are, however, dwindling and are already in short supply. That means Bangladesh must move to other primary sources such as coal. In future, therefore the cheapest base load option open to Bangladesh is coal. The type of power plant technology that is employed will depend on how much financing is available at the time of approval of a given coal fired power plant. The most advanced coal power technology is the supercritical technology which is 25% more efficient than conventional technology. Going by past experiences, the cheapest option, i.e., subcritical boiler is likely to be chosen, however. On the other hand, supercritical plants may be part of a NAMA and may be financed under its funding mechanism.

Apart from generation, the transmission and distribution network is also inefficient due to ageing, and the technical system loss is increasing gradually. Thus, a substantial part of the electricity produced may simply be wasted. The haphazard growth of many urban areas has been such that many feeder lines are overloaded causing high transmission and distribution losses. Low voltage and other problems of power supply can cause the power delivered to users to be of low quality. In addition, the need for power factor corrections in industries is high. There is a scope to improve the quality of supplied power through the use of capacitor banks.

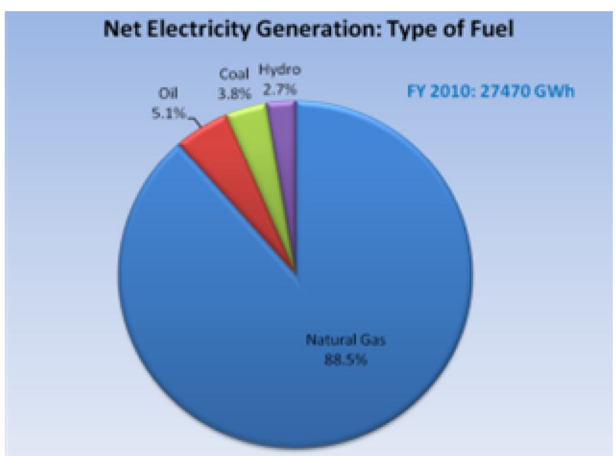


Fig. 4.1: Power Generation by Fuel (2009-10)

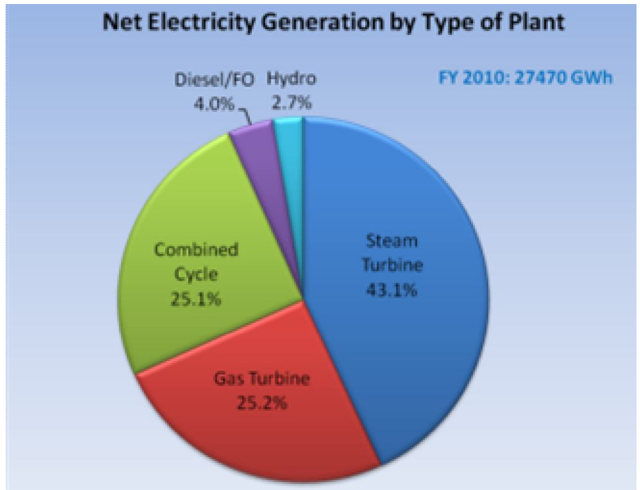


Fig. 4.2: Power Generation by Technology (2009-10)

The following power sector GHG mitigation measures may be identified in the public sector:

- CCGT to replace Steam Turbine (ST) plants
- Coal fired supercritical boilers instead of sub-critical boilers
- Rehabilitation of old power plants
- T&D upgrading and rehabilitation

On the other hand, the following power sector GHG mitigation measures can be encouraged in the private sector:

- Biomass gasification based electricity fed to the grid
- Waste based electricity fed to the grid
- Small generators to feed electricity to the grid and use the waste heat for boilers
- Wind and solar PV electricity fed to the grid

The private sector options are difficult type of mitigation projects, and are best pursued under some sort of carbon financing like CDM. In fact, several private investor groups are active in setting up of a biomass (rice husk) gasification plant of between 1 and 5 MW. The main constraint is that there are no feed-in tariffs for alternative fuel generation plants. Sugar cogeneration, which has the potential of adding up to 25 MW of renewable energy to the grid, cannot proceed because there is no guaranteed buy back at an incentivized tariff. The new renewable energy policy and the setting up of an authority to promote energy efficiency renewable energy are expected to give renewable electricity a boost in the future.

4.3.4 Transport Sector

The following measures/options in the transport sector are relevant for Bangladesh:

- Road – vehicle efficiency improvement, mass rapid transit and traffic management
- Railway – diesel to electricity; shift passenger and freight from road to railway
- Water – efficient engines; shift passenger and freight from road to water

Road Transport

In road transport, the following measures can be pursued:

- Traffic management to decrease congestion
- Urban planning to decrease traffic congestion and the need for mobility

- Decrease passenger travel distance by zoning
- Vehicle maintenance
- Drivers' training program
- Improvement of pedestrian walkway
- Improved mass Transit System

The worsening traffic congestion in the capital city Dhaka has forced the Government to seriously consider mass transit. All options including underground railway, elevated light rail and bus rapid transit (BRT) needs to be considered. Regarding bus transit, a pilot project has been undertaken in one corridor.

The problem in the urban centers of Bangladesh is aggravated by the presence of non-motorized transport (NMT). Even though from a GHG emission point of view one cannot advocate the removal of NMT, but the existence of mixed modes is causing severe congestion which also leads to higher emission without corresponding transport mileage as well as higher costs. The introduction of high quality BRT with good pedestrian walkway would shift substantial load from NMT thus increasing GHG emission, but the cumulative benefit of GHG reduction from three sources, namely (i) reduced idling time at traffic lights of motorized vehicles, (ii) shift of passengers from motorized three-wheelers and (iii) faster movement of motorized vehicle may more than offset the increased emission due to introduction of BRT.

Rail Transport

Less than 5% of the passengers and less than 10% of the freight is carried by Bangladesh Railway (BR). The present government has prioritized the expansion and modernization of railways and several projects are underway. Once implemented, it is likely to create economies in transport as well as economizing on energy use and lowering emission of GHGs.

Water transport

The main issues in mitigation related to water transport involves the efficiency of passenger kilometers carried by vessels. This depends critically on the energy efficiency of the vessel which has to do with the age of the motorized engines, technology as well as pricing of the fuels used.

4.3.5 Industry Sector

The following public sectors industries are prospective candidates for GHG mitigation because these are either energy intensive or exist in large numbers:

- Urea fertilizer plants
- Sugar Mills
- Paper Mills
- Cement (Chattak Cement Factory)
- Jute and Textile Mills

Most public sector industries are operating inefficiently mainly because of outdated technology. By simply building new plants the specific energy consumption can be lowered. In terms of GHG mitigation in the public industries the first two, Urea and Sugar, are the most prospective and have been chosen for further analysis.

Public Sector Industry: Fertilizer Plants and Sugar Mills

Bangladesh has seven urea fertilizer plants. The best performing plant is called KAFCO. Most of the Government owned plants are very old and performing poorly in terms of energy efficiency as well as inputs use efficiency. Compared to KAFCO, other Government owned plants are consuming 30% to 300% more natural gas to produce 1 ton of urea (Fig. 4.3). The GHG mitigation potential is obvious, but since the early nineties Bangladesh has not been able to secure investment funds for building new ammonia-urea plants so that old plants can be retired. The Natural Gas Fertilizer Factory (NGFF) plant consuming the maximum amount of natural gas to produce urea per unit was supposed to have been retired at least 10 years back, and a new one built in its place, but that hasn't materialized due to lack of funding.

There are 15 medium sized sugar mills owned by Bangladesh Sugar and Food Industries Corporation (BSFIC). Most of these mills are more than 40 years old, and use bagasse-fired very low pressure boilers to raise steam and generate electricity. Process improvements including more efficient cogeneration system to replace existing bagasse based electricity generation system can double the energy efficiency. State-of-the-art bagasse boilers worldwide are operating at 82 Bar, whereas most boilers under BSFIC are operating at 11 Bar. Each mill can export surplus electricity between 2-3 MW to the grid.

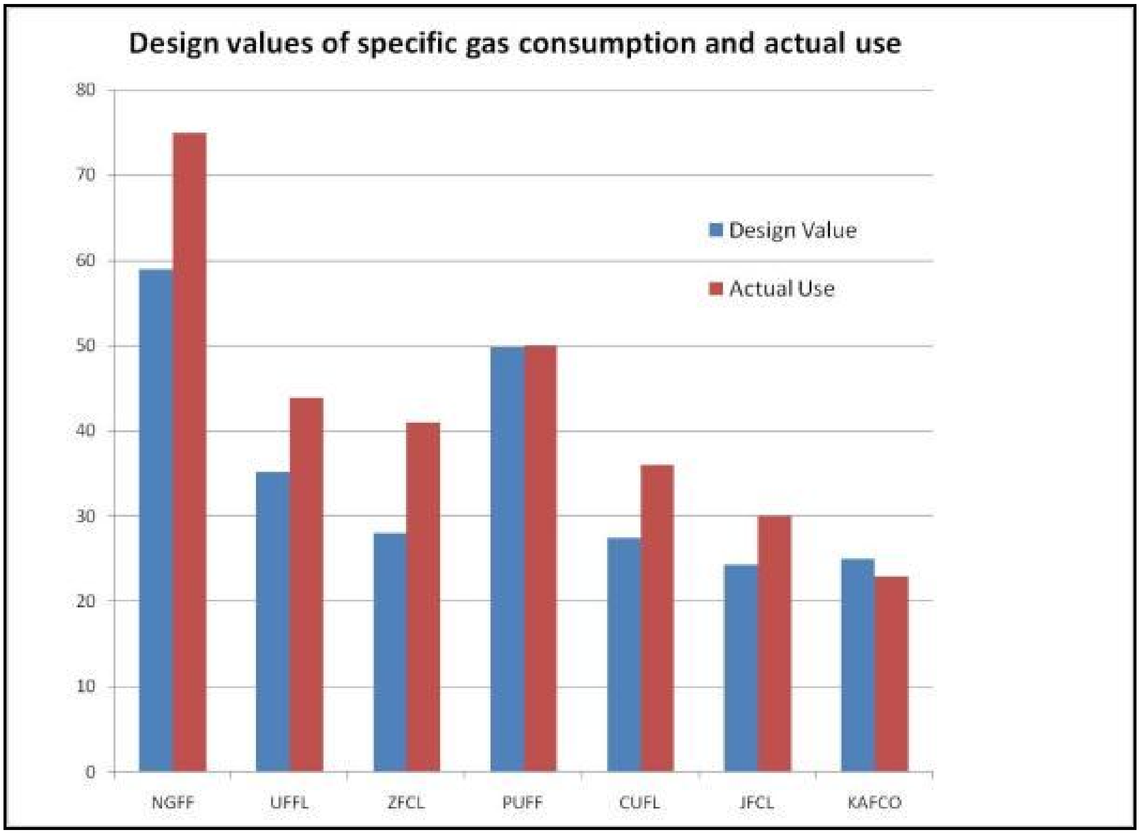


Fig. 4.3: Energy Consumption of Urea Plants in Bangladesh

Private sector industries

The following private sector industries are good candidates for GHG mitigation because these are energy intensive and exist in sufficient numbers to be significant energy consumers:

- Brick Kilns
- Steel Mills
- Glass and Ceramic Factories
- Clinker Grinding Plants

- Jute and Leather Mills
- Textile Dyeing
- Ice Plants and Refrigeration Plants (known as Cold Storages)

The first two are the most prospective candidates for GHG mitigation, and are discussed below in greater detail. The rest also have potential, but the interventions are more difficult to identify. A DSM type intervention, which considers motors, boilers, lighting and HVAC is likely to be more effective for these industries. For example, the main energy consuming item in Clinker Grinding Plant is the motor, which can be targeted for intervention. Some of these motors are in the MW range. Similarly, in Cold Storages either efficient chillers or combined heat and power (CHP) systems may be considered. In Glass and Ceramic factories efficient furnaces and advanced process control may be implemented.

Private Industry: Brick Kilns and Re-rolling Mills

Brick making is very energy intensive. Of the total industrial emissions, 15% is due to brick kilns. The steel recycling industry in Bangladesh is energy-inefficient. Most are crude operations. Energy component is more than 25% of product cost. In traditional operations both the steel melting electric furnaces and steel softening natural gas furnaces are inefficient.

4.3.6 Agriculture Sector

Irrigation is a big consumer of diesel and electricity. Eighty four of the irrigation pumps are run with diesel and rest with electricity. While there are issues of lowering energy consumption, it is an intricate issue. This is so because this is also an adaptation issue of water management fraught with problems of food security. So, what mitigation options to take depend on what adaptation measures have been taken. Given this one way of lowering emission is to use renewable energy from say solar panels for running the pumps. Through this option both diesel and electricity operated pumps can be displaced. Total power load for water pumping exceeds 1500 MW which gives the theoretical maximum that may be saved and consequent emission averted. Irrigation being a seasonal demand makes this, however, a costly option because the solar panels will only be used for 3-4 months of the year.

4.3.7 Residential/Commercial Sector

In Bangladesh context, the residential use of natural gas is more than 12% of the total and all of it is supplied without metering. There is strong anecdotal evidence of significant wastage in natural gas usage in the residential sector. The flat rate for domestic gas also implies that there is no incentive for conservation and for using efficient cook stoves.

Urban centers are growing rapidly in Bangladesh. The use of glass façades has now become standard for all commercial buildings. The cooling load for air-conditioners is significantly increased due to this practice. On the other hand, types of high strength bricks which is unnecessary for the present method of construction are still being used raising energy consumption and consequent emission of GHGs. Design of buildings and the type of materials for construction may therefore also be areas where mitigation interventions may be made.

4.3.8 Cross Sectoral Options

There are many mitigation options that have application in more than one sector. For example lighting devices, motors and air-conditioners can be improved in nearly all sectors. In addition, motors and boilers can be independently changed in various industrial processes. The following categories may be considered for mitigation:

- Boilers and Motors
- Cogeneration: waste heat boilers in industries and commercial installations
- Efficient Appliance (pumps, air-conditioners, lamps, fans, etc.)

Boilers and Motors

According to the Chief Inspector of Boilers (CIB) there are more than 5000 registered boilers in Bangladesh. Based on preliminary assessment, the CIB believes many boilers are operating in the 70% efficiency region. The most prospective size range for intervention in boiler efficiency improvement is the 1-5 mt/h because more than 50% of the boilers are in this size range.

Since more than 80% of the electricity in industries is consumed by motors, it is always worthwhile to consider mitigation options for motors. Consumption of electricity due to motors can be reduced by:

1. Intelligent Motor Controllers (IMC)
2. Variable speed drives or Cyclo-converters
3. Efficient motors

These are all standard measures, but because these increase the investment cost, entrepreneurs do not opt for these options. Efficiency improvement of motors is considered to be a difficult option in Bangladesh because all large motors are imported, and retrofitting motors have been found to be difficult. Moreover, at this time the government has no intervention planned.

Cogeneration in Private Industries

Bangladesh has more than 1200 MW of natural gas based captive generation (auto-generation) the average efficiency of which is around 30%. The existence of this large captive generation capacity presents an opportunity for setting up Combined Heat and Power (CHP) plants (or cogeneration plants). If cogeneration can be successfully promoted then the low efficiency of engine-based generators will not be an issue.

Efficient Appliances

Efficient appliances such as refrigerators, air-conditioners, fans, etc. are all universally applicable mitigation options. Since most appliances are imported into Bangladesh, it is very difficult at this stage to consider them as mitigation options. In the Bangladesh context, fans have been chosen because these are manufactured in the country, and there is a wide variation in power consumption for equivalent service.

There are literally millions of fans in the country. These are used in all sectors, but for the sake of intervention it is best to target establishments where there are a large number of fans in one place. Garments industry is one such establishment.

Efficient lighting is likely to be a major area of intervention for mitigation. The demand for electricity during the daily peak occurs during the evening is mostly for lighting and is estimated to be around 800 MW. There are already programmes for replacement of incandescent bulbs with CFLs to lower this demand.

4.3.9 Renewable Energy Technologies

Biomass

Biomass is still the main single source of energy in Bangladesh. The biomass options considered for the SNC are those that improve the efficiency of biomass use. Three such options are:

1. Parboiling efficiency improvement – up to 50% biomass can be saved
2. Improved cook stoves – efficiency can be doubled from present level

3. Biogas plants for cooking needs and small electricity generators – more than 1 million rural households can shift from biomass to biogas; more than 10,000 generators of 5-10 kW can be set up thus displacing approximately 75 MW of grid electricity and consequent lowering of emission.

The first two options have the potential to free up significant quantities of biomass, which can be used in biomass based electricity generation such as Biomass Gasification. Several efforts are underway in promoting and dissemination all three options, but considering the scale of biomass use, and the large GHG mitigation potential many more efforts can be undertaken.

In the SNC, *Parboiling Efficiency Improvement* and *Biogas for Cooking* have been considered. Some of the barriers associated particularly with Improved Cook stoves are:

1. Slow cooking – not liked by women
2. Benefits are not readily apparent to users
3. Higher initial cost and lack of after sales service

<u>Solar PV</u>

In the SNC, SHSs have not been considered because of the significant ongoing activities. More than a million SHSs have already been installed, and more than 10,000 units are being sold per month. On the other hand, Solar PV irrigation pumps, which have large potential, but are progressing slowly, have been selected.

Non-electrified households consume more than 350,000 tons of kerosene every year for lighting purposes. Those that can afford it are setting up SHSs in their homes. But, the vast majority cannot afford SHSs. Solar PV Lanterns, which is very high quality replacement of kerosene lamps can be a good option that also has the potential of mitigating GHG emission. A program over 20 years to disseminate 5 million solar PV lanterns each costing $50 has been considered in the SNC.

Government's approach towards mitigation

As part of the new generation expansion initiative in line with growing demand, Government has a plan to enhance national power generation capacity to16000 MW by 2015. Expected generation from renewable sources should be then at least 800 MW as envisioned in National Renewable Energy Policy (at least 5% from renewable sources). However, solar power has the most potential source among the renewable energy resources in Bangladesh. The Government has already undertaken a number of programmes in utilizing solar power. Around 1.5 million Solar Home Systems have been installed throughout the country generating 65 MW of electricity. The Government has envisioned achieving 500 MW solar power developments in Bangladesh with the support of bilateral and multilateral development partners. The programmes to be implemented are of following types:

- Installation of Solar Irrigation Pumps
- Roof top Solar Power Solution for Commercial and residential Buildings, Industries
- Solar Electrification at Railway Stations
- Solar Home Systems in Government and Semi-government Buildings, Remote Education Centres/Schools, Union Information Service Centres, Rural Health Centres, Religious Establishments, etc.
- Solar LED Street Lighting under City Corporations and Municipalities

An initiative to generate 100 MW from wind power in the off-shore area of *Anwara*, Chittagong has also been taken. It might be noted that Government has exempted income tax for next 5 years from commercial production from renewable energy.

On energy conservation, the Government took a project named Efficient Lighting Initiatives of Bangladesh (ELIB) to replace approximately 30 million household incandescent lamps (IL), with energy efficient CFLs. 10.5 million CFLs have been distributed to the consumers free of cost in 2010 reducing the demand of 260-270 MW electricity.

4.3.10 Mitigations Options Analyzed for the SNC

The mitigation options have been chosen after a evaluation of the following criteria (i) Government priority (ii) Potential of reduction (iii) Cost effectiveness (iv) Suitability of the technology to local conditions (v) Ease of implementation, and (vi) Data availability. These are:

Transport Sector

1. Modal shift from road to railway
2. Modal shift from road to waterway

Agriculture Sector

3. Solar PV irrigation pumps

Residential Sector

4. Metering residential gas supply
5. Improved gas cook stoves
6. Solar PV lanterns to replace kerosene lamps

Industry Sector (public and private)

7. New Urea fertilizer plants
8. Sugar mills (cogeneration plant efficiency improvement)
9. Steel re-rolling mills efficiency improvement
10. Brick making – Higher efficiency kilns
11. Industrial cogeneration for captive generators
12. Boiler efficiency improvement

Commercial Sector

13. Solar reflective glass for façades and windows
14. Use of hollow bricks as partition walls

Power Sector

15. CCGT to replace old Steam Turbine (ST) plants
16. Electricity distribution loss reduction
17. Supercritical boilers for coal fired power plants

Cross Sectoral Options

18. Efficient fans
19. Efficient lighting (T8 replaced by T5 fluorescent tube-lights)

Biomass Options

20. Efficiency improvement of parboiling
21. Biogas plants

Mitigation Potentials of the Identified Mitigation Measures

The potentials of GHG reduction has been shown in Table 4.1. These have been estimated by first determining the reduction potential of a unit (chosen somewhat arbitrarily), and then multiplying that by the unit penetration achieved by 2030. The *Penetration Rate* up to 2030 has been determined using expert judgment based on the prevailing Government plans and programs, implementation challenges and the historical achievements of targets. Basically this is an exercise based on certain plausible ideas and areas for mitigation and is a kind of “what if” analysis.

The *Investment Requirement* has been determined based on data from a variety of sources including the internet. However, this was the most difficult item among all the collected data because investment and O&M costs of the mitigation options were found to vary a lot depending on source country and manufacturing company. The *Cost Effectiveness* is a computed quantity indicating the cost of abating one mt of CO_2 by the option. The cost effectiveness has been calculated using the pair-wise analysis concept, i.e., a specific mitigation option is compared with the baseline option.

The main parameters/assumptions are:

i) Discount rate = 10%
ii) Life of the mitigation and baseline options were made equal using established engineering economics principles
iii) Incremental Cost (Mitigation Cost minus Baseline Cost) has been used wherever applicable. For replacement options the baseline investment cost is zero
iv) For cases where the in-country fuel prices were found to be very different from economic prices (prices without tax or subsidy), international fuel prices were used

Table 4.1 presents the cost effectiveness and potential of GHG reduction in 2030 (after the assumed unit penetration has been achieved); while a pictorial representation of the cost effectiveness of the options is presented in Fig 4.4.

As can be seen both positive and negative cost options exists for Bangladesh. While options like T&D and CCGT are very expensive options, there are options like Modal Shift from Road to Water Transport and Solar Lanterns which are very attractive from a financial point of view. It is worth pointing out that mitigation options may have negative costs i.e., their use actually saves money, but because of barriers those are not likely to be implemented without deliberate intervention.

Table 4.1: Cost of emission reduction and penetration rate for mitigation options

Selected abatement measure	US$/Ton CO_2	Unit type	Emission reduction Ton CO_2/Unit	Unit penetration by 2030	Emission reduction Kilo Ton CO_2/year
T8 Replaced by T5 Lamps	-0.89	Lamp	0.05	5000000	250
Efficient Boilers	-25.23	Boiler	97	3000	290
Shift from Road to Rail	21.55	Train	593	75	44
Efficient Fan	-33.29	Fan	0.08	1000000	80
Solar Irrigation Pump	2.53	Pump	2.8	10000	28
Hollow Brick	16.18	0.5 Million bricks	74	500 Million bricks	74
Rehabilitation, Steel Mill	-10.74	7500 ton of Steel	372	750000 ton of steel	37
Solar Reflective Glass	10.47	1000 ft^3 space	0.3	75000	23
T&D Rehabilitation	75.00	20 MW	1515	3000 MW	227
Biogas Replacing LPG	-18.37	1 plant for 20 persons	1.8	100000	180
Efficient Brick Production	1.41	15 million Bricks	2687	2.4 billion bricks	430
CCGT	48.89	200 MW	266600	600 MW	800
Cogeneration, Sugar Mill	29.83	Mill	7748	10	77
Improved Gas Stove	-14.19	Household	0.22	337500	74
Shift from Road to Waterways	-96.60	cargo vessel	1426	200	285
New Urea Plant	0.95	urea plant	1332115	1	1332
Cogeneration, Captive Power	-38.59	Plant	31.4	1200	38
Supercritical Boiler	8.51	650 MW	492822	1950 MW	1478
Metering NG Connection	7.08	Household	0.29	337500	98
Solar Lantern	-51.57	Household	0.14	5000000	700
Parboiler-Generator	30.95	1 MW	1291	500	645

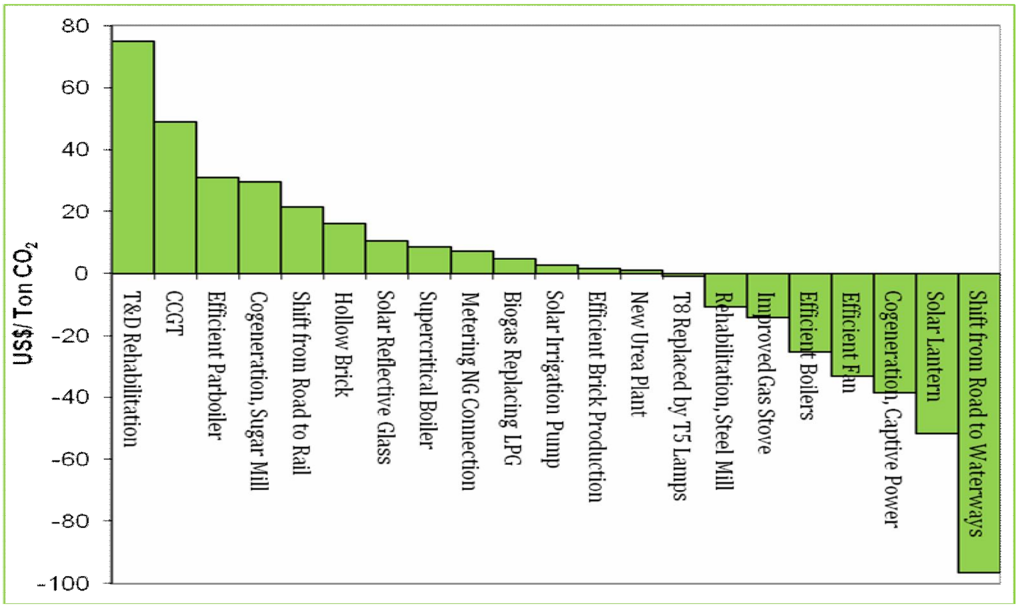


Fig. 4.4: Cost Effectiveness of Mitigation Options for Bangladesh

Table 4.2 gives the contribution in descending order of each option towards the total GHG reduction in the year 2030, while Fig. 4.5 gives a pictorial representation in ascending order of the GHG reduction potentials of the options. As can be seen the top ten (10) options, the top five (5) options and the top three (3) options are capable of reducing 90%, 70% and 50% respectively of the 2030 GHG reduction potential.

Table 4.2: GHG reductions due to key abatement measures

Abatement measure	Annual emission reduction, Th mt CO_2	% of CO_2 reduction
Supercritical Boiler	1478	20.56
New Urea Plant	1332	18.53
CCGT	800	11.13
Solar Lantern	700	9.74
Efficient Parboiler	645	8.97
Efficient Brick Production	430	5.98
Efficient Boilers	290	4.03
Shift from Road to Waterways	285	3.96
T8 Replaced by T5 Lamps	250	3.48
T&D Rehabilitation	227	3.16
Biogas Replacing LPG	180	2.5
Metering NG Connection	98	1.36
Efficient Fan	80	1.11
Cogeneration, Sugar Mill	77	1.07
Improved Gas Stove	74	1.03
Hollow Brick	74	1.03
Shift from Road to Rail	44	0.61
Cogeneration, Captive Power	38	0.53
Rehabilitation, Steel Mill	37	0.51
Solar Irrigation Pump	28	0.39
Solar Reflective Glass	23	0.32
TOTAL	**7190**	**100**

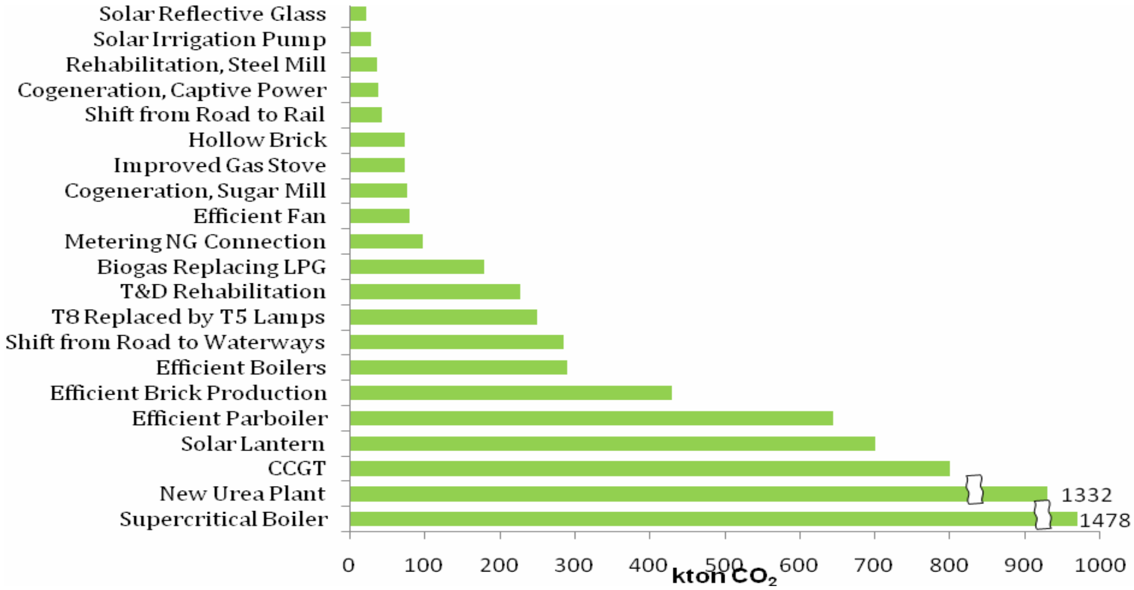


Fig. 4.5: GHG Reduction Potential of the Different Mitigations Options

Using 2005 as the base year, a GHG inventory projection for the energy activities up to 2030 has been prepared for the SNC (see Chapter 3 on Inventory). This is the baseline or business-as-usual scenario. If the 21 GHG mitigation options are implemented between 2010 and 2030 according to an assumed penetration rate, emissions will be less than the baseline; this reduced emission projection is the mitigation scenario for Bangladesh. The emissions according to the baseline and mitigation scenarios are shown in Table 4.3 and plotted as plotted as Fig. 4.6. If the mitigation scenario can be achieved a substantial quantity of CO_2 emissions can be abated.

Table 4.3: CO_2 Emission, Mn MT

Year	Baseline	Mitigation	Reduction
2015	66.68	56.83	9.85
2020	84.52	59.17	25.35
2025	108.71	75.16	33.55
2030	145.50	109.55	35.95

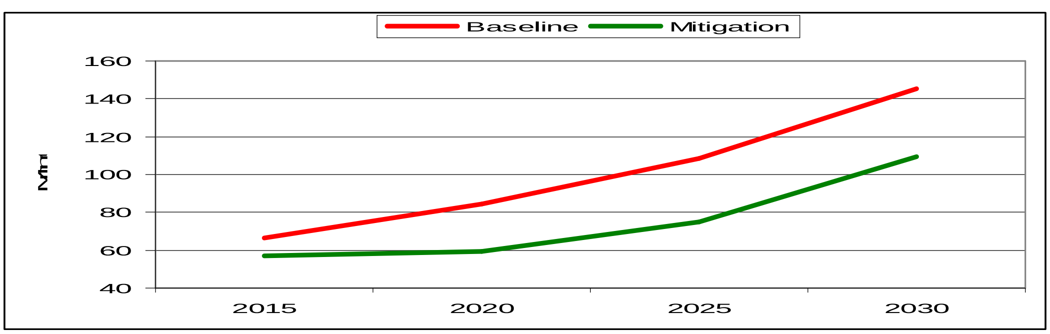


Fig. 4.6: GHG Emissions for the Baseline and Mitigation Scenarios

4.3.11 Options for Piloting

In terms of GHG potential and impact the following five options are significant, and these may be taken up as initial case studies through piloting:

1. CCGT to replace Steam Turbine (ST) power plant
2. More efficient and less polluting brick kilns
3. Efficient Parboilers
4. Supercritical boilers for new coal fired power plants
5. Solar PV pumps to replace Shallow Tubewells for irrigation

The CCGT option can be readilly implemented if funds are available. The only issue is closing down a similar capacity ST plant. With electrcity crisis prevailing this will be a very difficult proposition. Therefore, the CCGT will have to be set up as a greenfield project, and that may be much more expensive.

Female workers at Energy Efficient Hybrid Hoffman Kiln established with UNDP-GEF supported GREEN BRICK project, 2011

There are many competing technologies for efficient brick production. At present three technologies are allowed. To achieve long term sustainability, the best option would be to move to the Tunnel Kiln technology, which will not only give much better efficiency than the baseline, but also decrease local pollution significantly. It is worth pointing out that many efforts have been undertaken to reform this polluting industry, but only limited success has been achieved. Therefore, a well thought out financing and incentive scheme is required.

Environment Friendly Hybrid Hoffman Kiln established with UNDP-GEF supported GREEN BRICK project, 2011

Efficient paddy parboilers can only be promoted through a well structured financing mechanism because the industry is presently controlled by small-time entrepreneurs who are not willing to disrupt operations for the sake of greening their business. A combination of regulatory pressure and funding support will be essential.

Bangladesh will construct more than 10,000 MW of coal fired power plants in the next two decades. Since funding is always a problem, the best technology may not be used especially if the projects are bilaterally funded, and technology is sourced through supplier's credit. Pursuing this project through CDM would be ideal because the carbon financing would need to only provide the incremental investment.

Several Solar PV irrigation pumps set up as pilot projects are operating successfully. The savings from the fossil fuel displaced can recover the initial investment without interest of the solar PV pumping system in 7-8 years. Irrigation pumps are responsible for a seasonal peak demand which the utilities find very difficult to manage. Moreover, during the non-pumping season, the generated electricity can be used for other purposes. Therefore, if some sort of a "Green Fund" can be accessed then this option can be widely employed in rural Bangladesh.

Chapter 5

Vulnerability from and Adaptation to Climate Change Impact

5.1 Background

Bangladesh is one of the countries most vulnerable to the impacts of global warming and climate change. This is due to its geographic location, dominance of river floodplains, low elevation from the sea, high population density, high level of poverty, and overwhelming dependence on nature and its resources and services which are sensitive to climate variability and climate change. The country has a history of extreme climatic events claiming millions of lives and destroying past development gains. The people and social system have knowledge and experience of coping with the effects of such events–to some degree and extent. This chapter tries to examine the aspects of vulnerability of Bangladesh to climate change and assess the adaptation needs.

5.1.1 Approach and Methodology

The steps of approach to conduct the V&A assessment are shown in the following Figure 5.1.

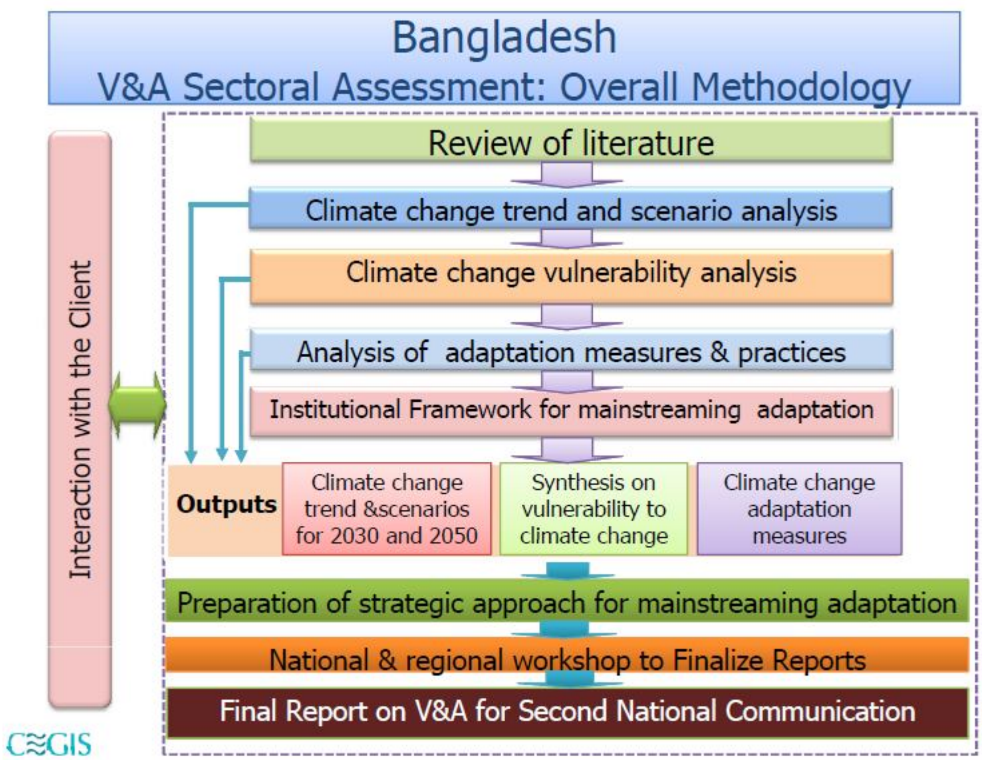


Figure 5.1: Overall approach of the study

Methodology

The generic approaches of the methodology were to (a) conduct impacts(and vulnerability) assessment study based on occurrence of climate induced hazards/disasters and climate hotspots in the country, with a focus on agro-ecologically hazard-prone regions; (b) conduct adaptation component of the study based on hazard susceptible sectors and cross cutting aspects; and (c) carry out policy and institutional study integrating all thematic and cross cutting aspects of institutional approaches to mainstream adaptation.

The expected deliverables of the task assigned consist of several components such as conducting study on vulnerability, attempting to build national expert level consensus on scenarios and impacts, and raising mass awareness on issues concerning adaptation. While the latter two are generally process related deliverables, the former is a tangible output which eventually formed the basis of this Adaptation chapter.

5.1 .2 Scope of Work

The major issues to be discussed in this chapter are:

a) The expected future socio-economic scenarios in absence of climate change

b) Present trends in climate variables

c) Expected climate change scenarios

d) Physical vulnerability arising from projected climate change

e) Demographic, economic, social and land use pattern changes due to impact of climate change and associated vulnerability on crop agriculture, non-crop agriculture, human health infrastructure, ecosystem services, urban habitation and livelihood, and gender dimensions of vulnerability along with possible adaptation measures in each case

5.2 Development Scenarios

5.2.1 Future Population under Climate Change Threats

Background

It may be mentioned that the physical vulnerability due to climate change is going to create major dislocations with the production systems as well as increase the frequencies of disasters which will exacerbate the present weather-related vulnerabilities and become major threats to lives and livelihood of people. One needs some indication of the proportion and number of people who may be so affected. For this it is important to have some kind of an idea of what the population would look like in the future.

Population Projection for the Future

The population projection for the 2010-50 period is made based on the NWMP methodology which estimates the future population of each district separately based on rate of growth estimated for the period between 1991 and 2001. Admittedly, this is a crude method of estimation as migration between districts is not considered which will mean upward bias for some (origin) districts and downward for others (destination). However, the basic idea here is to divide the population growth in absence of climate change by hydrological regions which has specific characteristics in terms of exposure to flood, water availability, rainfall patterns etc and consequently exposed to various risks due to climate change Hopefully, the relative distribution of population will not be much off-the mark despite the crude methodology that has been used here.

The projected population disaggregated by different sub-categories for the base year (2010) and for 2030 and 2050 are presented in Table 5.1. The national figures are also given in Fig. 5.2. The total population in Bangladesh in the year 2030 has been estimated to be slightly more than 188 mn, which increases to 238 million by 2050. But the most important finding here is that the absolute number of rural population remains largely constant and *much of the growth actually takes place in urban areas*. As a result, by 2050, the proportion of urban population comes to just under 50 percent. That means the vulnerability in urban areas needs to be given much more thought than what is done at the present.

The estimates for different hydrological regions show that the growth in population will be mainly in the North-central and the North-western parts of the country with somewhat lower additions in the South-west and the North-eastern parts of the country by 2050 (Fig. 5.3).

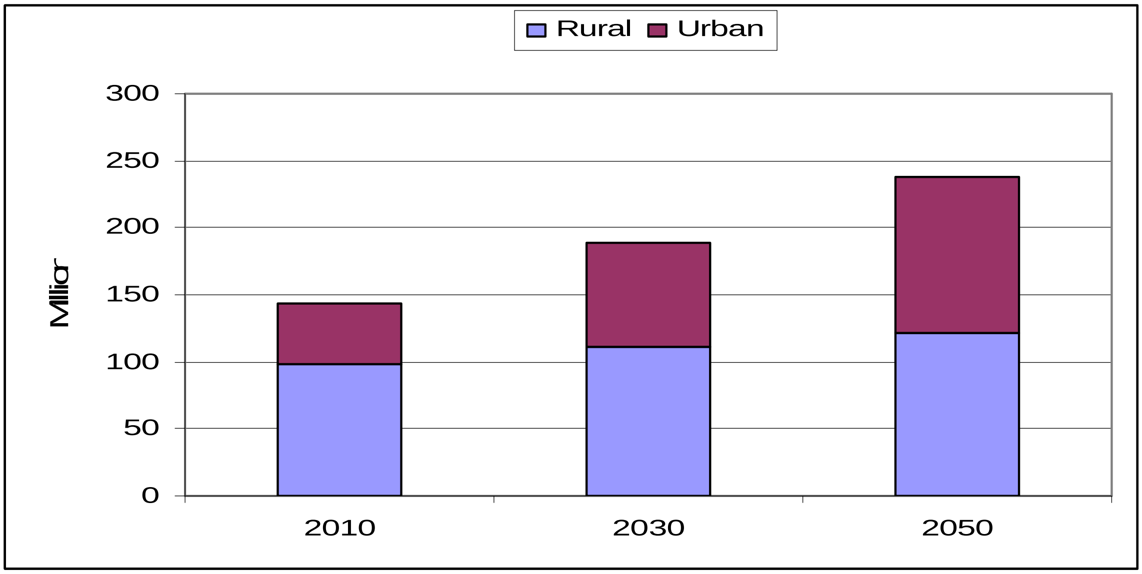


Fig. 5.2: Bangladesh Population Projection for 2030 and 2050

Table 5.1: Region wise Population Projection (Thousands) for Bangladesh
(2030 and 2050)

Region	**2010**			**2030**			**2050**		
	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban
SW	20,166	14,736	5,806	25,555	16,720	10,773	31,500	18,797	17,180
SC	11,521	8,638	3,697	13,666	9,307	8,507	15,958	10,383	15,115
NW	31,450	25,348	5,243	39,929	28,774	7,013	49,271	31,382	8,651
NC	30,630	14,154	15,608	43,437	14,754	23,988	58,686	14,856	32,723
NE	17,184	14,158	2,611	21,815	15,901	3,929	26,903	17,170	5,309
SE	14,686	10,561	5,318	18,283	11,888	12,434	22,195	14,046	21,995
EH	11,033	5,987	4,721	15,913	7,425	6,749	21,626	8,775	8,742
RE	7,501	5,346	2,240	9,599	5,952	4,084	11,940	6,567	6,386
BD	144,172	98,929	45,243	188,197	110,720	77,476	238,077	121,976	116,101

Note**:** SW= South West region, SC= South Central region, NW= North West region, NC= North Central region, NE= North East region, SE= South East region, EH= Eastern Hill region, RE= River and Estuary region

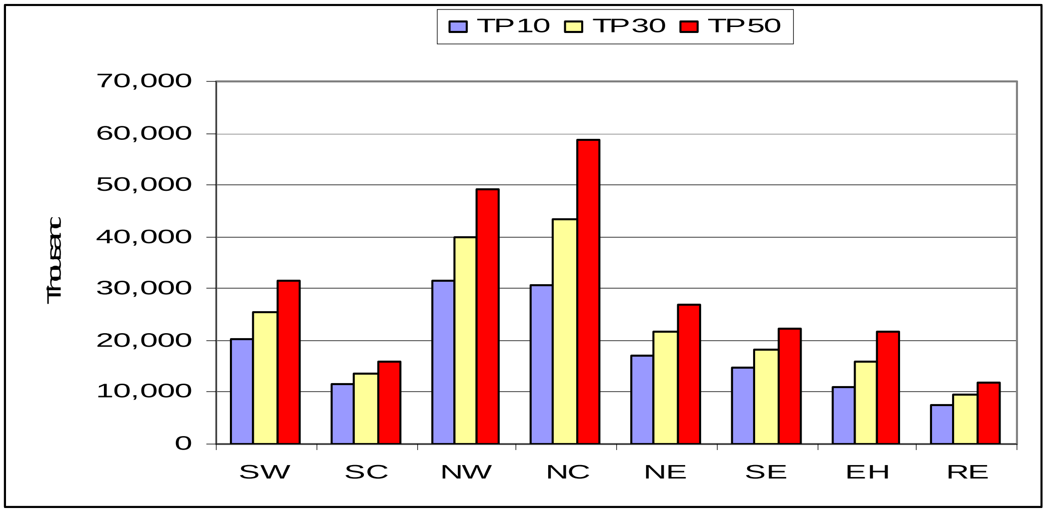


Fig. 5.3: Region wise Population Projection for Bangladesh
(2030 and 2050)

Note: TPX ; Projected population for year X. For regions see note in Table 5.1

5.2.2 GDP Growth

The GDP of the country has been rising at the rate of around 6.5% (at constant prices of 1995/96) for most of the years during the last one decade. So, the baseline annual rate of growth can be considered to be, say, 6.5% for the entire period up to 2050. However, it is expected that the growth rate will accelerate over years. Then an optimistic scenario can be developed in which the growth rate remains 6.5% up to 2020, rises by 0.25% for every 5 years up to 2030-40 and rises further to 8% over 2040-50. This is purely ad-hoc but not implausible. If the rates are so applied, we can have a baseline scenario and a fairly optimistic scenario for GDP growth. These are shown in Fig. 5.4.

The actual growth path of course depends on the assumed rates of growth and these may be either downward or upward biased. But given the history of Bangladesh, it may be just about right. This is so because already there are substantial year to year fluctuations in the growth rate and thus the average may perhaps be not much different from what has been assumed here. Note that for the year 2030, the baseline and optimistic GDP figures are 193 and 207 US$ bn. By 2050 the two are expected to grow respectively to US$ bn 680 and 931. Thus under the optimistic scenario the difference between the baseline and optimistic scenario is going to be far greater, more than US$ 250 bn.

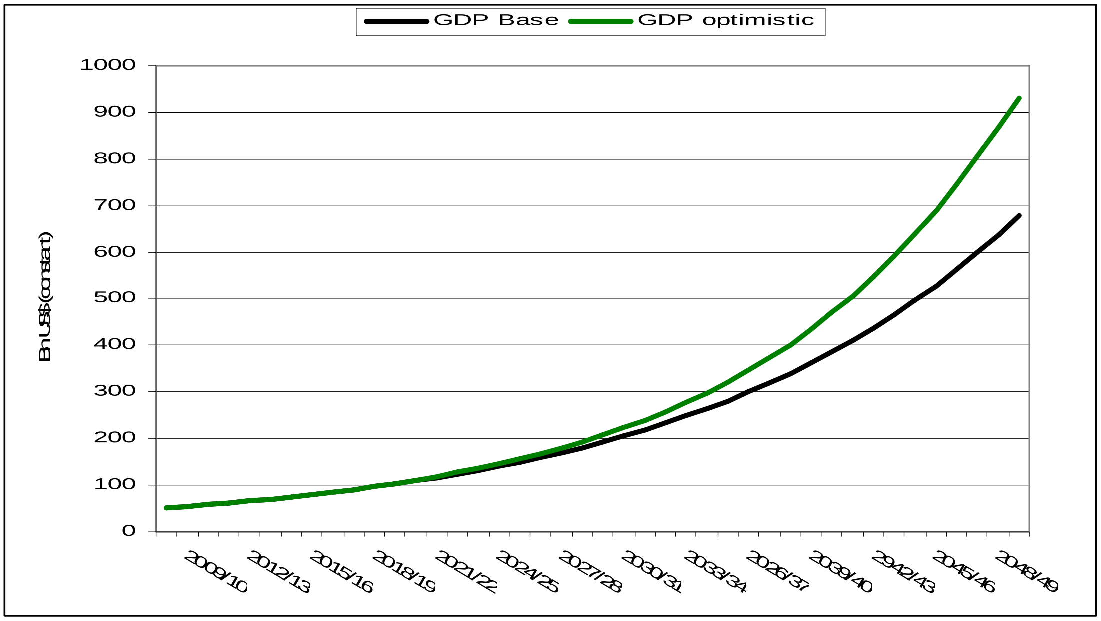


Fig. 5.4: Baseline and Projected GDP of Bangladesh (US$ bn)

5.2.3 Food Consumption Patterns and Demand

Increasing income and urbanization are triggering a rapid change in food consumption patterns in Bangladesh. Food grains dominate the total dietary consumption of the Bangladeshi people. Historical data (FAO, 2005) on consumption profile shows that, on an average, grains provide 82% of the calorie supply in total food intake. In addition to this, rice is the main food grain all over Bangladesh, which comprises around 88% of the total grain consumption. The non-grain food crops and animal products provided 8% and 4%, respectively, of the remaining calorie supply.

The BCCSAP has pointed out the absolute necessity to maintain food security. How far food supply may be impaired due to climate change thus becomes important and we need therefore to have an estimate of the demand for food. The Table 5.2 provides some ideas about how food demand may change over time.

The total demand for rice in 2050 may rise from 27.26 mn mt in 2010 to 38.32 mn mt and other dominant cereals like maize and wheat will respectively increase by more than 5 times and twice by 2050 over the same period. Non-cereal food demand will increase tremendously. These are all expected as income levels rise.

Table 5.2 Total Food Demand Projection (mn mt)

(a)

Year	Rice	Wheat	Maize	Other cereals	Pulses	Oil crop	Potato	Other roots
2001	24.54	1.01	0.33	0.05	0.85	2.46	3.74	1.94
2010	27.26	1.29	0.74	0.04	0.91	5.89	5.29	2.74
2020	30.06	1.65	1.66	0.04	0.98	13.98	7.43	3.85
2030	32.57	1.91	2.49	0.03	1.01	21.91	9.18	4.76
2040	34.73	2.18	3.43	0.02	1.01	30.99	10.81	5.61
2050	38.32	2.41	3.78	0.03	1.12	34.19	11.93	6.18

(b)

Year	Vegetables	Fruits	Sugar and sweeteners	Meat and poultry	Eggs	Fish	Milk	Miscellaneous
2001	11.97	2.35	0.45	.48	.29	2.90	2.62	0.29
2010	12.32	2.66	0.45	.63	.42	3.77	4.89	0.36
2020	12.58	2.98	0.43	.81	.61	4.86	9.06	0.44
2030	12.04	3.32	0.40	.94	.74	5.73	11.89	0.51
2040	10.87	3.68	0.36	1.07	.87	6.57	14.93	0.58
2050	11.99	4.06	0.40	1.18	.96	7.25	16.47	0.64

5.3. Climate Trend Analysis

The main source of climate data in Bangladesh is the Bangladesh Meteorological Department (BMD). Data from up to thirty-six stations spread over the country have been used for trend and seasonal distribution over the period. In some cases, the data are available for only some of the stations, not all. We have tried to indicate data from how many stations have been used in case of important climatic variables.

5.3.1 Climate Change and Variability: Definition and Differences

WMO has defined "climate change" as statistically significant change in either the mean state of the climate or in its variability observed over an extended period (typically decades or longer) while climate variability represents the variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events.

Methodology

Climate change has been measured using standard statistical procedure like parametric and non-parametric tests to detect trend in all observed temperature and rainfall stations of BMD spread over eight hydrological regions of Bangladesh. Climate variability is detected using the guideline provided by the WMO to gain a uniform perspective on observed changes in weather and climate extremes (World Meterological Organization (WMO), 2009). WMO suggested using a total of 27 core sets of descriptive indices of extremes. The indices describe particular characteristics of extremes, including frequency, amplitude and persistence.

Data Quality Control (QC) was considered as a prerequisite for indices calculations. In addition, QC also identifies outliers in daily maximum and minimum temperature.

Temperature

The surface air temperature is rising in Bangladesh, The mean annual temperature, mean maximum temperature and mean minimum temperature has risen respectively by $0.016^{\circ}\mathrm{C/year}$, $0.02^{\circ}\mathrm{C/year}$ and $0.012^{\circ}\mathrm{C/year}$ during the 32-year period from 1977 to 2008. The observed data indicates that the significance of the trends is regionally widespread. Thus, 19 out of 31 stations exhibited statistically significant rising trend in mean annual temperature. Significant rise in minimum temperature is found valid in observations from 17 out of 31 stations while for rising maximum temperature 17 stations out of 31 returned significant results.

Historically the average winter temperature in Bangladesh is within 15 to 20 degree Celsius. However, in recent *Cold Spell*s this average temperature has dropped to as low as 4 degree Celsius, a new record for the country. The most affected area during this calamity is the northern part of the Bangladesh which is closer to the Himalayas. Northern Bangladesh is the most poverty stricken area of the country where people have year round income poverty and seasonal food poverty during the time of agricultural lean seasons. The recent catastrophe of *Cold Spell* has magnified their sufferings to a severe extent, shortage of warm clothing and shelter has caused them even their lives (Shonchoy,A., IDE-JETRO 2011).

Climate variability in terms of annual count of summer days is found statistically to be significantly increasing in 13 out of 28 meteorological observatories (Mukherjee et. al., 2010). Other than this, an increasing as well as decreasing trend in the monthly maximum value of daily maximum and minimum temperature is evident in 14 out of 28, 5 out of 28, 9 out of 28 and 17 out of 28 stations.

Rainfall

In Bangladesh, monsoon is both hot and humid and brings heavy torrential rainfall throughout the season. About four-fifths of the mean annual rainfall normally occurs during monsoon. Warm conditions generally prevail throughout the season, although cooler days are also observed during and following heavy downpours. Post-monsoon is a short-living season characterized by little or no rainfall and gradual lowering of night-time minimum temperature. Mean annual rainfall is about 2,347 mm, which varies within the range of 1,640 mm to 2,831 mm.

The pattern of change in the rainfall is mixed and appears to indicate trend of heavier rainfall in the coastal region. Mean annual rainfall has risen statistically significantly in only 4 out of 31 observatories of the country. The dry seasonal (DJF) rainfall shows little change in most cases, but where it does (in 4 out of 5 stations), the trend is downwards. During the monsoon no significant trend is observed but for post monsoon seasonal rainfall, statistically significant rising trend has been observed in 11 out of 31 stations.

Irrespective of statistical significance, in all the seasons an overall increase in the mean seasonal rainfall is observed and found to be maximum during the pre-monsoon (MAM) and monsoon (JJA) season by around 100 mm. Although the winter season (DJF) experiences the minimum rainfall, the historical trend shows a positive trend in 27 out of 32 rainfall observatories of the BMD (Mukherjee et. al., 2010). Decrease in the pre-monsoon (MAM) seasonal rainfall is evident in 30 out of 32 stations of BMD. It is also valid and prominent in the coastal regional stations of Bhola and Madaripur in the range of 3-19 mm/year decrease in the mean seasonal rainfall (Figure-5.5).

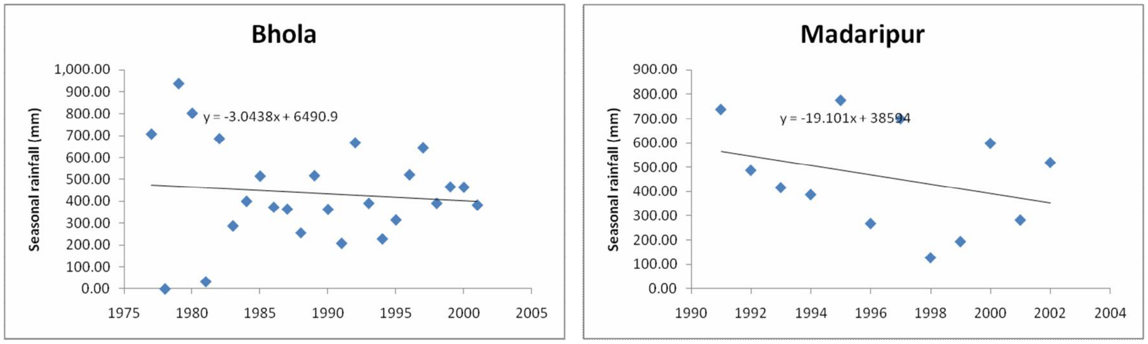


Figure 5.5: Observed trend in seasonal mean rainfall for pre monsoon seasonal month (MAM)

An increase in the monsoon (JJA) rainfall is observed in 18 out of 32 meteorological stations, which is not statistically valid but seen to be prominent in the coastal district observatories. Post-monsoon (SON) rainfall is also observed to increase in 24 out of 32 meteorological stations, which is statistically significant in some of the coastal observatories like Khepupara, and Maijdee Court stations in the range of 6-12 mm/year (Figure-5.6).

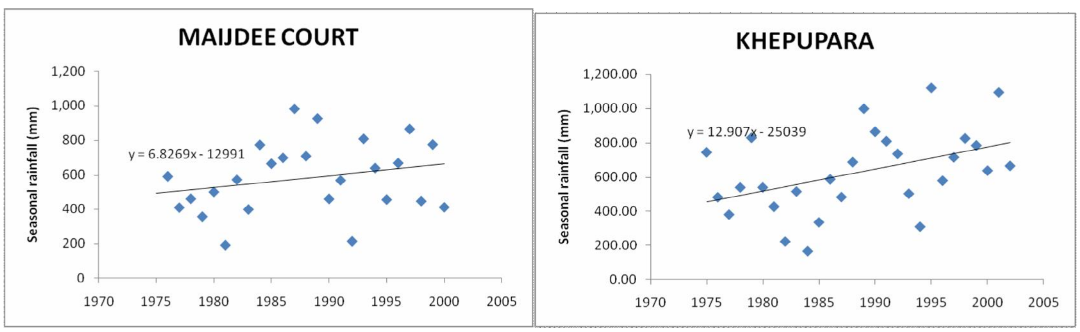


Figure 5.6: Observed trend in seasonal mean rainfall for post monsoon seasonal month (SON)

The positive trend is comparatively prominent in the coastal regional stations. A fall in the pre-monsoon (MAM) seasonal rainfall is evident in 30 out of 32 stations of BMD. It is also significant in some of the coastal regional stations. An increase in the monsoon (JJA) rainfall is observed in 18 out of 32 meteorological stations, which is not statistically significant but seen to be prominent in the coastal district observatories. Post-monsoon (SON) rainfall is also observed to increase in 24 out of 32 meteorological stations, which is statistically significant in some of the coastal observatories.

In terms of variability, the trend in the monthly maximum 1-day precipitation is found statistically significant only in one station, but the trend in the monthly maximum consecutive 5-day precipitation in found statistically significant in 4 out of 28 stations. The statistically significant trend in the annual count of days when precipitation is greater than 10 mm and 20 mm has also been observed (Mukherjee *et. al*., 2010).

<u>Observed Sea level Rise in Bangladesh</u>

There is a general perception regarding the inevitability and the adverse impact of sea level rise in Bangladesh. But the analyses of data on rising sea level is not clear cut on the issue of its extent, though not the direction of trend of rise A study by the SAARC Meteorology Research Centre found that the tidal levels at different locations rose from 4.0 mm/year to 7.8 mm/year over 1977-1998. These data had been later examined for various perturbations and the subsequent analyses had used data only from points where these are absent and noted that the mean sea level has indeed been rising and the observed range of sea level variance can be taken to be 5.05 mm to 7.4mm/yr.

Availability and Quality of Climatic Data

The data sets used for the analysis of trends suffers from various limitations. The data appears to have a significant proportion of outliers while there are gaps and inconsistencies. Due to unavailability of metadata, many of the questionable observations could not be verified. Moreover, the coverage of data is sparse, not adequate to facilitate various types of risk assessment. Daily data of over 50 years are available for only 20 stations. Such lack of data leaves little room for validating a climate model. Only recently, BMD has taken the initiative to improve its climatological database. Automated logger and radar-based rainfall data unit have been established to gather three-hourly observations in some of the regions. Such efforts need to be strengthened in order to have shorter time step based datasets with increased coverage. Once such a data collection system is developed, the country will be able to embark upon systematic climate change analysis in a few decades.

5.4 Climate Change Scenarios

5.4.1 Introduction

The fourth IPCC assessment report contends that for continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century, which would very likely be more severe than those observed during the 20th century. The global average, of course, hides many of the differences between regions, countries and locations within a country. Here we try to portray the changes that may take place in Bangladesh. .

5.4.2 Climate Scenario Development for Bangladesh

Previous Analyses and Scenarios

Several attempts have been made in climate scenario development in Bangladesh over the period using mainly GCMs and in some cases RCMs (Ahmed and Alam, 1998; Agrawala *et al*, 2003; Islam *et al*., 2008; Rahman *et al*., 2009a; Rahman *et al*., 2009b; Tanner *et al*., 2007). A general consensus from these exercises includes an over-all rise in temperature, drier dry season, and a wetter wet season. In general, change in the mean annual temperature expected to be around 1^{0}C by 2030 and 2^{0}C by 2050; change in annual rainfall is expected in the range of 0 to 2% by 2030 and 2 to 4% by 2050 with a greater variation in seasonal rainfall. Winter (December-February) rainfall is expected to decrease in most of the study results while monsoon (June-August) rainfall might increase in the future.

The models that have been used so far suffer from various deficiencies. Particularly, because of limited skills, experience and institutional capacity it has not been possible to develop own purpose-built models which can produce robust, scientifically rigorous and well validated significant climatic phenomenon like monsoon which is the life blood for the country due to its importance in ensuring food security. Against this backdrop, we reproduce results of a new analysis done specifically for the SNC.

Approach and Methodology

In order to estimate future climate change over Bangladesh, the 'Model for the Assessment of Greenhouse-gas Induced Climate Change' (MAGICC) and the 'SCENario GENerator' (SCENGEN) developed by the National Center for Atmospheric Research (NCAR), USA and Climatic Research Unit (CRU), University of East Anglia, UK have been used. MAGICC has a grid resolution of 2.5 degree by 2.5 degree. All model data available in MAGICC can be used to generate outputs at this resolution.

Nine GCMs which portray Bangladesh situation better than others have initially been chosen. One was finally rejected based on convergence criteria. The selected models are CGCM 3.1 (T47), CCSM 3.0, CSIRO-Mk3.0, GFDL-CM 2.0 and 2.1, INM CM-3.0, MIROC 3.2 (medres) and UKMO-HadCM3.

SCENGEN has been used to generate changes in mean temperature and precipitation. For this analysis two SRES emission scenarios A2-AIM and B1-AIM have been selected from the family of SRES scenarios (Nakićenović and Swart, 2000). Two periods have been selected for this projection, 2015-2045 (2030s) and 2035-2065 (2050s). MAGICC has been run to predict climate up to 2100 and SCENGEN has been used to generate the annual and seasonal averages for changes in temperature and precipitation for the 2030s and 2050s under A2 and B1 emission scenarios.

Temperature and Rainfall

Table 5.3A and 5.3B present the annual average temperature and precipitation changes that have been predicted for the 2030s and 2050s.

Table 5.3A: Changes in temperature and precipitation (A2 scenario, 2030s and 2050s) (Base year 2010)

Scenerios for Bangladesh		Time horizaon	
		2030s	**2050s**
Annual	ΔTemperature (°C)	+0.73	+1.32
	Precipitation (%)	+4.92	+8.10
DJF	Temperature (°C)	1.16	1.96
	Precipitation (%)	-27.68	-37.67
MAM	Temperature (°C)	0.76	1.41
	Precipitation (%)	24.00	32.61
JJA	Temperature (°C)	0.42	0.84
	Precipitation (%)	9.47	13.29
SON	Temperature (°C)	0.59	1.09
	Precipitation (%)	-2.81	-1.18

Table 5.3B: Changes in temperature and precipitation (B1 scenario, 2030s and 2050s) (Base year 2010)

Scenerios for Bangladesh		Time horizon	
		2030s	**2050s**
Annual	∆Temperature (°C)	+0.78	+8.41
	Precipitation (%)	+6.30	+8.41
DJF	Temperature (°C)	1.32	2.20
	Precipitation (%)	-58.40	-56.56
MAM	Temperature (°C)	0.91	1.85
	Precipitation (%)	19.52	7.34
JJA	Temperature (°C)	0.30	1.04
	Precipitation (%)	13.05	12.51
SON	Temperature (°C)	0.60	1.40
	Precipitation (%)	-2.26	3.88

Here, DJF (December, January, February); MAM (March. April, May); JJA (June, July, August); SON (September, October, November)

Annual average changes in temperature and precipitation for A2 and B1 scenarios for various regions/divisions of the country will, of course, vary around the national mean values.

Table 5C: Table presents the projected sea level rise in the year 2020, 2050 and 2080 for A2 and B1 respectively. Sea level rise in those years are considered to be the rise after base/reference year 2005

Scenarios	**Sea Level Rise**		
A2 (High emission scenario)	2020	2050	2080
High	6 cm	27 cm	62 cm
B1(High emission scenario)			
High	5 cm	23 cm	48 cm

Note: *Global sea level rise for the projected year 2020, 2050 and 2080 has been selected from Third Assessment Report (TAR) of IPCC 2001 for high and low emission scenarios of SRES (Special Report on Emission Scenarios).*

Figure 5.7 illustrates annual average temperature and precipitation over Bangladesh for the 2050s.

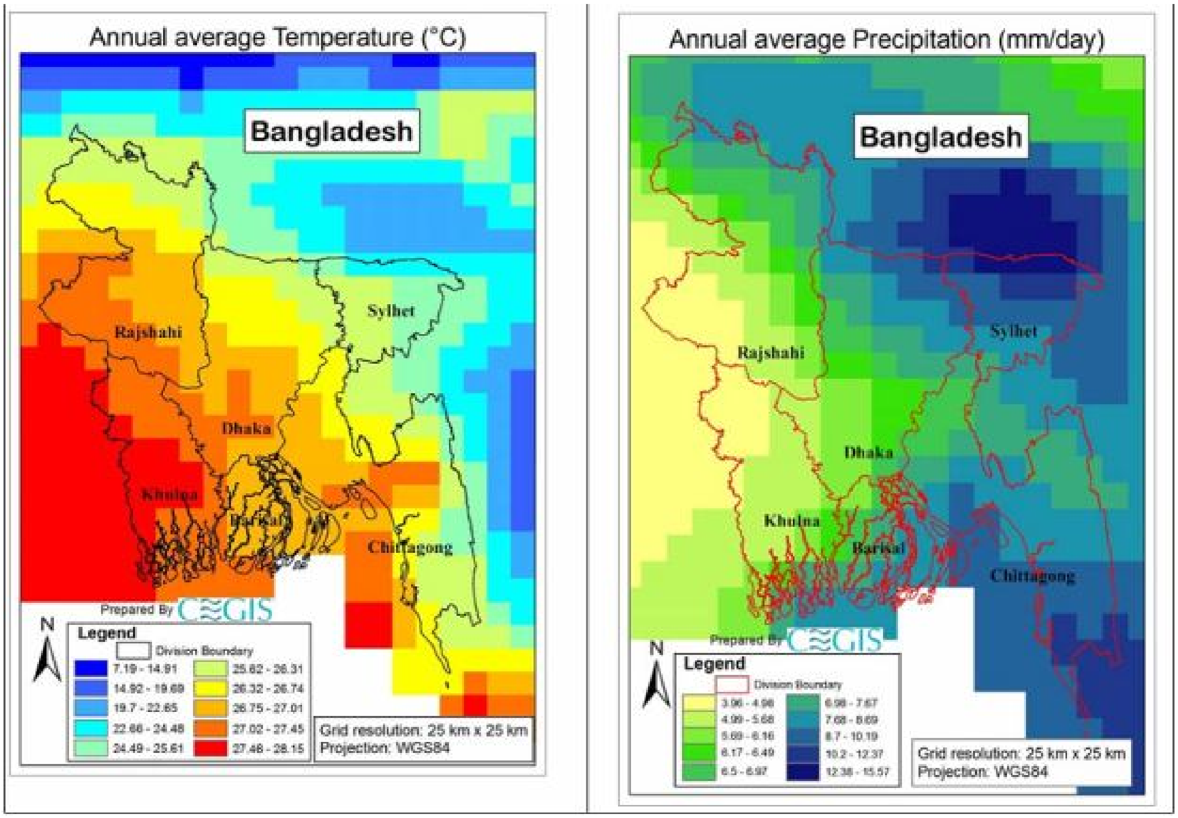


Fig. 5.7: Annual average changes in temperature and precipitation (A2 scenario, 2050s)

Source: Based on Consultants' estimates.

According to the above scenarios, the magnitude of these changes in climate may appear to be very small. But if added to existing climatic variability and events (such as floods, droughts, and cyclones), these could substantially increase the magnitude of these events and decrease their return period. For example, a 10% increase in precipitation may increase runoff depth by one-fifth and the probability of an extreme wet year by 700%. The consequences of climate change especially change of climate variability or uncertainties are discussed below briefly. The details of vulnerability to climate change are presented in the Vulnerability Assessment section.

Sea Level Rise, Coastal Inundation and Salinity Intrusion

Because of its low lying geographical location Bangladesh is very vulnerable to current coastal hazards and future sea level rise (SLR). Drainage congestion is already a growing important problem in Bangladesh and is likely to be exacerbated by SLR and increased river flooding as well as backwater effects during certain parts of the year. It is reported that inundated areas might increase by up to 3% (2030s) and 6% (2050s). Much of course will depend on how other weather variables may behave. Thus, Table 5.4 shows that in 2005 without SLR, the total area inundated is 17240 sq km. By 2050 under Scenario A2 with 27 cm rise in the level of the sea, the area inundated increases to 19722 sq km. For 2080 with a 62 cm SLR, the corresponding area becomes 21839 sq km. However, if there is 10% more rainfall compared to the baseline, the area inundated further jumps to 22717 sq km.

Table 5.4: Inundated area (> 30cm) in coastal districts for different SLR

Total Area (Km2)	Base (Km2)	Inundated area for Sea Level Rise (Km2)			
	2005 B1 No SLR	2080 B1 (15cm)	2050 A2(27cm)	2080 A2 (62cm)	2080 A2 (62cm+ 10% rainfall)
47,194	17,240	18,685	19,722	21,839	22,717

It is expected that due to sea level rise more area will be under tidal influence. Area under tidal range of less than 30cm is considered to be non-tidal zone. For different sea level rise scenario, tidal penetration length has been estimated based on model results. These indicate that the tide will penetrate upstream by 10 km for 27cm SLR and 20 km for 62cm SLR compared to the base condition.

Population exposed to sea level rise

The exposed population in the settlement area is estimated for different inundation scenarios using Risk Class categories as defined in Table 5.5. This risk classification has been done based on probable damages. Using the flood risk zones and population density, the exposed population for respective scenarios is estimated. The table clearly indicates that as the SLR increases so does the population exposed to increasingly higher risk categories.

Table 5.5: Population in Coastal Area Exposed to Risk under Different SLR Induced Inundation

Scenarios	Population under Risk (mn)			
	No risk	Low (<25 cm)	Medium (25-50 cm)	High (50-100 cm)
B1, 2080, SLR 15 cm	25.6 (56)	19.9 (44)	0	0
A2, 2050, SLR 27 cm	36.3 (53)	26.7 (37)	7.0 (10)	0
A2, 2080, SLR 62 cm	41.5 (49)	17.4 (20)	12.0 (14)	14.4 (17)

Note: Figures in parentheses are percentage of total coastal area population

Absolute population figures differ as the delineation of coastal area changes.Modeling studies show salinity intrusions along much of the coastline, Rates of intrusion vary with local conditions and are strongly influenced by dry season river flows and the rate of SLR. Large uncertainties are associated with regional to district level estimates of inundation which is due to the confounding effects of, *inter alia*, variable rates of uplift and sedimentation, river flooding and erosion.

<u>Cyclones and Storm Surges</u>

Roughly 3 to 7 cyclones hit the Bangladesh coast each decade year. Some of the studies indicate that regional frequency of tropical cyclones may change but none shows that their locations will. There is also evidence that peak intensity may increase by 5% to 10%, which would contribute to enhanced storm surges and coastal flooding.

Much may actually depend on the rise of sea surface temperature (SST). If at present the maximum wind speed as observed during 1991 cyclone is 225 km per hour, for a 2^0 C rise in SST the velocity shall rise by 10% to 248 kmph and for a 4^0 C rise by 22% to 275 kmph with consequent destructive power. For a situation without SLR, the present maximum storm surge is 7.6 metres. For a 2^0 C rise in temperature, and SLR of 1 metre, the storm surge shall be 10.6 metres high i.e., the coastal defenses are likely to be easily overtopped.

Modeling results show that for a 62cm sea level rise under A2 scenario, inundation may occur in 13 polders. Due to the overtopping of the embankment, more than 120 thousand ha of land within these polders will be deeply flooded (more than 60 cm) whereas in base condition inundated area is only about 42 thousand ha. Thus, about 3 times the base area will be deeply inundated due to overtopping of embankment.

It is reported that cyclones may penetrate further inland and cyclone High Risk Areas are likely to increase in size. Increases in the wind velocity and storm surge height result in further inland intrusion. The cyclone High Risk Areas (HRAs) of 8,900 sq km may increase by 35% and 40% in the 2020s and 2050s, respectively.

Cross-boundary River Flows

The climate change induced alterations in temperature is likely to affect the timing and rate of snow melt in the upper Himalayan reaches. As a result, the hydrological aspects of the eastern Himalayan rivers and the Ganges-Brahmaputra-Meghna (GBM) river basins could change significantly. GBM river systems may begin to swell early, while increased precipitation in monsoon would generate additional volumes of runoff. During the winter period, however, flows in the GBM rivers might decrease because of lower rainfall and higher surface evaporation. Developments and climate change induced moisture stress in the upstream areas of the river basin may result in an increase of the rate of water withdrawal for agricultural, domestic and industrial activities. This might lead to even lower availability of water flow in the cross-boundary rivers in Bangladesh during the winter months.

5.5 Vulnerability Assessment and Adaptation

5.5.1 Understanding Climate Change Vulnerability

Climate change has two basic elements, viz., a rise in temperature and a change in the precipitation regime. These two give rise in their wake to many types of second level changes in the physical natural world which may or may not be exacerbated or ameliorated by human intervention. The initial changes in the parameters of the climate along with the consequent second round impacts in the physical and natural world give rise to changes in the human systems of agriculture, industry, energy, infrastructure, health, livelihood as well as disaster. Whatever happens, many and much of the impacts will be through some kind of changes in the water regime. We therefore first try to understand such changes in the Bangladesh context.

5.5.2 Water Resources

Water Availability

Future water availability for Bangladesh has been assessed in recent years using the Global Water Availability Assessment (GWAVA) model. The GWAVA model uses four water availability indices to identify water deficit and water surplus grid cells.
The country-wide distribution of water availability indices based on climatic input from Hadley Centre models are presented in Figure 5.8. The range here is divided into five groups for better representation of the water stress condition. The negative range is divided into four equal intervals and the positive range is treated as one interval.

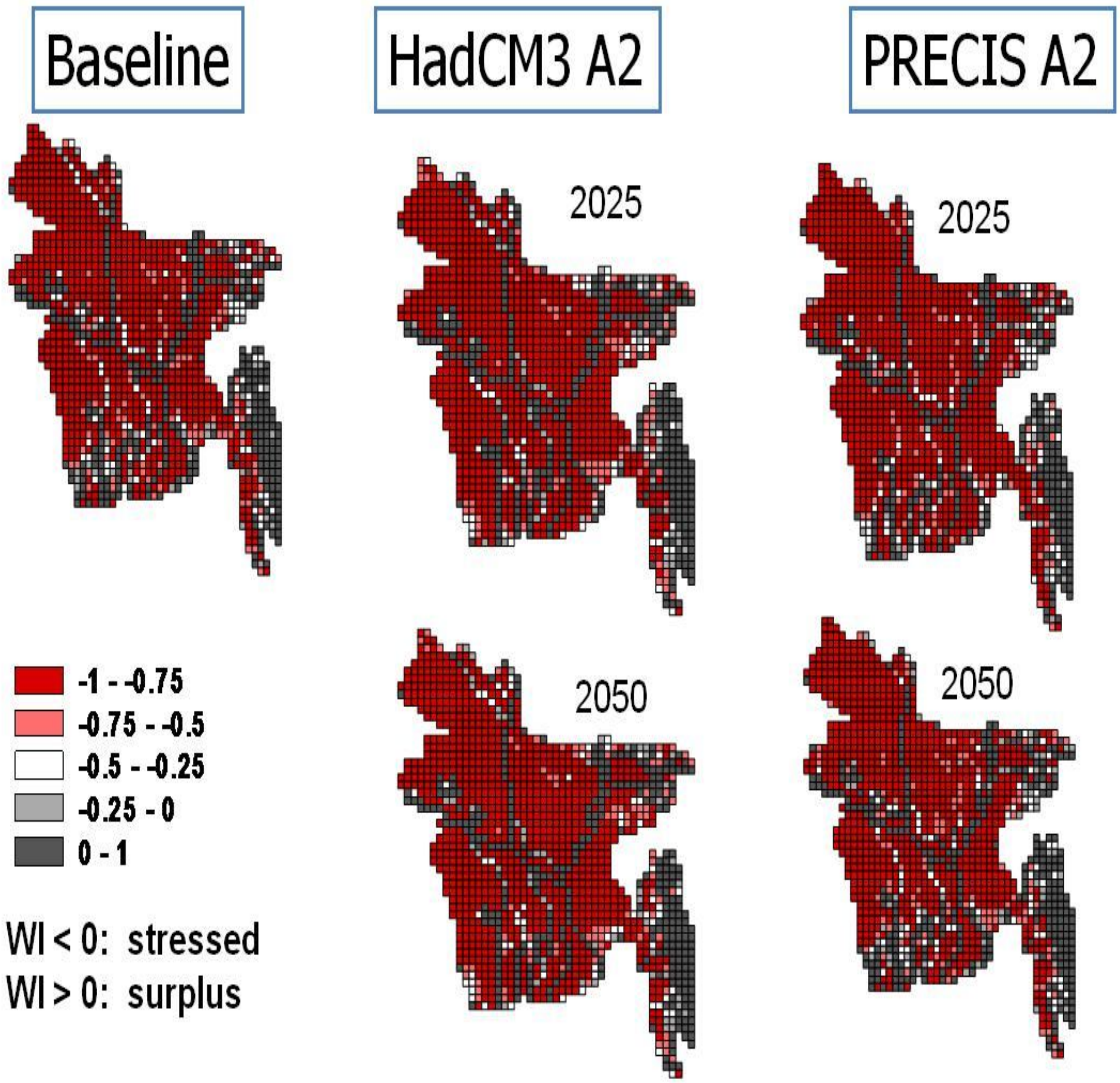


Figure 5.8: Water availability index

Fig. 5.9 and Fig. 5.10 illustrate the changes in distribution of water availability in 2025 and 2050 respectively. In the baseline condition, about 40% of the total grid cells in the country are in no deficit condition while about 45% of the grid cells are in the highest deficit interval. Water availability index indicates that water deficit is the highest in the NW region and the second highest in the SW region. One may note from these figures that whether in the baseline or the climate change condition, both the surplus and the most stressful situation dominate. The moderate stress conditions are comparatively rare. Second, as the climate change develops, compared to the baseline the number of grid cells in the no-stress situation decrease. In 2025, the number of grid cells in the highest stress interval increases for PRECIS-A2. In 2050, HadCM3-A2 shows increases in the number of grid cells in the highest stress interval while PRECIS-A2 shows a slight decrease.

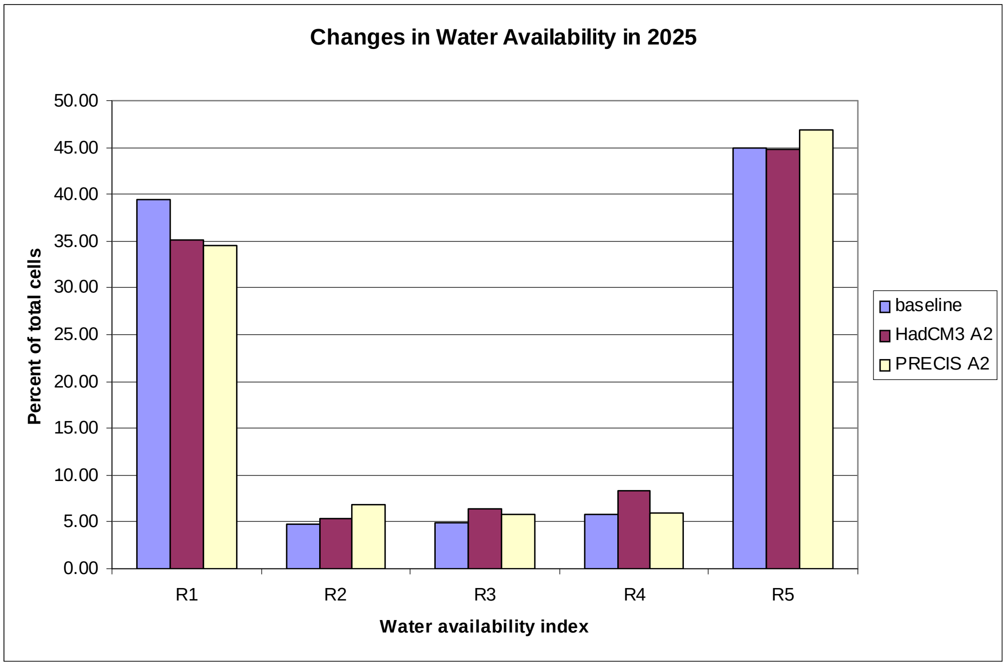


Figure 5.9: Changes in Water Availability in Bangladesh in 2025 due to CC

<u>Water availability index (WI)</u>

R1: 1≥WI ≥0, R2: 0 ≥WI ≥-0.25, R3: -0.25 ≥WI ≥-0.5, R4: -0.5 ≥WI ≥-0.75
R5: -0.75 ≥WI ≥-1

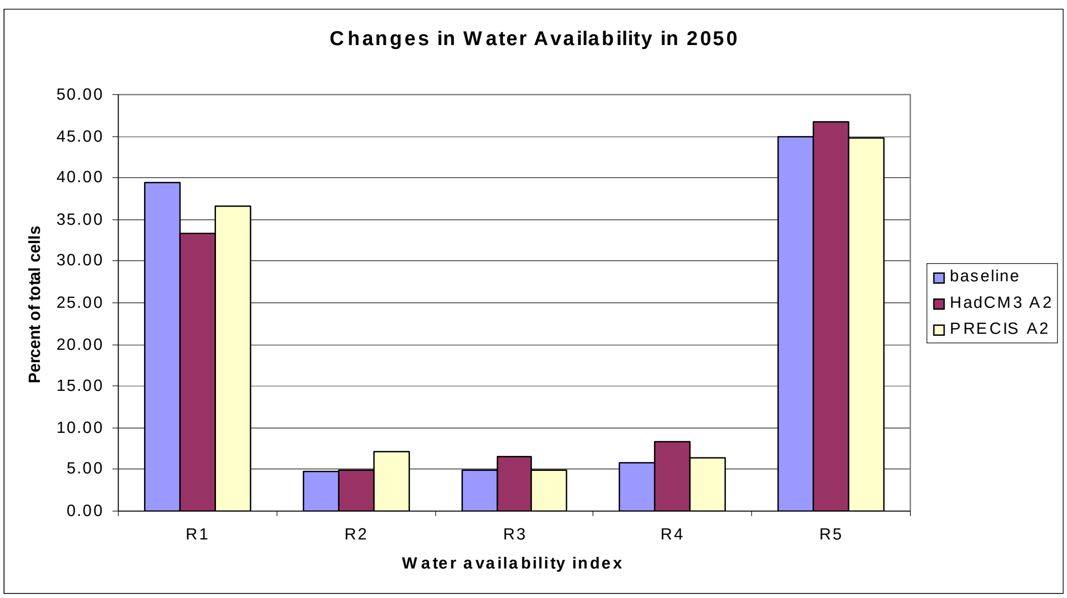


Fig. 5.10: Changes in Water Availability in Bangladesh in 2050 due to CC

<u>Water availability index (WI)</u>
R1: 1≥WI ≥0, R2: 0 ≥WI ≥-0.25, R3: -0.25 ≥WI ≥-0.5, R4: -0.5 ≥WI ≥-0.75, R5: -0.75 ≥WI ≥-1

Flooding in future

Flood occurs every year with clockwork regularity. In an average year 20-25% of the country is inundated due to river spills and drainage congestions. Results from a recent study which has used MIKE 11 and MIKE BASIN models have been chosen to illustrate some of the possibilities regarding future flooding in the country. The results of the flooding analysis have been presented here based on flood depth classification.

This classification includes five flood phases/land type, based on a three-day maximum flood depth, theoretically with an exceedence return probability of 1 in 2 years. In this classification F0 is 0-30 cm; F1 is 30-90 cm; F2 is 90-180 cm; F3 is 180-300 cm and F4 is over 300 cm of maximum flood depth. Fig. 5.11 illustrates 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 2030s and 14% by 2050s. Given that in years of severe flood, 80% or more of the country may be inundated at one time or other, these are dire predictions indeed.

Flash Flood and its Characteristics

In Bangladesh flash floods generally occurs in the north-east, south-east and Chittagong region. But devastating and extended flash flood is a recurrent phenomenon for the north-east region of Bangladesh. Flash floods normally occur between mid-April to end April. Recently this trend has been changing and local people reported that in recent years flash floods have been coming earlier than usual.

Drought

Droughts are a recurrent feature in Bangladesh. The droughts occurring in Bangladesh are not meteorological droughts but merely agricultural droughts which could be also termed as severe moisture stress. Generally, two critical dry periods are notable in Bangladesh (Karim et al., 1990). Rabi and pre-Kharif drought (January/May), due to: (i) the cumulative effect of dry days; (ii) higher temperatures during pre-Kharif (> 40^{0}C in March/May); and (iii) low soil moisture availability. The drought affects all Rabi crops, such as HYV Boro, Aus, wheat, pulses and potatoes especially where irrigation possibilities are limited. Drought affects sugarcane production. It also affects fruit trees, such as jackfruit, litchi, and banana, which often die during this period. But the loss of rice production is the most costly damage incurred through droughts in Bangladesh.

Kharif drought from June/July to October, created by sub-humid and dry conditions in the highland and medium highland areas of the country (in addition to the west/northwest; the Madhupur tract in the central parts of the country is also drought prone). Shortage of rainfall affects the critical reproductive stages of transplanted Aman rice crops in December, reducing yield, particularly in those areas with low soil moisture holding capacity.

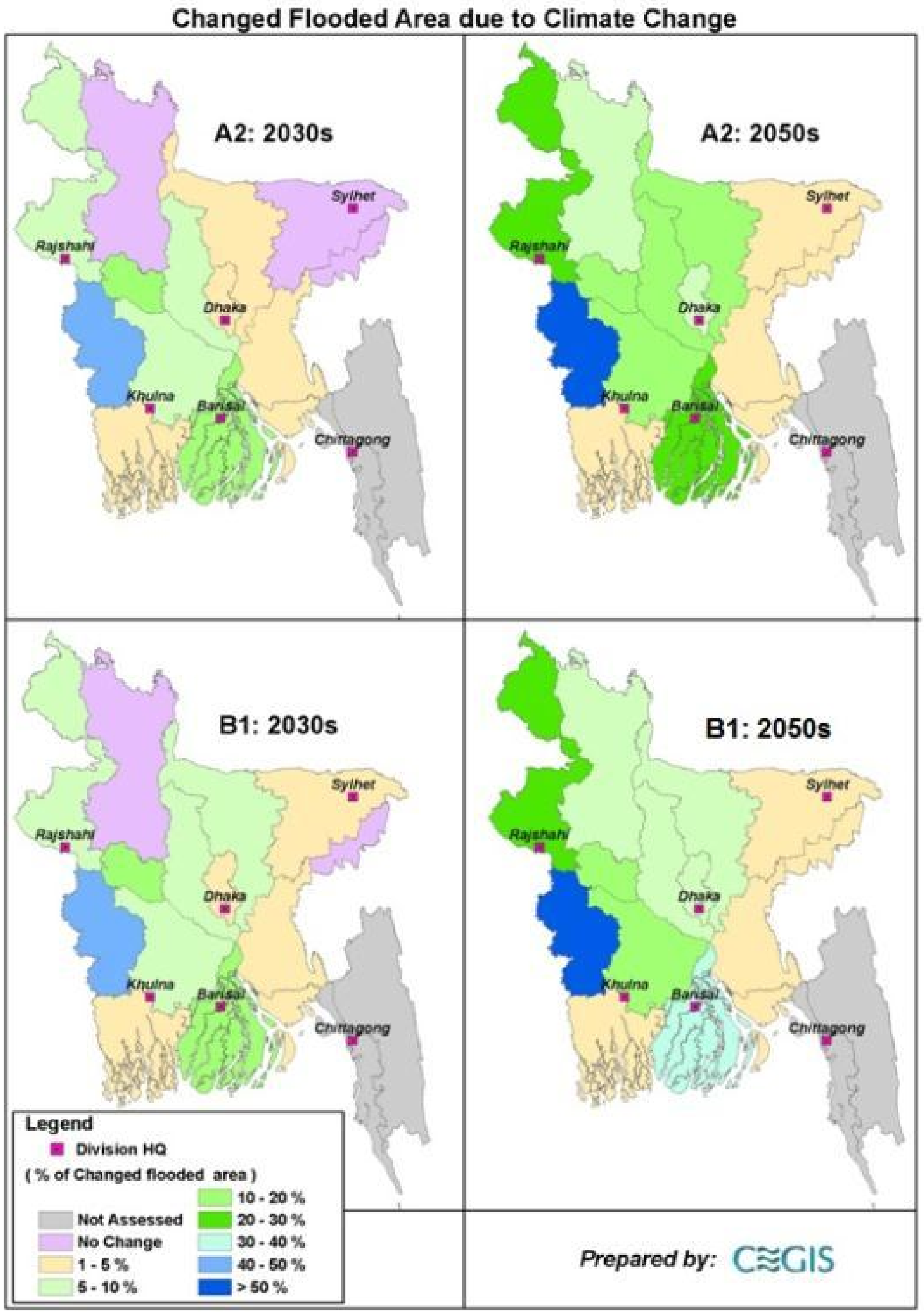


Fig.5.11: Changes in Flooded Area in Bangladesh in 2030s and 2050s

Salinity Intrusion

Salinity and its seasonal variation are dominant factors for the coastal eco-system, fisheries and agriculture. Therefore, any change in the present spatial and temporal variation of salinity will affect the biophysical and human systems of the coastal area. A recent study has assessed the present salinity situation and the future up to 2050 in the coastal areas. Figures 5.12 and 5.13 present isosalines for the present and for 2050 respectively.

These figures indicate that in the base condition about 10% area is under 1 ppt salinity and 16% under 5 ppt salinity. The respective saline areas will increase to 17.5% (1 ppt) and 24% (5 ppt) by 2050. So, there will be around 7% increase in area under 5 ppt salinity levels.

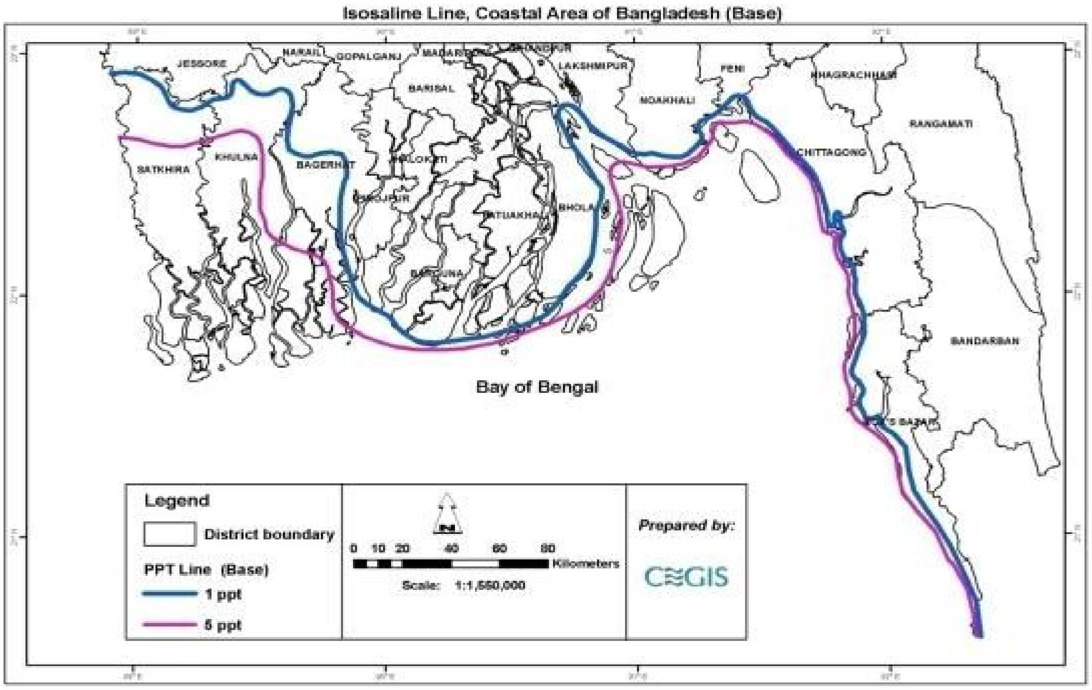


Fig.5.12: Salinity Condition in Coastal Area (base condition)

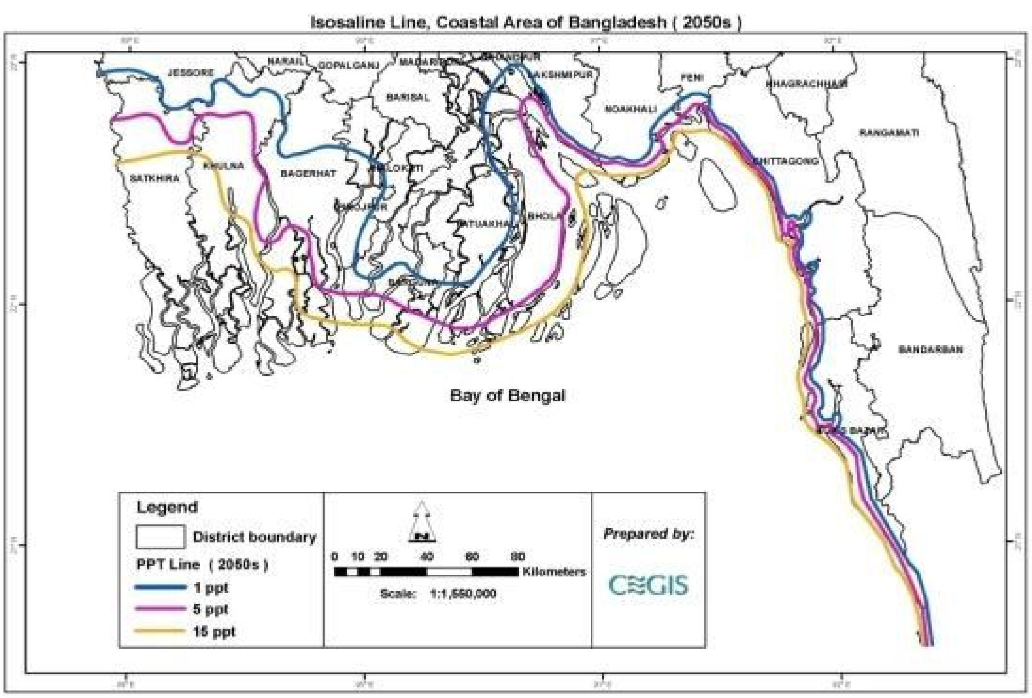


Fig. 5.13: Modelled Salinity Condition in Coastal Area (2050)

River Erosion and Accretion

Bangladesh is a riverine country. The morphology of the country's rivers is highly dynamic and river bank erosion is also a regular phenomenon, particularly along the banks of the main rivers. In a study by CEGIS (2009), two major rivers–the Jamuna and the Padma have been considered asproxies for riverbank erosion in Bangladesh(Fig.5.14).

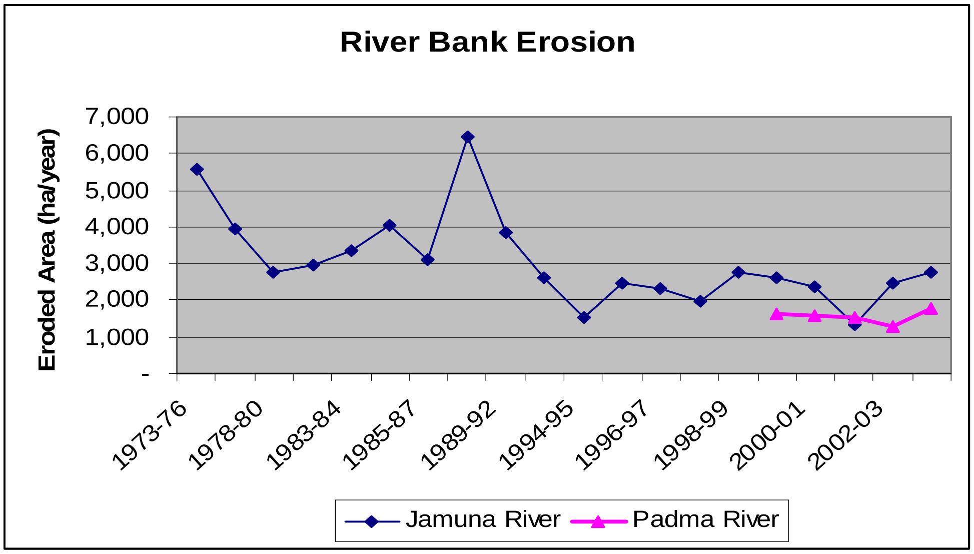


Figure 5.14: Riverbank erosion in the Jamuna and Padma rivers, Source: CEGIS 2009

The present rate of the Jamuna bank erosion is about 2500 ha per year while bank erosion by Padma river is about 1500 ha per year. In 2008, erosion along the bank of the Jamuna was 530 ha, along the Ganges around 880 ha, and the Padma 535 ha, of which about 85 ha, 75 ha, and about 100 ha respectively comprised settlements.

The Jamuna river is widening over time as found in a study. This means that the river is eroding its banks. The river has been widening at an average rate of about 130 m per year. This corresponded to a loss of about 70,000 ha in 23 years, while only 11,000 ha had been accreted Changes in the river flow and sediment transport due to multi-faceted impacts of climate change are expected to increase the dynamics of these rivers even more.

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

At Bhairab Bazar (Meghna), peak discharge is decreasing and delaying slightly as it has moved to the last week of September from mid-July in the late 1970s. At Hardinge Bridge station on the Ganges, peak discharge is increasing but the time of peak is advancing. The date is advancing by about one day in a decade. If the present trend of advancing of the peak prevails, the chances of coincidence of Ganges and Brahmaputra peaks will be less lessening the probability of catastrophic and long-duration floods.

Potential Adaptation in Water Resources Sector

Water-related natural hazards have been common in Bangladesh and so have been the attempts to manage water regarding surface flows, inundation, ground water use, drought, and water logging in various ways. A substantial part of the efforts has gone into structural measures such as construction of embankments, polders and dykes depending on situation against flood, saline water intrusion and over-topping by storm surges in the coastal areas. The situation is made more complex due to the fact that 85-86% of the river surface water flow originates outside the international border in the neighboring countries and without a regional framework for sharing and caring for water, some of the efforts now or in the future may not bear much fruit.

Excavation (removal of siltation) of river systems to allow greater passage for drainage during peak flood periods, creation of safe haven for economically and strategically important areas, revisiting and strengthening of embankment systems along the coastal zones, implementation of tidal river management in the longer run to avoid water logging, allowing sustained flow regime in the sea going rivers along the Ganges Dependent Areas by means of regulating and managing flow through a barrage system in the Ganges, engaging in regional cooperation to ensure greater flow regime in other non-negotiated international river courses are amongst the high priority adaptation ideas recommended by experts and scientists.

There are about 3,000 cyclone shelters throughout the coastal zones which can help over 7 million coastal dwellers at times of cyclones. These cyclone shelters need to be built in greater numbers and their designs may need to be changed to make those more user-friendly including better suited for use by women than at present.

The BCCSAP has called for embarking upon knowledge management in order to reduce people's vulnerability, especially regarding water resources. Systematic research will be necessary to highlight where to place focus and how soon the relevant institutions must consider adaptation. Collection and generation of data and monitoring of the currently deployed mechanisms should also be done with utmost care. In an attempt to further reduce future investments from water related hazards, land use processes should be guided based on the situation on the ground. Land use zoning may be given high priority in certain situations.

The Table 5.6 below briefly mentions the major adaptation needs and modalities to be considered for the water resources sector in Bangladesh for the future:

Table 5.6: Major Adaptation Modalities for Water Resources Sector

Water Related Issue	Major adaptation modalities perceived / recommended
Flood	• Early Warning System (including EWS for flash floods) • Revisiting embankment design, adjusting embankments as per local situation and predicted climate change impacts • Frequent monitoring of weak embankments, repairing of weak embankments • Water infrastructure realignment / re sectioning • Raising plinth height of infrastructure (where possible), including dwellings • Building flood shelters, building rural markets above flood levels • Designated high grounds / increasing height of grounds above flood levels to maintain cattle during flood (including community surveillance) • Community based flood management
Drought	• Irrigation for compensating water deficit • Re excavation of canals / ponds / *Kharees* • Improvement in water use efficiency • Bringing a balance between the use of both groundwater and surface water towards irrigating crop lands

Water Related Issue	Major adaptation modalities perceived / recommended
In-stream salinity ingress	• Flow regime improvement • Ganges barrage and linking canals (as in case of NWMP) • Drainage improvement
Storm surge	• Revisit design criteria of coastal embankments • Tidal river Management • Early warning System • Coastal afforestation • Desiltation of rivers at estuary
Cyclone	• Cyclone Shelters • Evacuation planning and drill • Enhancement of CPP • Killa for livestock • Early warning System • Coastal wind barrier / green belt
Erosion	• Early warning System • Rivetment, flow diversion by structure • Resettlement in safer places
Drinking water availability	• Drainage and storage facilitation • Alternative water supply systems: rainwater harvesting, pond sand filters, desalinization • Regional cooperation to forge water sharing treaty with neighboring countries
General	• Develop long-range weather forecasting capacity • Knowledge management • Research • Data updating • Monitoring / surveillance of infrastructure • Land Use Zoning • Planned Urban development

5.6 Crop Agriculture

5.6.1 Present Status and Expected Problems

In Chapter 2 on National Circumstances, the present trends and structure of agriculture have already been discussed. To reiterate, the cropping system is largely rice-based. While rice can be grown in three seasons, at present boro, the irrigated rice during largely rainless months of late winter / early summer accounts for nearly 60% of total domestic rice production. Aman, which is partly rain fed and partly irrigated (if supplementary irrigation is needed at later stage of plant growth), accounts for much of the rest of the domestic rice output. As it has been seen earlier, drier months are likely to be even drier in future and wet months wetter. That means in general, the aman which is now affected by floods, erratic rainfall and coastal cyclones and storm surges is likely to be even more so while boro will be more dependent on irrigation. Given these uncertainties, one may try to model the future of rice production. This has been attempted using a DSSAT model of rice production in the future.

Climate Change and Crop Agriculture

Climate change may induce several other changes in the conditions for crop agriculture. It changes the temperature, rainfall, and consequent availability of soil moisture and it changes the carbon content of the atmosphere. All three impact upon plant growth and output in various ways. In case of salinity increase, climate change also changes the quality of water which influences plant growth and output some time very adversely. Then again, the various second round physical impacts as well as extreme events do lead to crop losses. Ideally modeling climate change impact on crop agriculture needs to take all these factors into account but it may be quite complex. Hence some of the results we shall show of exercises done with crop models should be taken more as indications of the gravity and direction of the future situation rather than definitive expected changes.

Vulnerability of the Crop Agriculture Sector

A recent study used the Decision Support System for Agrotechnology Transfer (DSSAT v4.5) model to simulate crop yields under a range of climate change scenarios in Bangladesh. Crops chosen were rice under three seasons (Aus, Aman and Boro) and wheat. No minor crop yield or output could be modeled. Simulations of changes in cereal yield include impacts from climate elements only (CO_2, temperature and precipitation) as well as of riverine floods and coastal inundation, both separately and in combination.

The results of impacts from climate only (CO_2, temperature and precipitation) are presented in Fig. 5.15. The impacts on Aman, Aus and Boro rice and wheat are shown here at district level. The changes are for the 2050s in percentage of yield change due to climate change impact. The figure indicates that there will be positive effects on Aman, Aus and wheat yield almost in all districts while almost all districts will experience negative impacts on Boro yield. Note that this does not include the losses due to natural hazards which is indicated in the Figs.5.16a to c.

As DSSAT could not include the effects of flooding, a methodology developed for Bangladesh by Hussain (1995) has been used (Yu et al., 2010). The flooding damages include riverine flooding and sea level rise induced coastal inundation. For riverine flooding, only Aman and Aus have been considered as Boro and wheat are grown during the dry season. Flood damages are assessed according to the duration that rice plants are submerged to various percentages of the plant height, as well as the rice phenological stage when the flood occurs. Figs. 5.16a-c present the crop damage (aman) due to flooding. These damages assume clear flood waters, which are slightly less damaging than water with high silt content (Hussain, 1995).

The results indicate clearly that late flooding and longer duration flooding are more damaging and that shallow and shorter duration flooding at mid-stage of plant growth is less damaging. Yet, if the flooding is widespread, it may mean much damage in terms of total output.

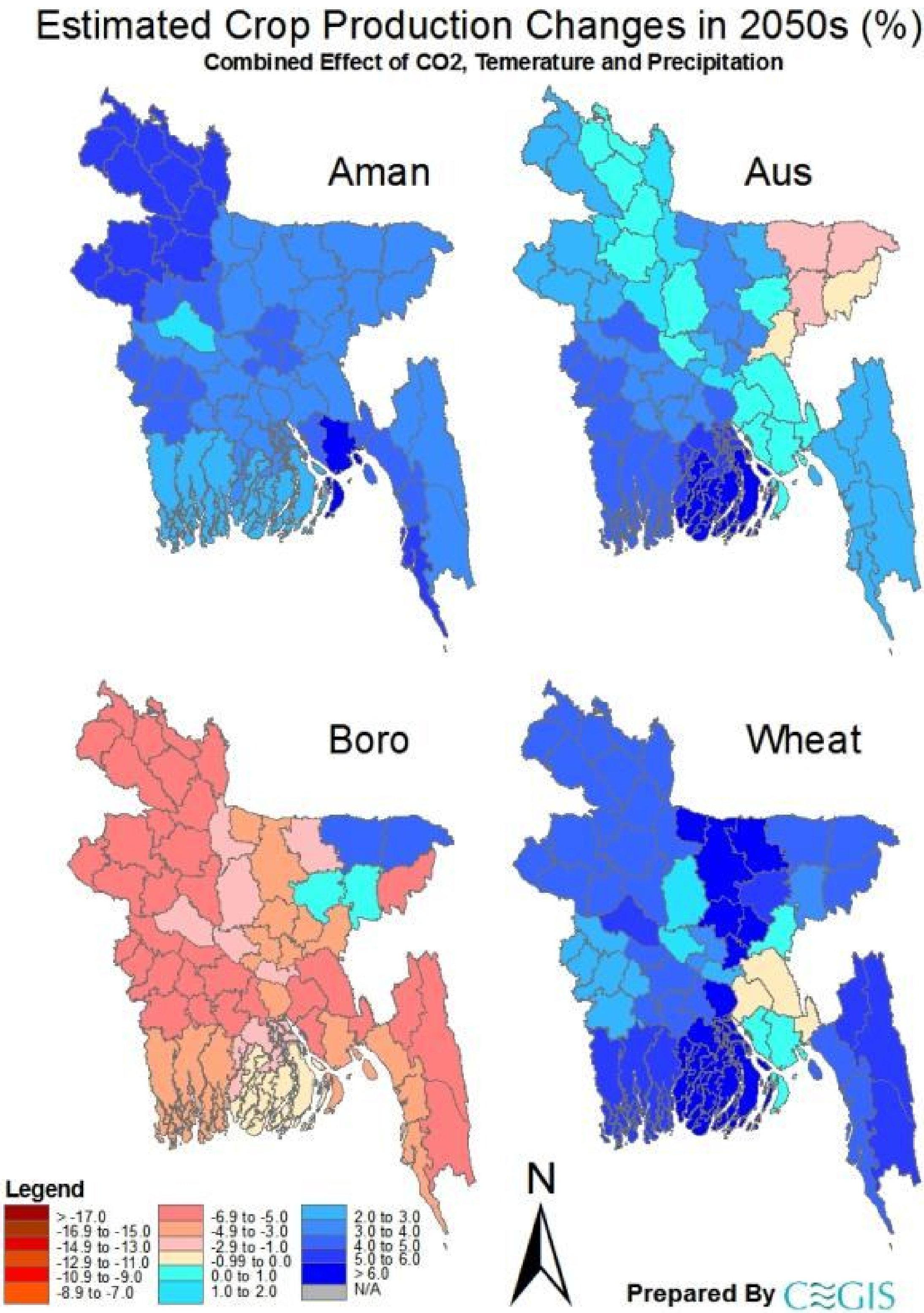


Figure 5.15: Estimated Crop Output Changes in the 2050s for CC Impact

(Source: Hassan et. Al., 2010)

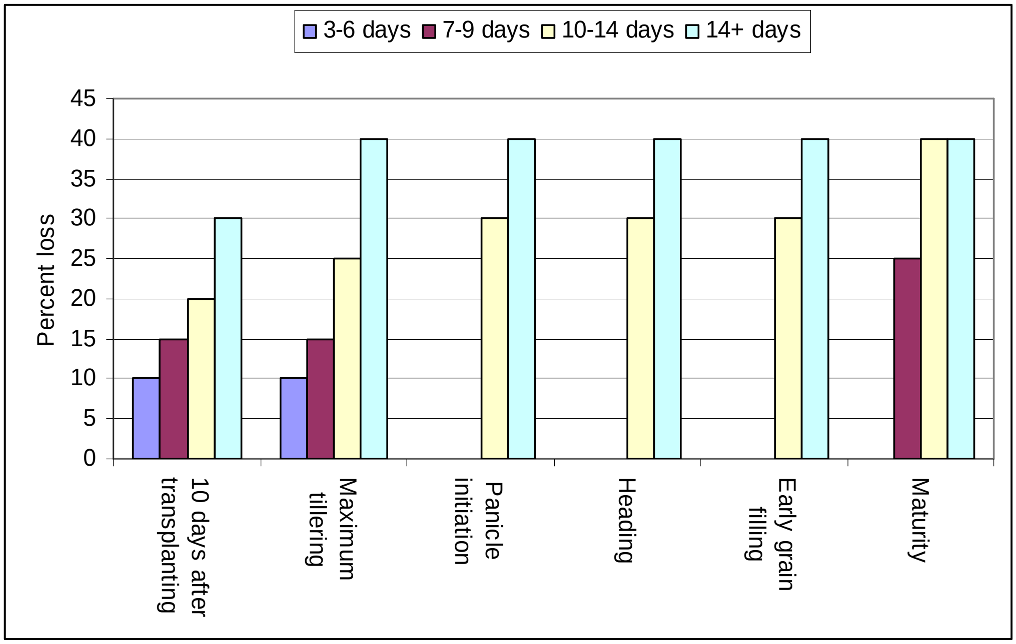


Fig. 5.16a : Rice Yield Loss by Stage of Plant Growth, Depth and Duration of Inundation
(Flood depth 25-50% of plant height)

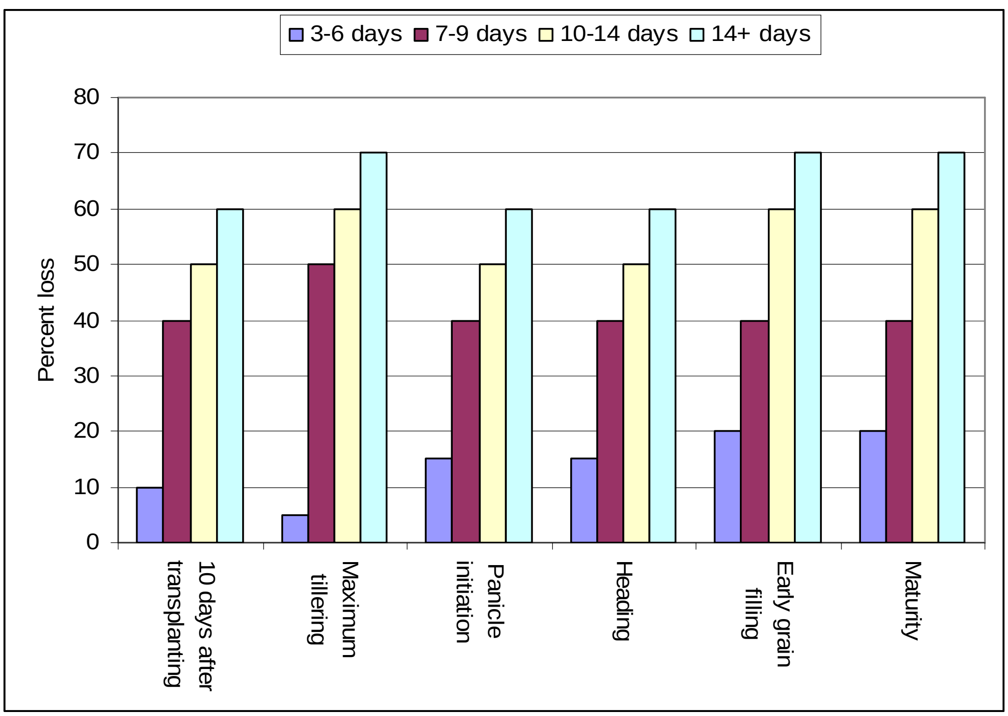


Fig5.16b: Rice Yield Loss by Stage of Plant Growth, Depth and Duration of Inundation
(Flood depth 50-75% of plant height)

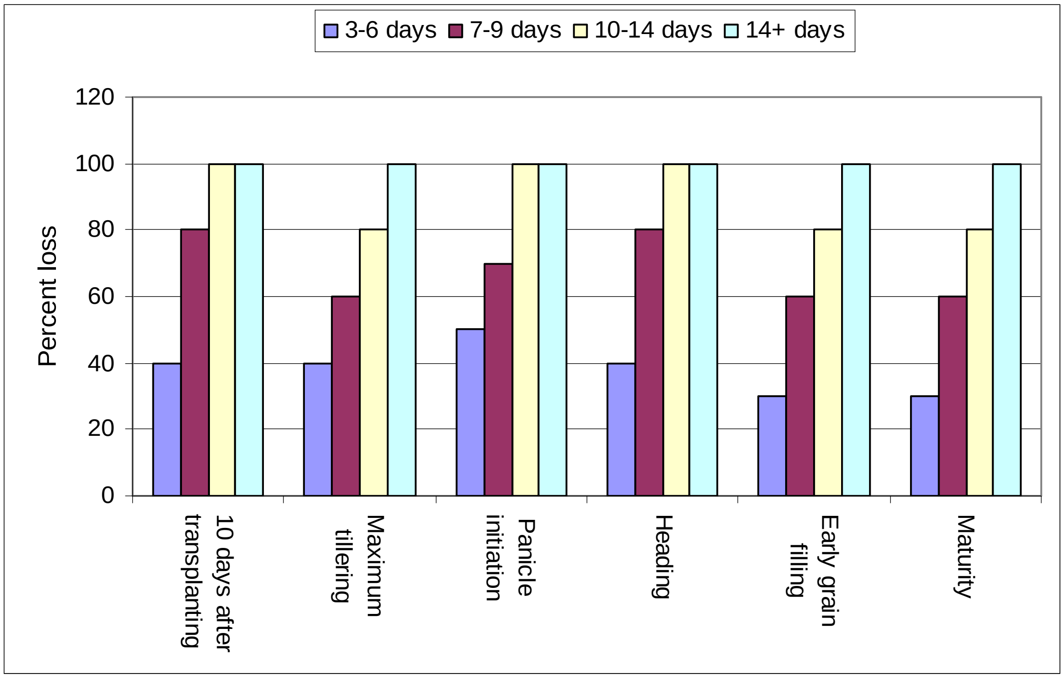


Fig. 5.16c: Rice Yield Loss by Stage of Plant Growth, Depth and Duration of Inundation
(Flood depth 75-100% of plant height)

The impacts of sea level rise induced coastal inundation have been assessed based on changes in area due to future coastal flooding. The combined effects of climate, river flood and coastal flood are presented in Fig. 5.17. The results show positive impact in case of wheat production and negative effects for Boro production. Aman production shows positive effects in most of the parts of Rajshahi and Chittagong divisions and negative effects on other parts of the country.

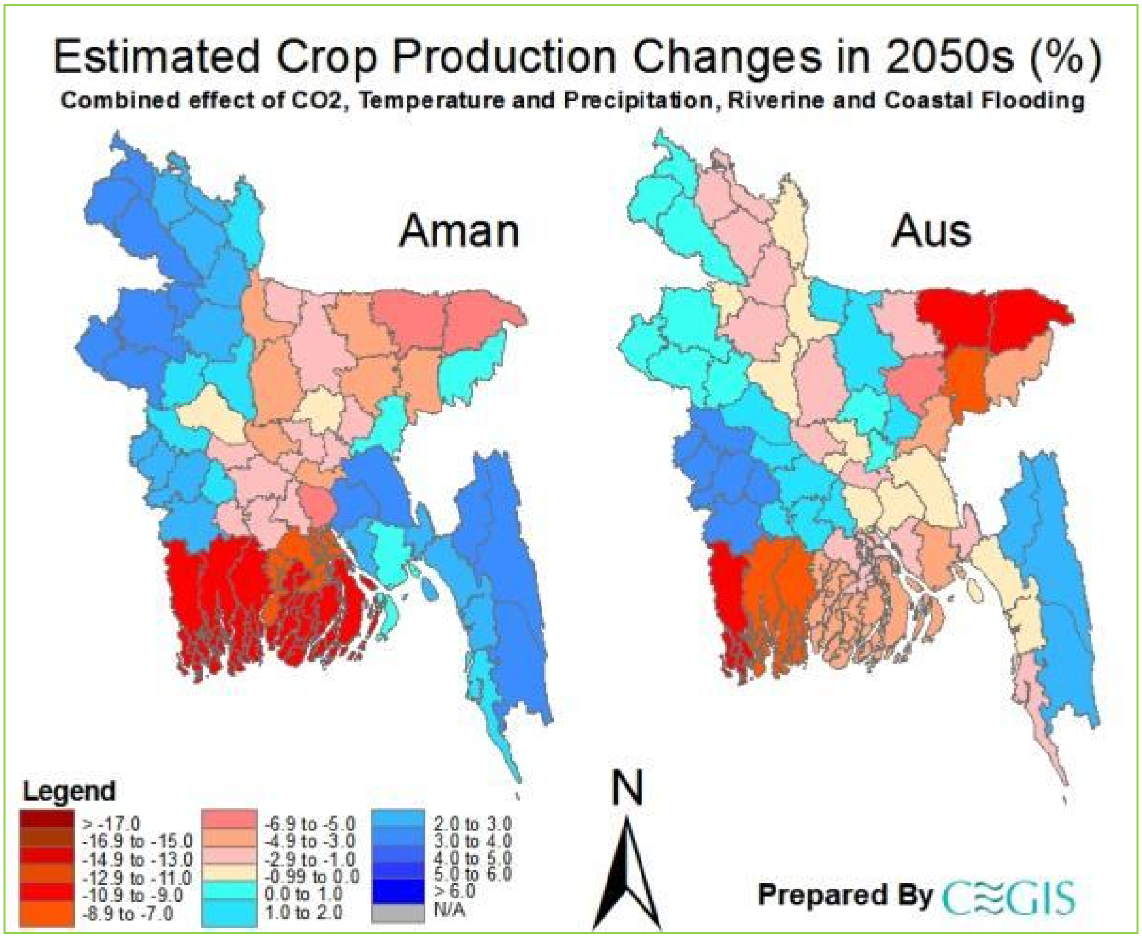


Fig. 5.17: Combined Output Effects of CC and Flooding Damages in 2050s
Source: Hassan et. al., 2010

Impacts of Flash Flood on Crop Damages

Flash floods have several impacts on the physical environment such as those on river morphology (changing channel topography, sedimentation) and vegetation. They also cause major damage to crops, infrastructure, culture fisheries, and homesteads. Flash floods are a major problem for agricultural production in Sylhet division in the north-east. During the period from 2000 to 2004, Boro crop areas in Sylhet division that has been fully and partially damaged by flash floods were about 4.7 lakh and 3.0 lakh acres respectively. Loss of boro paddy production during these periods was about 5.7 lakh metric tons.[1]

Flash flood water carries sediments, which are eroded from the hilly catchment area. During heavy rainfall in the hilly region, massive erosion takes place on the exposed surface of the hill. If the high intensity rainfall is continued for certain period then coarser sediment such as big sized stone, boulders etc start to erode and move along the rivers. Finally, these sediments are deposited on the riverbed, khals, canals, beels and agricultural land causing sand carpeting.

During flash floods, sediment transport rates increase significantly of the rivers. and over the years, sediment has get deposited mainly on the riverbed and depressed portion of the

[1] I lakh is 100 thousand.

haor. According to local people, about 4 to 5 m sediment has been deposited in some places on the riverbed, which has created an obstruction for water flow, allowed flood waters to overflow the banks easily and causing bank erosion as well as hampering the river navigation system in the northeast region. In some cases drainage congestion has taken place. Due to deposition of sediment, the wetland beds have been raised causing scarcity of water in the dry season and ultimately hampering fisheries and agricultural activities.

Crop Production Changes Due to Salinity

In Bangladesh, over 30% of the cultivable area (2.85 Mha) is in the coast of which 0.83 Mha are adversely affected by different degrees of seasonal soil salinity. In an average year, salinity not only causes a net reduction of about 0.2 Mmt of rice production, but also diminishes potentials of boro and wheat cultivation in saline affected soils of the coastal areas (World Bank: 2000).

The impact of soil salinity on crop yields in the coastal area of Bangladesh was studied in 170 locations by BARI and reported by the MPO (1986). According to BARI data, the reduction in local transplanted aman yields ranges between 11 and 35% on moderately saline soil and increases with salinity to a maximum of 72% on highly saline (S4 category) lands.

For estimating the damages to crop production due to salinity, several damage factors have been considered based on salinity levels. Table 5.7 presents these factors. These figures indicate that the soil salinity increase can be a major threat to crop production. This will happen in more than one way. First, more and more land may be inundated due to SLR which will affect more land with salinity and secondly less saline lands will become more saline as these get inundated due to tidal and similar influences for longer periods as well as lowering of fresh water flows or lower rainfall if these happen. Only by modeling salinity intrusion for which there is some analysis and then overlapping that with present cropping patterns and their future changes would it be possible to estimate these future damages.

Table 5.7: Crop Damage Factors for Salinity Levels

Salinity Level (ppt)	**Damage factor**
>0 – 0.5	0.4
0.5 – 1	0.6
> 1	1

Impacts of drought on crop yield

While Bangladesh experiences on average high rainfall, drought is not totally uncommon in the country. Drought prone areas are those where dry climatologic and hydrologic conditions, limited water availability (precipitation, soil moisture, groundwater, surface water and inadequate irrigation facilities) result in significant reduction in agricultural yield. Due to shortfall in local rainfall and other factors as mentioned drought conditions may prevail during the basically rainless rabi season as well.

During the last 50 years, Bangladesh suffered about 20 drought conditions. Between 1949 and 1979, major drought occurred in 7 years out of thirty with the lowest affected area being 18% in 1966 and the highest 47% in 1957. The drought condition in northwestern Bangladesh in recent decades had led to a loss of rice production of 3.5 million tons in the 1990s. If losses to other crops are accounted for the over-all damage to income and livelihood of people becomes much heavier.

Drought in Bangladesh is generally considered for the two cropping periods of the year. They are: a) the Rabi and pre Kharif period, which starts from November and ends in June, with the critical dry period of this season starting from March and continuing up to May; and b) the Kharif period, between July to October, with the critical dry period generally comprising the months of September and October. Hence the future rainfall patterns during these two periods become crucial for the availability of water for soil moisture, irrigation and also for human consumption.

Some analysis has been done based on models of drought in future years. The drought analysis for rabi season considers the temperature, while the Kharif season considers both rainfall and temperature. For the Kharif season, monsoon precipitation may increase by 12% and 27% for 2020s and 2050s, respectively. Fig. 5.18 shows how area under drought may affect the country in the future. A temperature rise of 1 degree Celsius is assumed for 2030 and a 2 degrees Celsius rise for 2075.

Drought is extremely damaging to crop yield. For transplanted aman even for moderate drought, 35-40% yield reduction may take place. For more severe drought it may go up to 45%. For wheat and potato, for moderate drought the yield losses are estimated to be up to 50%. Quite naturally unless adaptive measures are there with increased areas experiencing drought in future, there is likely to be heavy crop output damages.

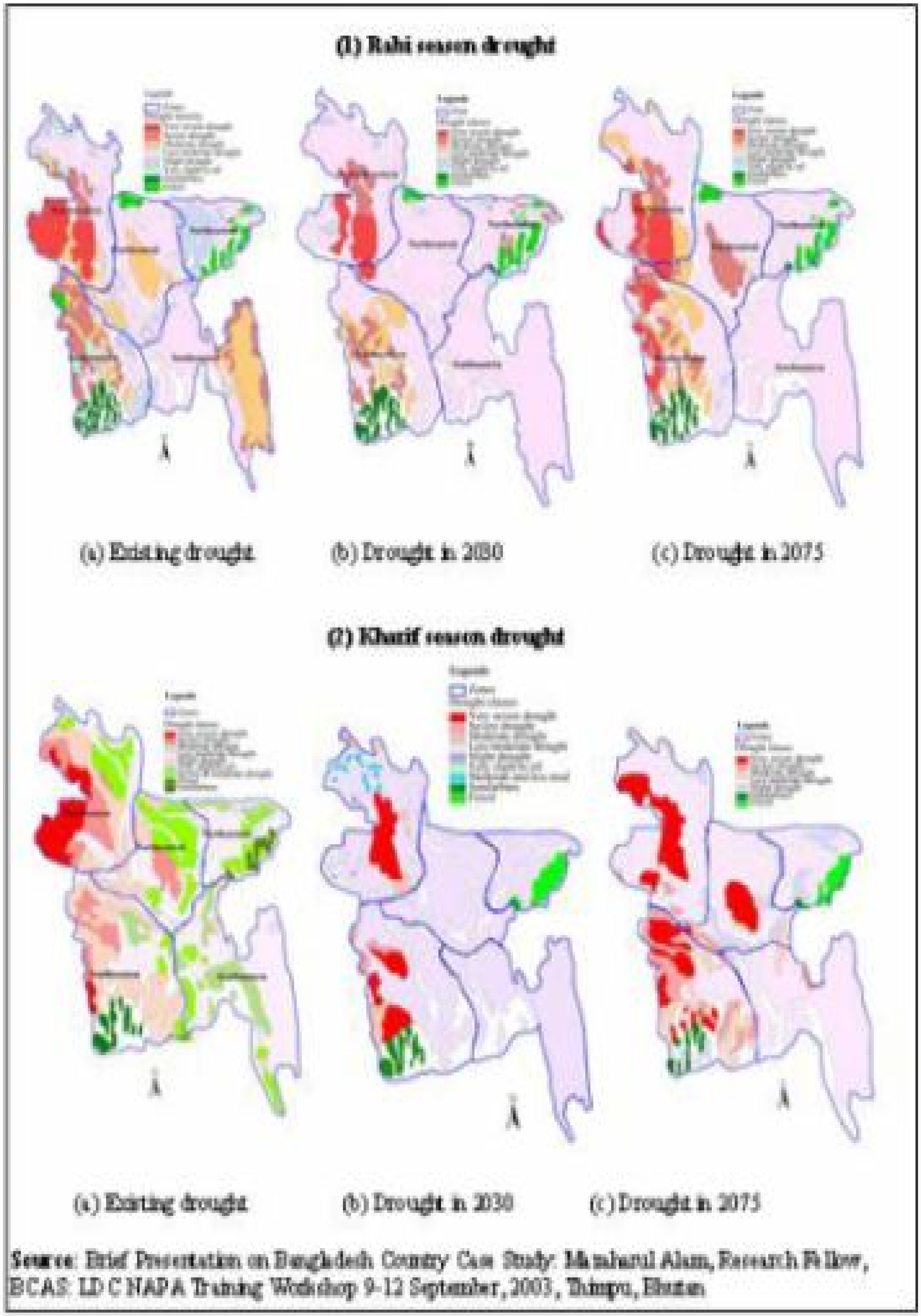


Fig. 5.18: Existing and Future Drought-affected Area

5.6.2 Adaptation Measures in Crop Agriculture Sector

Over time there has been analyses of the various types of adaptation that may be applicable to crop agriculture. These include development and cultivation of varieties more suitable to the changed agro-climatic and hydrologic conditions, avoidance of hazardous conditions, and risk spreading by various means (mixed cropping, insurance). However, as it is the farmers who actually have to be the main agent of change, awareness building among farmers through various kinds of extension activities including farmer's field schools, demonstration plots, the use of folk media, etc. should also be part of the adaptation mechanism.

Furthermore, an enabling situation needs to be created through R&D for new varieties, new cropping systems and new agronomic practices. There had been some recent successes in Bangladesh in this case A good number of climate stress-tolerant varieties of rice have been developed. These include varieties which are tolerant to moderate salinity, drought, flood and also varieties of shorter maturity which allow avoidance of late drought. The flood tolerant variety is remarkable in the sense that it can withstand submergence for two weeks or so yet do not significantly lose its yield potential.

Adaptation options in crop agriculture can be classified into the following categories:

- Technological developments (e.g., new crop varieties, new cropping systems and agronomic practices, water management innovations);
- Government programmes and insurance (e.g., agricultural subsidies, insurance);
- Farm management practices (e.g., crop diversification, irrigation); and
- Farm financial management (e.g., income stabilization programmes).

These adaptations could be implemented by a number of different groups, including individual producers, government organizations and the agri-food industry. These groups have differing interests and priorities, which may at times conflict. Therefore, before determining which adaptation options should be promoted or implemented, these should be carefully and thoroughly assessed.

Based on the classification, adaptation options can be further divided into high, medium and low priority categories as shown in Table 5.8 below.

Table 5.8: Adaptation Option with Priority

Adaptation options		High	Medium t
Technological developments	New crop varieties	✓	✓
	Water management innovations	✓	
Government programmes and insurance	Agricultural subsidies	✓	✓
	Insurance	✓	
	Credit support	✓	✓
Farm management practices	Crop diversification	✓	✓
	Irrigation	✓	✓
	Fertilizer	✓	
	Pesticide	✓	
	Seed	✓	✓
Farm financial management	Crop shares	✓	
	Income stabilization programmes	✓	✓

Note: Tick mark means need of high, medium or low priority for action or investment

The applicability and success of different adaptation options will vary greatly depending on the specific situation and the type of adaptation. To determine whether an adaptation option is appropriate for a given situation, its effectiveness, economic feasibility, flexibility, and institutional compatibility should be assessed. In addition, the characteristics of the producer and the farm operation should be considered, given the nature of the climate change impact.

More importantly, however, the adaptation option should be assessed in the context of a broader decision-making process. Researchers agree that agriculture will adapt to climate change through ongoing management decisions, and that the interactions between climatic and non-climatic drivers, rather than climate change alone, will direct adaptation.

5.7 Fisheries Resources

5.7.1 Present Status and Expected Future CC Impacts

Present status

In Chapter 2 a brief description of the present fisheries situation has been provided. At the cost of repetition it may be said that the fisheries sector plays a vital role in income, employment (including women's employment), nutrition, and foreign exchange earnings and other areas of the economy of Bangladesh. The fisheries sector accounts for 4% of the GDP of the country and within agriculture contributes nearly 23% to gross value added.

There are two basic sources of fish, inland and marine. The inland fishery is divided into three types, viz., flood plain fishery which is seasonal and the capture fishery in the rivers, wetlands, mangroves etc. There is also culture fishery. Each of these (capture and culture) accounts for nearly 40% of the total catch. Marine fishery accounts for the rest. Nearly 5 mn ha of land is permanently or seasonally used for fishing. What happens to fishes under CC depends on what happens to the fish habitats as well as the impact of several climatic factors on fish at different stages of life.

In the inland open water system of Bangladesh, there are 264 species of finfish belonging to 55 families (Rahman, 2005), about 63 species of *palaemonied* and *penaeid* prawn and several species of crab belonging to the *Potamonidae* family. In addition, 31 species of turtles and tortoises are found of which 24 live in freshwater (Sarker and Sarker, 1988).

Climatic factors linked with fisheries and aquaculture

Different climatic parameters like temperature, rainfall, ocean acidification, sea level rise induced salinity intrusion and other extreme events all affect fishery habitats, fish physiology, growth, species distribution and ultimately fish production. Among the climatic parameters, temperature and rainfall are driving factors that affect fish growth and yield directly. Furthermore, growth and yield may fall/rise abruptly when extreme conditions of drought, flood or high temperatures occur (World Fish Center, 2008). However, in Bangladesh the critical aspects of climate in relation to fish culture depend on (a) the onset time and reliability of the pre-monsoon rains; (b) the reliability, extent, distribution, and ending time of the monsoon rains; and (c) the rise, duration, and recession of floods (Das & Shaha, 2008). On the other hand, extreme events not only affect fisheries production but also affect fisheries dependent livelihoods.

Climate change impact on fisheries

The adaptation study has attempted to examine the impacts of climate change on open water (floodplain) fisheries and aquaculture. Maintenance cost for pond fishery during the summer season has been assessed also.

Indicative species for climate change impact assessment

Impacts on fisheries have been assessed for three types of fish habitats i.e. fresh, brackish and marine water. For capture fisheries seven indicative species were selected while three species were selected for fresh water culture fisheries and two species were selected for brackish water aquaculture.

The following Table 5.9 shows the indicative fish species selected for climate change impact analysis.

Table 5.9: Indicative Species along with Their Habitats Selected for Impact Assessment

Habitat Category	Habitat Type	Local Name	Fish Species
Capture			
Fresh Water Habitat	River	Rui	*Labeo rohita*
		Ayer	*Sperata aor*
	Beel	Catla	*Catla catla*
		Shingh	*Heteropneustes fossilis*
		Shol	*Channa striatus*
Brackish Water	Estuary	Ilish	*Tenualosa ilisha*
Marine	Sea	Bombay duck	*Harpondon nehereus*
Culture			
Fish Pond	Cultured pond	Rui	*Labeo rohita*
		Catla	*Catla catla*
		Mrigel	*Cirrhinus cirrhosus*
Shrimp/ Prawn Farm	Shrimp farm	Bagda	*Penaeus monodon*
	Prawn farm	Golda	*Macrobrachium rosenbergii*

Impact on fisheries ecosystem

Water is the life supportive medium for fish and other living aquatic organisms. Some of the changes in the hydrological system that are relevant to fisheries include increasing water temperature, increasing evaporative loss induced low flows, erratic rainfall induced flooding intensity and magnitude. Under the changing climatic regime for aquatic environment, the combined effect of rainfall and higher evaporation would have calamitous consequences.

Warming effect would exacerbate the existing environmental stresses for fish in rivers and wetlands. It may change the chemical composition of water where fish inhabits. Water holds less oxygen at higher temperature while fish requires more oxygen as the temperature rises. Most of the carp species are very sensitive to dissolved oxygen while some species like catfishes can thrive at the depleted level of oxygen. The standard parameters of the suitable environment for fish and shrimp are given in the Table 5.10

Table 5.10: Physical Parameter Preferences in Habitats for Fish Species

Species	Depth (m)	Cruising velocity	Timing of spawning migration	Temp (^{0}C)	pH	Turbidity (NTU)	Salinity (ppt)
Labeo rohita	1-1.8	300	May-July	28-34	6.8-7.8	5	-
Sperata aor	5- 30	65	April-May	28-34	6.8-7.8	5	-
Catla catla	1-1.8	315	June- July	28-34	6.8-7.8	5	-
Heteropneustes fossilis	0.15-0.2	60	March-April	29	6.8-7.8	5	-
Channa striatus	0.15-0.2	350	March-April	28-34	6.8-7.8	5	-
Tenualosa ilisha	14-18	160	September-October & February-March	17-28	6-8.5		0-40
Harpondon nehereus	10-40	50		17-25	6-8.5		11-30
Cirrhinus cirrhosus	1-1.8	280	June- August	28-34	6.8-7.8	5	-
Penaeus monodon	1.2	50	June-January	28-31	6-9		5-35
Macrobrachium rosenbergii	1.2	50	June- January	28-31	6-9		0-4

Breeding and recruitment

The majority of riverine fishes breed during the monsoon months i.e. May to August because of their dependency on seasonal floods which inundate the floodplain and which are essentially needed for reproduction and feeding. If precipitation decreases during the breeding months, it may alter the required flow and turbidity of the water essential for the breeding of major carp. On the other hand, if precipitation increases in post breeding months (September to December), when resumption of eggs sets in, it also hampers the spawning performance of major carp. The preferable temperature ranges at different stages of life cycle are given in Table 5.11.

Impact of rising temperature on fish species

Fish species are highly susceptible to temperature fluctuations. For assessing the fish vulnerability to temperature, a recent study considered the A2 emission scenario for 2050. According to the study shows that the prevailing riverine water temperature during DJF and SON is moderately suitable and riverine water temperature during MAM and JJA is highly suitable for the *rui* and *ayer* species in A2 scenario in 2050. Similarly, the prevailing floodplain water temperature during DJF is moderately suitable for the catla species. Water temperature during MAM is highly suitable for catla except in the Sylhet region while during JJA the floodplain area is highly suitable for catla. During SON the southwestern half is highly suitable and the northeastern half is moderately suitable for catla. Water temperature during DJF and SON is highly suitable for hilsha in the coastal area and major rivers. Pond water temperature during DJF is highly suitable while SON is moderately suitable for common carp. The MAM and JJA seasons have low suitability for common carp in the southwestern part.

Table 5.11: Preference Range of Climate Factors for Indicative Fish Species

Habitat	Species	Optimum temperature (°C)	Spawning temperature (°C)	Lower limit of temperature tolerance (°C)	Dissolved oxygen (mg/l)
River	Rui (*Labeo rohita*)	28-34	31.1-33.6	13.9	4-8
	Ayer (*Sperata aor*)	28-34	22.3-31	7	3-8
Beel	Catla (*Catla catla*)	28-34	28	18.3	4-8
	Shing (*Heteropneustes fosilis*)	20-29	26-29	4	3-8
Estuary	Ilish (*Tenualosa ilisa*)	17-28	23		4-8
Fish pond	Common carp (*Cyprinus carpio*)	20-25.9	22	15	4-8

Source: Boyed (1982), Das (1998), EGIS (1997)

Impacts on floodplain fisheries

Although climatic changes will affect most species to some degree, some species may be particularly vulnerable (such as *Labeo rohita*, *Heteropneustes fossilis*, etc.). In the event of climate induced reductions in habitat related quality or quantity, fish species in these habitats would be unable to migrate to potentially more suitable habitats in other drainage basins. In riverine systems, many species rely on inundated floodplains for reproduction, nursery habitats and successful recruitment, and the life cycle of these species are strongly dependent on the regularity of the seasonal cycles of the rainy and dry seasons.

A recent study investigated the changes of floodplain fish habitat area and corresponding fish production for 2030 and 2050 based on existing annual yield rate in two scenarios such as B1 and A2. In the study, the base floodplain fish habitat area was divided under various inundation level. The model results indicate that the overall floodplain fish production may increase by 3% by 2030 and by 9% by 2050 under the A2 emission scenario. For B1 emission scenario, the corresponding increases are 4 and 7%.

The average change, however, will be not be observed everywhere. Some regions will fare better than others. Recent model results also show that, among the 16 floodplain regions of Bangladesh, the highest production is in the north-eastern part of the country where the output change will be negligible, though it may not fall under either of the CC scenarios or either of the years. In general the output gain will be most in the regions which account for rather small proportion of total catch.

Hampered hatchery and nursery operation

Favorable temperature and rainfall are most important for successful fish breeding and nursery. A study has found that higher temperature and lower rain hampered fish breeding and nursery. Hatchery and nursery owners mentioned that due to higher temperature fish does not ovulate, eggs are not fertilized or are not fertilized well and hatching rate is low. On the other hand, absence of or lower rain fall has led to various adverse impacts on fish such as low water availability, reduced feeding behavior, disease prevalence and high mortality of fishes (Alam and Salam, 2009).

Pond based aquaculture might be affected by submergence of ponds

Generally, ponds are constructed 0.5-1.5m above flooding level to avoid overtopping during floods. Normally, the chance of fish pond overtopping is 1 in 8 to 10 years. With increasing river basin discharge flood of same intensity will occur with shorter return period. Quite a few of the hydrological regions will face such shorter periodicity of flooding. Thus, unless people excavate ponds at higher elevation, the chances of fish stock being washed away will be higher than before and the livelihood of fishermen or pond owners will be negatively impacted.

Similarly, the frequency and intensity of tropical cyclones may change for the worse. The peak intensity of cyclones may increase by 5% to 10% which would contribute to enhanced storm surges and coastal flooding for which coastal fish culture may be hampered. After the occurrence of the cyclone Sidr a very large survey of fish farmers of five coastal districts revealed that more than 60% of fish ponds and shrimp *ghers* (enclosed farming area) were fully damaged and the remaining 40% were partially damaged.

Increased operating cost due to increased temperature

Higher temperature may lead to increased operating costs for fish farmers. A study reports that 63% of the study respondents stated that due to higher temperature, the management cost had increased more or less 15% as increased temperature leads to increased aeration and other water management costs. At the same time, water installation and feeding costs also increased by 53 and 57%, respectively. Feeding cost increases as higher temperature increases the appetite of the fishes. Moreover, mortality has increased by 20% (Alam and Salam, 2009) indicating that costs per unit of output increases.

5.7.2 Adaptation Measures

Climate change is likely to affect freshwater fisheries adversely except floodplain fisheries. Due to climate change capture fish production, especially from floodplain fisheries, may increase due to expansion of flooded area while culture fish production (pond fish) may fall due to overtopping of floodwater and increase of temperature in the dry period. Sea level rise could also push saline water further into the Ganges-Brahmaputra-Meghna (GBM) delta reducing habitat for freshwater fish.

Under the context as stated above for capture fisheries, perhaps little can be done that relates specifically to the vulnerability of the fish production system to climate change. In fact, the largest part of it i.e., food plain fishery benefits from climate change in Bangladesh due to the rejuvenating effect of more extensive flooding. Yet, it may help further if the connectivity of wetlands is restored. On the other hand, note that more intensive flooding may harm capture fishery due to overtopping as well as rise in temperature creating problems at different stages of life for the fish. Raising of flood embankments and dykes may help, so will the development of speciestolerant to stresses such as higher temperature, salinity as well as introduction of species which are known for their better adaptability to adverse climatic conditions.

5.8 Livestock

5.8.1 Present Status and Expected Problems due to Climate Change

The current contribution of the livestock sub-sector to the overall GDP is about 2.73%, which is 17.15% of agricultural GDP. The export earnings from leather and leather goods is 4.31% of total export. Twenty percent of the population is directly and 50% is partly dependent on this sector.

The livestock population in Bangladesh, according to the Agricultural Census of 2008 was 25.6 million cattle, 0.5 million buffalos, 16.3 million goats, 1.3 million sheep, 98 million chickens and 39.4 million ducks. Most of it is held in rural households.

Bangladesh has one of the highest densities of livestock in the world, 145 large ruminants/km2 compared with 90 for India, 30 for Ethiopia and 20 for Brazil. Despite the highest density of cattle population in Bangladesh the productivity of all the species is far below the world average. Milk yield per head per lactation is 206 kg against the Asia average of 1220 kg, India-1014 kg and Pakistan 1179 kg (FAO-2005).

Impacts of Natural Hazards and Extremes on Livestock

The average weight of local cows ranges from 125-150 kg, bulls 200-250 kg that falls 25-35 short of the average weight of all-purpose cattle in India. Average body weight of goats is 8 kg, sheep 10 kg, buffalo 150 kg.

As has been discussed elsewhere natural hazards are quite common in Bangladesh and these affect livestock adversely. In 1987 and 1988, floods killed nearly 400 thousand cattle and buffaloes. Cyclone Sidr resulted in death of 1.8 mn cattle heads. The Agricultural Census of 2008 investigated the causes of death of livestock and found that of the 932 thousand deaths of large ruminants in 2008, 12% died due to flood, 8% in cyclones, and nearly 48% due to various diseases. In fact disease was a major cause also for small ruminants, poultry and duck.

Climate Change Consequences

How can climate change impact on livestock? There are several pathways. CC can change the feed availability and quality as well as availability and quality of water and thus indirectly affect livestock. Similarly increased natural hazards such as floods and cyclones can become major causes of mortality while more favourable climate for bacteria and pathogens may increase the disease burden of livestock. More directly, temperature and heat stress along with humidity beyond a certain threshold can cause major problems with the biological functions of the cattle and particularly in case of dairy cattle and may result also in death.

For assessing the heat stress on cattle, beef and dairy production changes Alam *et al* (2010) has conducted a study. A specific model (CNCPS v.6.1) has been used to evaluate the effect of heat stress on beef and dairy cattle. For the beef production experiment, a beef cow of 1-2 years of age has been evaluated. The results indicate that predicted Dry Matter Intake (DMI) is constant for 15°C - 25°C temperature and for all levels of humidity. For temperature above 25°C, DMI decreases and increasing humidity further reduce the DMI. The allowable body weight gain from metabolizable energy (ME) shows rapid increase from 15°Cto 20°C and is almost constant for 20°Cto 40°C. This slightly decreases for temperature above 30°C and humidity above 70%. Besides this, maintenance requirement of the cattle is almost constant for 20°C - 40°C temperature which slightly increases for 95% humidity at 40°C.

The present and future weight gain rates have been estimated utilizing temperature prediction for the 2030s and 2050s for A2 and B1 scenarios. The results show that there will be an increase of around 2% in Dec.-Feb due to increase in winter temperature while there will be no change in other seasons. This results in an overall annual gain of 0.6%.

The dairy cattle experiment evaluates the impact of changes in temperature and humidity for a three year old dairy cow weighing 220 Kg and normally producing 3.5 Kg of milk per day. The model results show that the DMI remains constant for temperature range of 15°C to 25°C for all humidity and above this range the DMI decreases which rapidly reduces with increasing humidity.

It has been found that maintenance requirement from Metabolisable Energy (ME) increases with increasing temperature and there is a large variation for increasing humidity also. As Table 5.12 shows increasing temperature and humidity have a considerable ultimate negative effect on milk production. By 2050, milk yield of dairy cattle may fall up to nearly 8% and this in a country with major shortages of milk and other dairy food with major deleterious effects on human nutrition.

Table 5.12: Predicted Milk Production Changes (%) for Dairy Cattle

Scenario	Year	DJF	MAM	JJA	SON	Annual
A2	2030s	-1.66	-3.19	-2.63	-2.82	-2.52
A2	2050s	-3.19	-5.88	-5.25	-5.12	-4.76
B1	2030s	-1.96	-3.82	-1.88	-2.82	-2.61
B1	2050s	-3.65	-7.77	-6.51	-6.58	-5.98

Source: Alam *et. al.*, 2010

Recommended Adaptation Measures

There are a number of options to assist in minimizing the effect of climate change on livestock. In high risk drought prone areas where water availability for livestock management may become highly stressful, it is recommended not to invest on high value livestock management. But that means that alternative livelihood options need to be found for those who are at present dependent on livestock for their employment and income.

In a bid to maintain livestock health during water stress, the animals must be placed in sheds during peak summer and highly humid periods (April-May and August, respectively) and provided with sufficient drinking water. The other two primary options are making some ration adjustments and altering the environment that the livestock lives in. This will, however, necessitate research under local conditions to find out the proper adjustments to feed type, quantity and feeding practice which can make livestock resilient to the negative impacts of climate change.

Livestock health care is found to be a rather poorly attended subject, though the disease burden of livestock is quite substantial and may become more so under climate change impacts. As an adaptation measure, the BCCSAP calls for strengthening veterinary services towards improving animal health care under climate change. The basic animal husbandry services with primary animal health care services, especially by empowering women with adequate skills (as paravets) in rural areas may greatly boosts 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.

In the coastal areas there are cyclone shelters for protecting lives of people along with movable properties as far as practicable. Along with that there are raised grounds (*killa*) for safekeeping of livestock. As future cyclones under climate change is likely to be more frequent and intensive, more such killas may be constructed and adequate provisions should be made for repairing them after a cyclone passes.

The current institutions involved for the promotion of livestock management have very little understanding of climate change related risks on the sector. The capacity of these institutions needs to be enhanced with targeted capacity building programmes. The Bangladesh Agriculture Research Council (BARC), in association with the Bangladesh Livestock Research Institute (BLRI), may embark upon a programme of rigorous scientific research risks to livestock and livestock management under climate change. Since it is also stated as one of the agenda item for the BCCSAP, the authorities concerned must develop a collaborative research programme as part of capacity building funded under one or other Convention-mediated funding.

5.9 Human Health

5.9.1 Present Status and Expected Problems

The various aspects of human health situation in the country have already been discussed in Chapter 2 above. An attempt has been made to get a generic view of the manner in which human health may be affected by climate change.

<u>Climate Change Impact on Health</u>

As climate and weather patterns have major impact on human health, climate change may adversely affect human health both directly and indirectly. Human beings are exposed to climate change directly through changing weather patterns (for example higher levels of temperature and humidity due to more rainfall) and indirectly though changes in water, air, food quality and quantity, ecosystems, agriculture, and livelihood. These direct and indirect exposures can cause death, disability and suffering (IPCC, 2007).

According to the IPCC 4th assessment report the emerging evidence of climate change effects on human health (IPCC, 2007) shows that climate change has:

- altered the distribution of some infectious disease vectors
- altered the seasonal distribution of some allergenic pollen species
- increased heat wave-related deaths

According to the World Health Organization the health effects of CC will be manifested by those related to temperature, extreme weather, air pollution, water-food borne diseases, vector and rodent-borne diseases, food and water shortage, mental, nutritional, infectious and other health effects.

The adverse health impacts are expected to be the greatest in low income countries. Those at greater risk include, in all countries, the urban poor, the elderly and children, traditional societies, subsistence farmers and coastal populations.

<u>Direct Impacts</u>

Bangladesh is frequently affected by natural disasters like floods, tropical cyclones, storm surges and droughts etc, which are likely to become more frequent and severe in the coming years due to climate change impacts. Deaths and injuries during and in the aftermath of the cyclones and storm surges have already been discussed earlier in Chapter 2. While no figure was given there on the number of people injured, in fact that is sometime also very high as was in 1965 when nearly 50 thousand perished but the number of injured was more or less 600 thousand. In 1991 also the number of injured was very high, nearly 140 thousand. The increase in the number of extreme weather events is almost certainly likely to cause more loss of lives and injuries unless adequate adaptive measures are taken. Loss of lives of dear and near ones and grave injuries also might lead to psychological distress, i.e., negative mood, stress-related physical symptoms, and psychological symptoms (O’Neill, 1999).

Indirect Impacts

The indirect impacts of climate change on the public health of Bangladesh are expected to be much more severe and diverse compared with direct impacts. Indirect impacts can be in two forms: (a) health consequences due to environmental change and ecological disruption that occur in response to climate change; and (b) diverse health consequences, for example, traumatic, infectious, nutritional, psychological, etc. that occur in demoralized and displaced populations in the wake of climate-induced economic dislocation, environmental decline, and conflict situations. (Haider, 2007). Some of the possible indirect impacts of climate change on outbreaks of disease are discussed below.

Vector-borne Diseases: The temporal and spatial changes in temperature, precipitation and humidity that are expected to occur under different climate change scenarios will affect the biology and ecology of vectors and intermediate hosts and consequently the risk of disease transmission. Mosquito species such as the *Anopheles funestus, A. darlingi, Culex quinquefasciatus* and *Aedes aegypti* are responsible for transmission of several vector-borne diseases, and are sensitive to temperature changes (Githeko, et al, 2000). Rising temperature, changes in precipitation and consequent availability of suitable breeding grounds and environment of some of the vectors such as types of mosquitoes carrying the parasites causing malaria, dengue and other such vector borne diseases may result in heightened levels of disease prevalence or its spatial and seasonal or yearly distribution putting public health system under stress.

Malaria: Malaria is one of the major public health problems in Bangladesh. Out of 64 districts, 13 bordering districts in the east and northeast facing the Indian states of Assam, Tripura and Meghalaya and part of Myanmar belong to the high-risk malaria zone. A total of 14.7 million people are at high-risk of malaria in the country, although there is sporadic incidence of malaria in other parts of the country. More than 95% of the total malaria cases in the country are reported from these 13 high endemic districts. The three Hill Tract Districts (Bandarban, Khagrachari and Rangamati) and Cox's Bazaar district report more than 80% of the malaria cases and deaths every year. These areas experience a perennial transmission of malaria with two peaks in pre-monsoon (March-May) and post-monsoon (September-November) periods. Malaria is caused by a species of parasites belonging to the genus Plasmodium. Both falciparum and vivax malaria are prevalent in the country of which Plasmodium falciparum is the predominant infection (75%) of the total cases in recent years due to increasing drug resistance. The principal malaria vectors are mosquitoes of the genus Anopheles of which A. dirus, A. minimus and A. Philipinensis are the principal vectors.

The prevalence of *P. falciparum* and *P. vivax* is influenced by complex interaction of various physical and climatic parameters. While some understanding exists of these interactions, what it would actually be in a changed climate can only be understood clearly over time as the climate change impacts are better understood because the vectors and their parasites or the bacteria may mutate to adapt to the changed climate. Given this caveat, we can compare the present distribution of the malaria infested districts with what may happen by 2050 (Fig. 5.19).

The figure shows that the total malaria affected area will increase in future. Some new areas also will be exposed to malaria. For example, Tangail district in the north-central part of the country which is not currently vulnerable to malaria may become so in 2050. However, the areas under high and medium risk zones may not change much but their spatial distribution will change and low risk areas will increase.

Dengu:

Before 2000, the disease was fairly unfamiliar though its presence was known at least since 1996-97. The first outbreak started in the summer of 2000 as an acute febrile illness involving mainly three major cities of Bangladesh: Dhaka, Chittagong and Khulna, with the highest incidence rate in Dhaka. Between 2001 and 2008, the highest number of dengue cases was in 2004 when it reached nearly 4000 practically the whole of it concentrated in the capital city as it was the case in all other years.

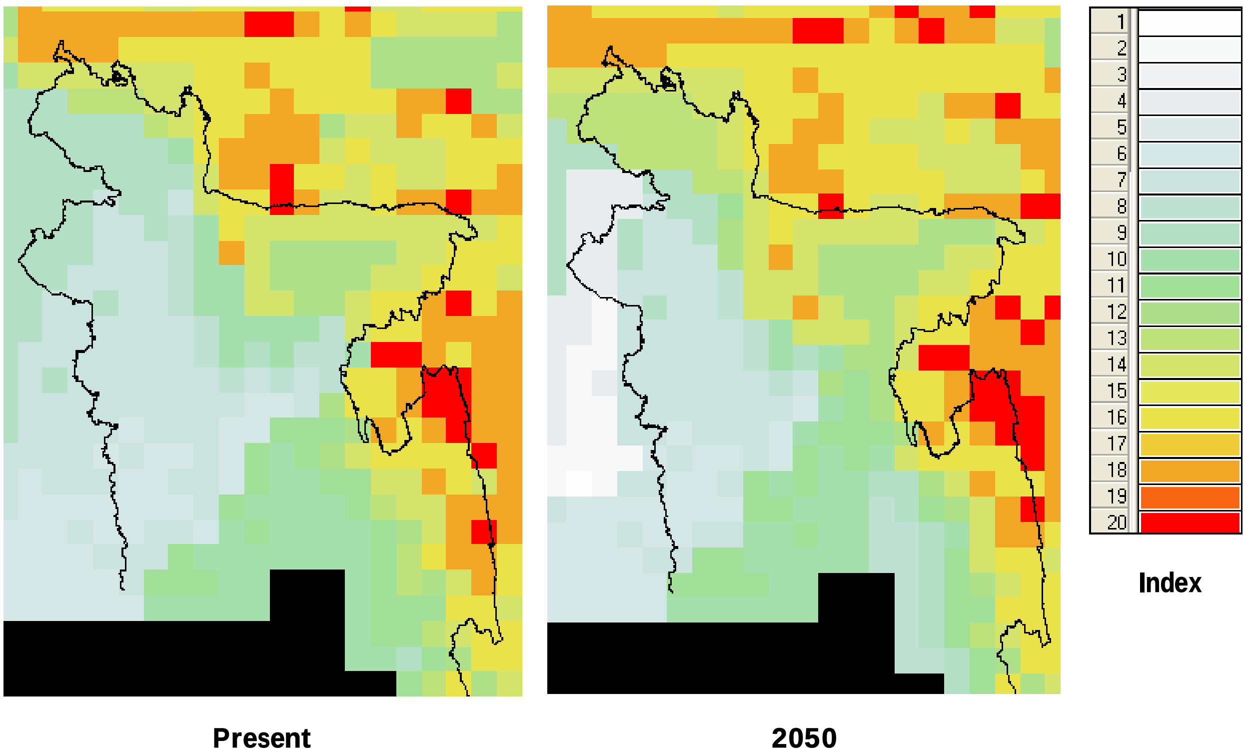


Fig. 5.19: Area Exposed to Malaria due to Climate Change, *Source*: Mazumder et al., 2010

Aedes aegypti is the vector spreading this disease. The occurrence of this disease is related with climatic variables. The minimum temperature required for survival of dengue viruses in Aedes mosquitoes is 11.9^{0} C (IPCC, 2001) and the viruses cannot multiply in the vector at lower than 18^{0} C temperature (Watts, et al, 1987). The vector is also climate sensitive. Temperatures beyond 42^{0}C are inimical for the survival of immature stages of Aedes mosquitoes (Rueda, et al. 1990). In a study in Delhi, the seasonality in the populations of Aedes mosquitoes has been found to be associated with rainfall and relative humidity (RH) (Ansari and Razdan, 1998). As climate change will inevitably increase the temperature, it may create at least initially favourable conditions for *Aedes aegypti* along with the virus where rainfall changes may also be favourable. However, what may be the conditions under which the vector and its parasite may survive, mutate or may become ineffective must be known in Bangladesh conditions and this may also vary by location within then country. This must be scientifically examined before specific adaptation measures may be recommended. Subject to that of course, other public health measures need to be undertaken.

Kala-azar: Kala-azar or visceral leishmaniasis is one of the complex diseases, called leishmaniasis and is caused by the trypanosomatid parasite Leishmania donovani. Visceral leishmaniasis, if left untreated, has a high mortality rate. In South Asia, it is transmitted by the sand fly, Phlebotomus argentipes. In endemic areas, children and young adults are its principal victims. Without timely treatment the disease is fatal.

Kala-azar has been reported in 14 northern districts, with the highest rates in the districts of Mymensingh, Pabna, and Tangail. In Mymensingh specifically, the average annual incidence rate between 1994 and 2004 was 5.8/10,000, and currently is as high as 300/10,000 in the most affected communities (DGHS, 2009).

During the last few years, the kala azar situation assumed epidemic proportion with the number of reported cases increasing from 3,978 in 1993 to 8,505 in 2005. Present surveillance is weak and the current estimated total cases are about 45,000. Annually 10,000 cases are treated by the control programme; but the cases treated by private clinics and practitioners are not reported. Bangladesh is now running a programme against kala azar with the objective of eliminating the disease by 2015 and with an aim to reduce the cases to less than one per 10,000 populations in endemic upazilas of Bangladesh.

It is not clear how visceral leishmaniasis might respond to higher temperature. But kala azar cases seem to cluster near flood control embankments. Building more embankments, a likely response to flood and sea-level rise, may favour visceral leishmaniasis vectors and may result in increasing cases of visceral leishmaniasis in Bangladesh (ICDDR,B, 2007). This means that the health impact may be not simply due to climate change but may be exacerbated due to other adaptation measures that may have to be undertaken. Such trade-offs obviously makes adaptation a far more complex issue than may otherwise be thought off.

Waterborne Diseases: Bangladesh is vulnerable to outbreaks of waterborne diseases such as diarrhoea, cholera, dysentery, etc. These diseases usually increase during the hot summer months and are closely interlinked with quality of water supply and sanitation facilities. Due to climate change the temperature (SST) and flooding is expected to increase while rainfall patterns may change depending on location and creating favourable environment for the bacteria and viruses causing these diseases. We discuss the possible impact of CC on some of these diseases in future.

Diarrhoea: Diarrhoea is one of the major causes of mortality and morbidity in Bangladesh, particularly of children. At one time, one third of the total child death burden was due to diarrhoea (Victora et al, 1993). Previously every year, a rural child might suffer on average 4.6 bouts of diarrhoea, from which about 230,000 children did die (BBS, 1996; Mitra, 1994). The disease is associated with use of unsafe water and poor sanitation coupled with poor food handling practices and bottle-feeding of infants during the first few months of life. The main immediate cause of death from acute diarrhoea is dehydration resulting from loss of fluids and electrolytes. Other causes of death are dysentery and malnutrition resulting from incorrect management of diarrhoea.

Several microorganisms cause the disease, but the major ones among them are Shigella, *E. coli* and rotavirus. Rotavirus remains the leading cause of childhood diarrhoea worldwide. It is detected in Bangladesh all year round. A study (Hashizume *et al,* 2007) finds a significant positive association between the number of hospital visits for rotavirus diarrhoea and temperature above a threshold. The risk began to rise as the temperature increased above 28°C - 29°C. For a 1°C increase above the threshold, the number of rotavirus diarrhoea cases increased by 40·2%.

According to the WHO, climate change is projected to increase the burden of diarrhoeal diseases in low income regions by approximately 2% to 5% by 2020. Due to climate change, precipitation may increase in future which may result in more area being flooded. According to a government report, flood-related diarrhoeal disease cases and the number of death due to diarrhoea in Bangladesh have increased in recent years (DoE, 2008). In coastal areas salinity intrusion is aggravating the fresh water scarcity problem leading to increased waterborne diseases like diarrhoea.

For vulnerability assessment due to diarrhoea, two factors may be considered: flooded area and temperature. Table 5.13 provides a combination of the two which may lead to high, medium or low risks of diarrhea outbreak. The table indicates that the temperature >35^{0}C coupled with nearly 22% area being flooded may lead to high risks of the outbreak of the disease (provided no intervention is made against it).

Considering these two factors in the future with CC, a vulnerability map of diarrhoea has been prepared. This is shown in Fig. 5.20. The figure shows that by 2050 the central, eastern and southern parts of Bangladesh will be highly vulnerable to diarrhoeal incidence due to climate change.

Table 5.13: Factors influencing the incidence of diarrhea

Factors	High	Medium	Low
Temperature	>35^0 C	29-34^0 C	<29^0 C
Flooded area	>22 %	10-22%	<10%

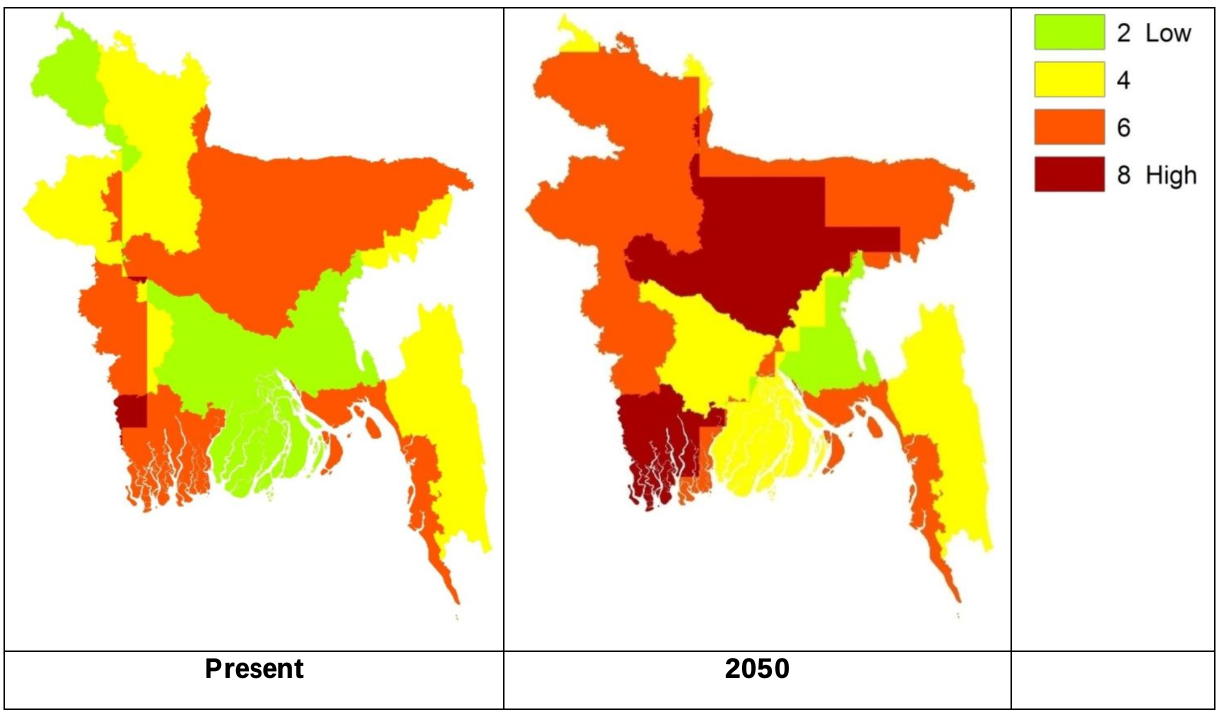


Fig. 5.20: Vulnerability to Diarrhea due to Climate Change, *Source: Mazumder et al., 2010*

Cholera: Cholera, an acute water-borne diarrhoeal disease caused by the bacterium *Vibrio cholerae*, has reemerged as a global killer in recent decades. It lives and thrives among phytoplankton and zooplankton in brackish estuaries where rivers come into contact with the sea. It has been found that the blue-green algae provide the *Vibrio cholerae* the favourable environment in which it resides when there is no major outbreak of cholera. This has a serious implication in terms of adaptation because the issue of blue green algae is important in reducing the application of nitrogenous fertilizer which causes major release of nitrous oxide, an extremely potent GHG. Again it has been found that adaptation may not be a simple affair and may be quite complex as trade-offs with other necessary interventions may exist.

Cholera epidemics in Bangladesh have been historically linked to a range of environmental and climate variables including precipitation (Pascual et al., 2002; Hashizume et al., 2008), floods (Koelle et al., 2005), peak river level (Schwartz et al., 2006), sea surface temperature (SST) (Lobitz et al., 2000; de Magny et al., 2008), sea surface height (Lobitz et al., 2000), coastal salinity (Miller et al., 1982), and fecal contamination (Islam et al., 2006).

In Bangladesh, cholera outbreaks occur in January-March, during the period of low river flow. The low river flow allows seawater from the Bay of Bengal to move inland, transporting bacteria-carrying plankton. A second epidemic occurs in September and October, after monsoon rains have raised water levels. The rising water levels cause floods that cover 20-25% of the land in an average year. Floodwaters mix water from sewers, reservoirs and rivers. As the floods recede, contamination is left behind (Akanda, Antarpreet and Islam, 2009).

Cholera incidence is highly influenced by flooded area, salinity intrusion and sea surface temperature. Due to climate change these three factors will change in such a way that will increase the incidence of cholera. For example the monsoon flooded area will increase by 6% in 2030 and 14% in 2050. In case of salinity, the area within >5ppt salinity range will be 12,986 sq. km in 2050 whereas the existing area is 8,180 sq. km. A recent research predicted that the regions of Bangladesh where cholera is merely a seasonal disease can become a regular phenomenon in future due to climate change (ICDDRB, 2009).

<u>Other health related implications</u>

The above discussion was related to some of the major killer diseases which might have more frequent outbreaks in future due to climate change directly or indirectly. Other various health related problems may also occur. There may be heat waves in future, particularly the heat island effects in the major urban areas may be quite extensive. This may lead to various heat stress related health disorders such as heat stroke, dehydration and aggravation of cardio-vascular diseases in elderly people. Higher temperature along with higher humidity as well as high density of population, particularly in low income slums may lead to or cause to aggravate present problems such as skin diseases. Access to safe drinking water may become a major problem due to lower rainfall, contamination or other such factors. Apart from these there may be also rising malnutrition if CC leads to food shortages in general and lower access to food by low-income people. Furthermore, in the coastal zone, higher salinity may cause widespread hypertension and may cause health disorders for pregnant women and may even lead to auto-abortion.

5.9.2 Adaptation Measures

The basic health services need to be geared up in general while future public health facilities need to follow the possible geographical shift of the outbreaks of disease or their prevalence in areas where this was not a problem previously. Other measures may include the following:

- Awareness-raising among health professionals about the health impacts of climate change
- Awareness raising campaign among the general public regarding simple measures in certain types of health problems such as heat stroke and heat stress (such as drinking more water) use of halotab/water purifying chemicals in order to avoid exposure to water borne diseases etc. (Ahmed, 2008; Neelormi *et al.*, 2007).
- The water supply infrastructure and sanitation facilities need to be protected and improved (making tube levels higher than expected flood levels, pond sand filters, rainwater harvesting, drilling for non-saline aquifers along the coastal zone,

conservation of water in water courses/reservoirs, increasing capacity of reservoirs to avoid scarcity of drinking water during critically low flow periods, etc.)

- In terms of longer term planning, two issues must not be lost sight of. First, the diseases are caused by vectors and parasites and viruses whose behavior is known at present climatic conditions. These may not remain the same in future. All of the microorganisms and their vectors may adapt to the changing climate, mutate or become more virulent. Without a close monitoring and research on their changing behaviour may not be known and proper adaptation measures may not be possible to be undertaken. Monitoring and research on major killer diseases in the local circumstances therefore need to be undertaken and existing systems strengthened with adequate attention given to building human and institutional capacity.
- The second long term planning issue involves finding the trade-offs of the adaptation measures that may be undertaken with adaptation or mitigation measures elsewhere in other sectors. If these trade-offs are not given proper attention from right now, mal adaptation will be likely.

5.10 Ecosystems and Forests

5.10.1 Current State of Ecosystem, Biodiversity and Forests

Bangladesh is exceptionally endowed with a vast variety of flora and fauna (see Chapter 2 above). A broad range of ecosystems are found in Bangladesh, including tropical rain forests, mangrove forests, floodplains and charlands, freshwater and coastal wetlands, and the littoral, sub-littoral and benthic communities of the Bay of Bengal (GOB,2004). These ecosystems host a large stock of biodiversity.

Over the years, Bangladesh has experienced a number of threats to its biodiversity. The major threats to its biodiversity include loss of habitat, over harvesting of resources, increasing production, natural calamities etc. Global warming and CC are expected to have even more adverse impacts on these ecosystems (including forests), their services, and biodiversity. Forestry has a specific role apart from its normal services as this also is a part of the mitigation activities particularly related to REDD+.

Various elements and physical effects of climate change including increased temperature, variability in precipitation, increased salinity due to SLR and extreme weather events such as floods, cyclones and droughts will have profound negative impacts on the country's forests and other ecosystems. Consequently, the livelihood of the people who are dependent on the various ecosystems will also be under threat.

5.10.2 Impact of Climate Change on Ecosystem and Biodiversity

Vulnerability of the Ecosystems

Most of the ecosystems in Bangladesh are dependent on the weather patterns and other natural elements and are thus expected to be vulnerable to climate change. Climate change induced natural hazards are potential threats to habitats and ecological integrity. The ecosystem and biodiversity of the Sundarbans mangrove and wetlands along with fish and other aquatic life are at risk due to climate change (Koudstaal et. al., 1999). The endangered species include 50 species of fish, 41 species of mammal, eight species of amphibian and 58 species of reptile. (Lin Zhi, 2010). Among plants the most threatened species are those found in terrestrial forests, where endemicity is also the highest (GOB, 2004). Many others, especially medicinal plant species, are facing great pressure due to loss of habitat and indiscriminate exploitation.

The vulnerability of major ecosystems to climate change is summarized in Table 5.14. Although the extent of impacts are not shown and not known either with certainty, the table shows that various ecosystems may be affected in various manner by elements of climate change and its impacts. Exactly how the systems will be affected in future due to CC however is difficult to speculate at the moment because the dynamics of the various ecosystems including the symbiosis among elements within them and their interaction with anthropogenic factors are only poorly understood at the moment.

Table 5.14: Climate Change Induced Hazard Affecting Ecosystems in Bangladesh

Major ecosystems	Climate change induced hazards				
	Temperature (heat stress)	Flood	Cyclone	Drought	Salinity
Himalayan Piedmont Plain	X			X	
Barind tract	X			X	
Madhupur Sal tract	X				
Teesta floodplain		X		X	
Ganges floodplain		X	X	X	X
Brahmaputra-Jamuna-Floodplain		X		X	
Surma –Kushiyara Floodplain		X			
Meghna floodplain		X	X		X
Haor Basin	X	X			
Chalan Beel	X	X			
Kaptai Lake	X				
Gopalganj/ khulna peat lands		X	X		X
The Sundarbans			X		X
Chakaria Sunderban			X		X
Coastal Plains			X		X
Offshore Island			X		X
Narikel Jinjira Coral Island	X		X		X
Meghna estuarine floodplain	X		X		X
Sandy beach/sand dunes			X		X
Chittagong hills and the CHT	X				
Sylhet hills	X				
Lalmai-Tipperah Hills	X				
Saline tidal floodplain			X		X
Major rivers	X	X			
Coastal and marine waters	X		X		X

Forest ecosystem

The forest ecosystems will be affected in various ways partly determined by its location and type. Various forests have particular natural climatic conditions where it is best suited (Table 5.15). As CC may lead to deviations of these parameters from the present ones, the forests are expected to be affected in their present state. Which way the actual impact will go is difficult to be definitive about as there is hardly any rigorous study on the ecosystem services, flora and fauna and the dynamics of their symbiosis with each other. There are some results based on a study of SLR impacts on the mangroves, however.

Table 5.15: Climatic Condition in Forests of Bangladesh

Forest type	Climatic and Other Factors			
	Mean annual temperature	Mean annual rainfall	Mean annual humidity	Salinity Level
Tropical evergreen	22.22°C to 25.55°C	2540 mm	83%	-
Tropical semi ever green	24.4°C	2413 mm	75%	-
Tropical moist deciduous	22°C to 24°C	2032 mm	80%	-
Mangroves	23.88°C to 35°C	1650-1770 mm	75-80%	5-30 ppt*

*Source: Champion, 1965, * Siddiqi, 2001*

The study on impacts of sea level rise shows that at present 23% of the Sundri coverage is in poor condition. Twenty percent of Sundri dominant areas with a very good health index (height >15m, diameter> 24cm age>80 years and soil texture-sandy clay loam) will be reduced to 10% with 32 cm SLR and a further 2% with 88 cm SLR. The areas with different types of plants in the Sundarbans show that the well-diversified area (area supporting the growth Sundri-Gewa-Goran and Sundri-Gewa) will reduce from 60% at present to 30% by the year 2100 with 88 cm SLR. As a consequence, the Sundarbans will be dominated by mono species. The growth of the Goran will be more favorable with sea level rise (CEGIS, 2006). As Sundri and gewa are the major economic species grown in the Sundarbans, this will lower its over-all economic value with corresponding loss of livelihood of many who are dependent on the harvesting and processing the harvests from the Sundarbans.

5.10.3 Potential Adaptation Measures

As has already been pointed out earlier the ecosystems are still only inadequately understood as to their functioning, services and their response to various stresses. It is difficult therefore to suggest very specific adaptation measures against ecosystem vulnerability due to climate change. Yet, there are some definitive measures that may be undertaken which will in general address some of the stresses that ecosystems may go through. One of these is the replenishment of fresh water flow in the South-western parts of the country by keeping the Gorai river recharged with water from the Ganges. This may be done by keeping the off take point of Gorai from the Ganges free of obstructions and arranging for both capital and maintenance dredging on a regular basis. This will allow augmentation of freshwater flow through the Sundarbans and rejuvenate the growth of the main economic species, i.e., Sundri.

The following additional adaptive responses may also be given due emphasis to safeguard forest species and ecosystems:

- Develop adequate technical, institutional and mobilize financial resources to adapt to climate change impacts on ecosystem and forest sector.
- Develop a national strategy for integrated ecosystem based water resources management to protect aquatic plants and animals
- 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 for safe environment perspective.
- Afforestation including expansion of coastal greenbelt to protect the mangroves and coastal wetlands.

None of these, however, may work well unless the dynamics of the various ecosystems are understood well and more harm may be done by trying to remedy a situation from a state of ignorance. Vigorous R&D efforts are therefore necessary to examine and study the ecosystems dynamics and take measures on the basis of findings of these studies.

5.11 Infrastructure

5.11.1 Present Status and Expected Vulnerability

The major physical infrastructures of the country include settlement infrastructures, transportation infrastructure (roads, highways, and railways), school buildings, disaster rehabilitation centres (shelters such as multipurpose cyclone shelters), health care centres (hospitals/clinics/dispensaries etc.), water infrastructure, embankments, market places, food storage infrastructure, urban centres, village growth centres, industrial and manufacturing units, ports (inland and sea-bound), utilities, and communication infrastructures that support livelihood activities. The present status of these infrastructure has already been discussed in Chapter 2 above. Here we concentrate more on the vulnerability of these infrastructures to CC and its impacts.

<u>Damages to Infrastructures due to Natural Hazards</u>

Flood is a major natural hazard and sometime very destructive. Severe damage to infrastructure has been observed due to flood in the last 25 years as shown in Table 5.16. Note that floods have been devastating in its effects on infrastructure particularly in late 1980s, late 1990's and also early part of the present decade.

Table 5.16: Infrastructure Damage during the Last 25 years Due to Floods

Year	No. Affected		Infrastructure damage			
	District	Upazila	Road Full (Km)	Road Partial (km)	Bridge/ Culvert (Nos)	Embankment (km)
1986	19	175	3094	1610	164	13
1987	50	347	12624	11534	3429	1272
1988 (First)	23	165	1202	5659	312	67
1988(Second)	52	345	45840	14016	2397	1651
1989	27	70	289	2195	4	-
1990	17	58	171	1210	123	125
1991	7	35	624	1195	392	339
1991	23	97	176	2157	249	124
1991	28	170	892	5567	1774	186
1993	33	224	4367	12217	2175	1013
1994	15	40	60	475	9	18
1995	40	259	4146	1981	2335	2398
1995	22	88	2170	3643	537	211
1995	14	100	2565	7839	1567	267
1996	48	222	1635	10922	1573	448
1997	37	180	3490	4210	811	586
1998	52	366	15927	45896	6890	4528
1999	28	-	-	-	-	-
2000	9	40	409	8874	1234	118
2002	36	209	3720	15690	9406	4734
2003(First)	31	189	1925	15096	2390	1504
2003 (Second)	5	20	94	397	26	31
2004	39	265	14271	45528	5478	3158
2007 (First)	1	15	-	-	-	-
2007 (Second)	46	263	3,705	27,125	360 (Fully)	88 (Fully)

Source: DMB website (www.dmb.gov.bd)

The coastal areas are particularly vulnerable to tropical cyclones and associated storm surges. The major devastating cyclones that occurred in 1970, 1985, 1991 and 1997 caused huge losses and displaced millions of people in the coastal areas. Recently Bangladesh experienced two destructive cyclones, Sidr (2007) and Aila (2009), within a short period. The estimated damage and loss caused by the cyclone was 115.6 billion taka (GoB, 2008). Table 5.17 presents a historical account of damage to infrastructures due to cyclones.

Table 5.17: Infrastructure Damage due to Cyclonic Storms

Year	No. Affected		Infrastructure damage			
	District	Upazila	Road Full (Km)	Road Partial (km)	Bridge/ Culvert (Nos)	Embankment (km)
1985	9	30	32		11	10
1986	7	30	132			1
1988	21	131	515	976	39	18
1989	33	71				
1991	33	102		764	496	707
1994	2	8	169		83	97
1995	28	67				
1996	2	9				
1997	12	66	392	3906	612	402
2007	30	200	1714	6361	1687	1875
2009	11	64	2233	6621	157	1742.53

Source: DMB website (www.dmb.gov.bd)

5.11.2 Vulnerability Assessment of Different Infrastructures

Flood occurrences now and in future

The vulnerability assessment carried out in this study is mainly based on the impact of flood hazard. For this, one should first have an idea of what would happen to the water levels in the major rivers, the Ganges/Padma, the Jamuna/Brahmaputra and the Meghna. Three of the hydrographs for 2050 under scenario A2 are shown in Figs. 5.21-5.23. The hydrographs for both the Ganges and the Jamuna clearly indicates that the pre-monsoon period will experience higher water level than at present both in 2030 and 2050. For Meghna, the changes are not pronounced. The peak water levels in all the three rivers may not change appreciably than at present. In general the pre-monsoon water levels will be higher than at present, particularly in case of the Jamuna/Brahmaputra.

The result of the higher water levels in the future particularly indicates that along these rivers, the level of future floods will be higher and comparatively less elsewhere. The estimated water level changes in 2050 under A2 scenario by various sub-regions indicate such flooding clearly (Table 5.18). On the other hand, however, as the higher water levels will be more prominent during the dry period, this may provide some new opportunities for surface water irrigation in some areas.

Note that the changes in water level are the highest for sub-region 4 along the left bank of the Jamuna, sub-region 6 with many wetlands and vulnerable to flash floods, sub-region 13 along the upper Ganges and sub-region 14 along the lower Ganges but with major depressions. Sub-region 13 which will experience the highest levels in future is not so much of a flood-prone area at present. Note also region 1 which does not experience flooding now and will not do so in future either. Thus, while in general flooding will perhaps be more frequent and severe, the onslaught will be faced unequally across various parts of the country and its seasonality may also change.

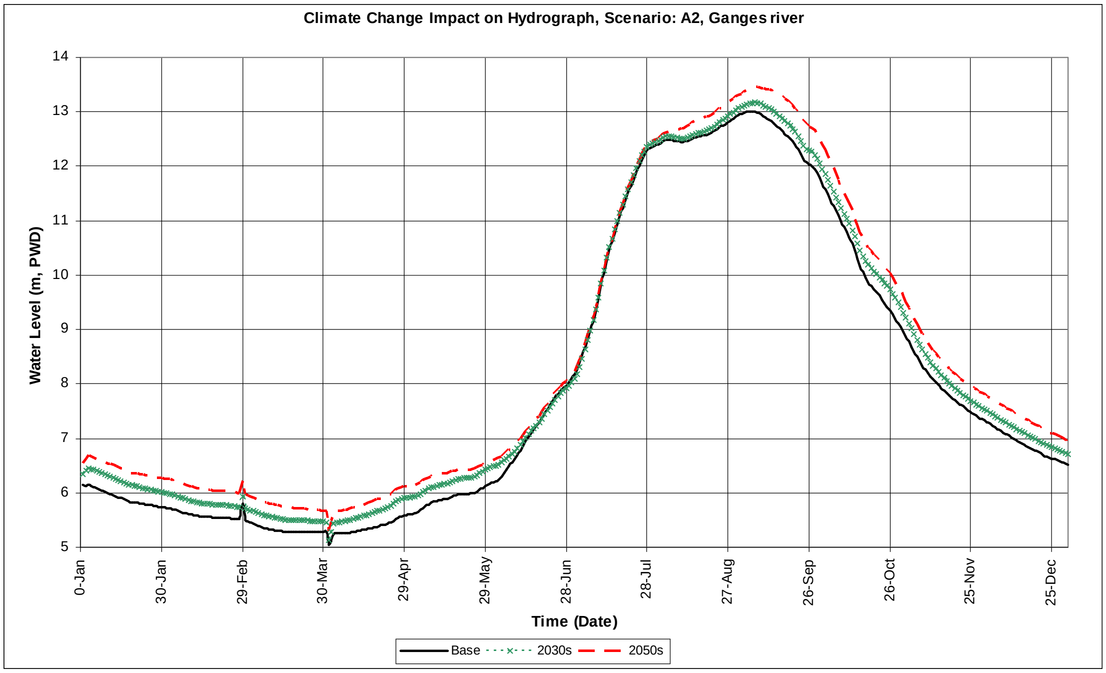


Fig. 5.21: Water Level Hydrograph under A2 Scenarios at the Ganges River
Source: Hossain et. al., 2010

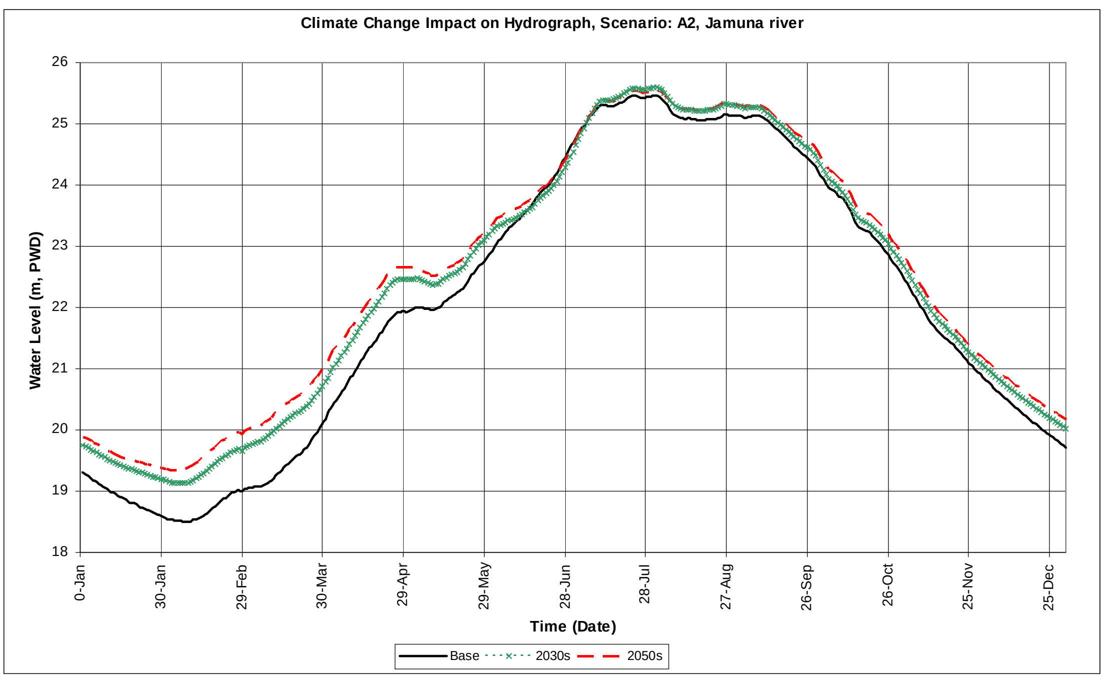


Fig. 5.22: Water Level Hydrograph under A2 Scenarios at the Jamuna River
Source: Hossain et. al., 2010

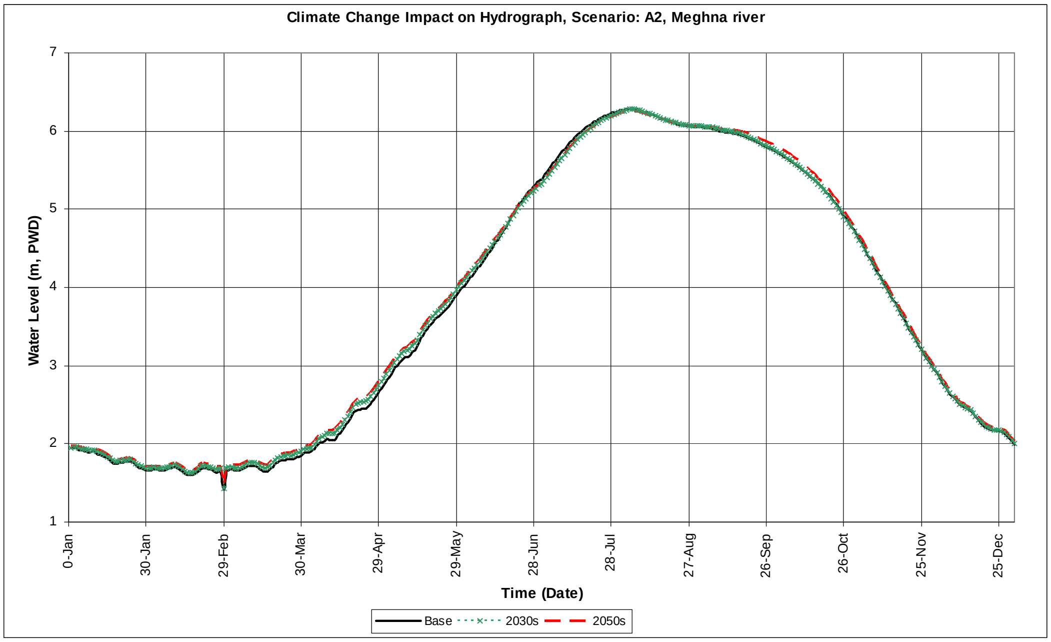


Fig. 5.23 : Water Level Hydrograph under A2 Scenarios at the Meghna River
Source: Hossain et. al., 2010

Table 5.18 : Change in Water Level at Sub-regions for Different Flood Return Periods in 2050s(cm)

Sub-region	Return Period (years)						
	2	2.33	5	10	20	50	100
1	0.08	0.08	0.07	0.06	0.05	0.03	0.02
2	17.20	17.76	20.20	22.19	24.09	26.56	28.41
3	2.27	2.32	2.50	2.65	2.79	2.98	3.12
4	13.60	13.71	14.20	14.60	14.98	15.47	15.85
5	9.17	9.61	11.57	13.16	14.68	16.66	18.14
6	10.48	11.11	13.87	16.12	18.27	21.06	23.15
7	0.04	0.28	1.33	2.19	3.01	4.08	4.88
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	8.60	9.14	11.47	13.37	15.19	17.55	19.32
13	49.09	51.67	62.87	71.99	80.75	92.07	100.56
14	13.83	14.62	18.06	20.86	23.54	27.02	29.63
15	1.42	1.45	1.54	1.62	1.70	1.79	1.87
16	2.88	2.74	2.12	1.62	1.13	0.51	0.04

Source: Hossain et. al., 2010

Roads and Railways

Generally infrastructures are designed considering different return periods of flooding to protect them. The design return periods for infrastructures in Bangladesh are presented in Table 5.19. Vulnerability of infrastructure has been assessed based on the changes in water levels in the 2050s (Table 5.20) (Hossain *et. al.*, 2010). Table 5.18 indicates that about 50% of national highways are under medium vulnerability while another 8% are highly vulnerable. Similarly, 10% of regional highways and 8% of railways are under high vulnerability due to future flooding.

Table 5.19: Design Return Period of Infrastructure

Infrastructure Type	Design return period (Year)
National highway	100
Regional highway	50
Feeder Road – A	30
Feeder Road – B	20
Rural Road	10
Railway	100
Embankment	30 (on average)

Table 5.20: Vulnerable Infrastructure due to Flood

Infrastructure type	Total Length (km)	Vulnerable Infrastructure (km)				
		Not Assessed	Not vulnerable	Low	Medium	High
National highway	3,459	561	882	-	1,742	274
Regional highway	1,596	243	524	-	659	169
Feeder Road – A	13,973	3,261	3,806	-	6,011	896
Feeder Road – B	11,026	801	3,014	1,026	5,014	1,171
Rural Road	25,296	3,266	7,694	3,360	8,921	2,055
Railway	2,835	209	798	-	1,594	233
Embankment	10,011	3,734	3,653	-	2,493	130

Source: Hossain et. al., 2010

Note: Feeder Road A and B are local roads which connect to national and regional highways.

5.11.3 Potential Adaptation in Infrastructure

Various types of infrastructure may face damages due to increased physical impacts of CC such as flood and cyclones and storm surges depending on locality and the local relief and natural conditions. Communication infrastructures of all types may be under threat while residential houses as well as institutional facilities such as schools, hospitals and market places may have to close if the problems become severe. Retreat and relocation can be a type of adaptation in such cases. But this may be costly and not very easy because, new locations may not simply be available. Yet, it may be necessary to protect key institutions The National Water Policy calls for safeguarding major economic and strategic centres (MOWR, 1999). In future the selection has to be right so that the cost of protection, both economic and environmental, does not appear to be bigger than the loss in a long term perspective.

The drainage situation along a number of urban centres including Dhaka, Chittagong and Khulna metropolitan cities must be improved in order to reduce vulnerability to frequent inundation, especially in view of increasing intensity of extreme rainfall events. Similarly, roads across the country must have proper water infrastructure (such as culverts, bridges etc.) in order to facilitate drainage during peak flood periods (Ahmed, 2005). The BCCSAP also calls for due emphasis on adaptation in drainage infrastructure and water infrastructures along roads and railways (MOEF, 2009).

The coastal embankments must be brought under immediate scrutiny. In the short run, weak infrastructures should be identified and refurbished and monitored on a regular basis.(Ahmed, 2008). However, in the longer run the regional water planning process must be revisited by integrating the concerns over sediment flow, especially in view of the northward movement of the salinity regime under climate change. Tidal river management may shift emphasis from regular maintenance of weak embankments to new ecological balance between land-water-vegetation and cropping/livelihoods practices (Ahmed, 2010).

The existing cyclone shelters should be brought under regular monitoring and maintenance (Ahmed, 2008), while efforts must be continued to build new cyclone shelters, based on population density (Ahmed et al., 2007). New shelters should offer improved provisions and facilities for women.

5.12 Urbanization and Interface with Climate Change

5.12.1 Characteristics of Urbanization in Bangladesh

<u>Trend in urbanisation</u>

Earlier in Chapter 2, the pace of urbanisation has been noted to be rather fast. The number of urban centres has increased over time from 108 in 1974 to present day number of 536. It is not that all of them may be called urban in its proper sense and many has been declared urban areas due to administrative or political reasons without so much of any urban facilities being easily available.

Presently there are 536 urban centers including a megacity, 3 Statistical Metropolitan Areas (SMAs), 223 municipalities and 309 urban growth centres in Bangladesh (BBS, 2003). In 2001, nearly 50.46% of the total urban population was concentrated in Dhaka, Chittagong, Khulna and Rajshahi SMAs whereas Dhaka Megacity consisted of 33% of the total urban population.

<u>Risks, Hazards and Trends</u>

Here we assess the hazards, risks and trends of climate change on Dhaka (capital and flat floodplain), Chittagong (hilly area), and Khulna (coastal area), which are the three major and spatially different cities of Bangladesh, to get an overview of the vulnerabilities of the population living in large urban areas of the country. These three cities account for 2/3rds of the total urban population of the country.

Dhaka city: Dhaka, the capital of Bangladesh, is expected to earn the dubious glory of being the second largest mega city of the world by 2015. The Dhaka Statistical Metropolitan Area (SMA) or megacity with a population of 9.67 million, has an area of 1,371 square kilometers. The city area under the jurisdiction of the Dhaka City Corporation covers an area of 289.92 sq.km and population of 6.2 million. The population growth in the last decade is estimated to be about 4% per annum.

Around 30% of the population of Dhaka lives in shanty towns or slums numbering 1,925. The population density in the slums is roughly 200 times greater than the country's average population density. Dhaka is poised to be at risk due to climate change induced disaster (Alam and Rabbani, 2007) which may bring sufferings to many, a large part of who are poor.

The space under built environment within Dhaka is increasing fast at the cost of whatever open space it had both wetlands as well as vegetative cover or empty space. A land cover change analysis of the Dhaka Metropolitan Area covering 360 sq. km using multidate Landsat images showed that built up area within the city boundary has expanded from 23% to

47% during 1993 to 2007. Consequently, other types of land use have decreased over the same period for vegetation area from 58% to 40%, and wetland and water bodies from 14% to 8.7%. At these rates and assuming no intervention to halt the trend, the built up area will be 60% or so and the other categories shall account for very little as shown in Fig. 5.24. Such a development will result in and may have already resulted in the heat island effect in Dhaka.

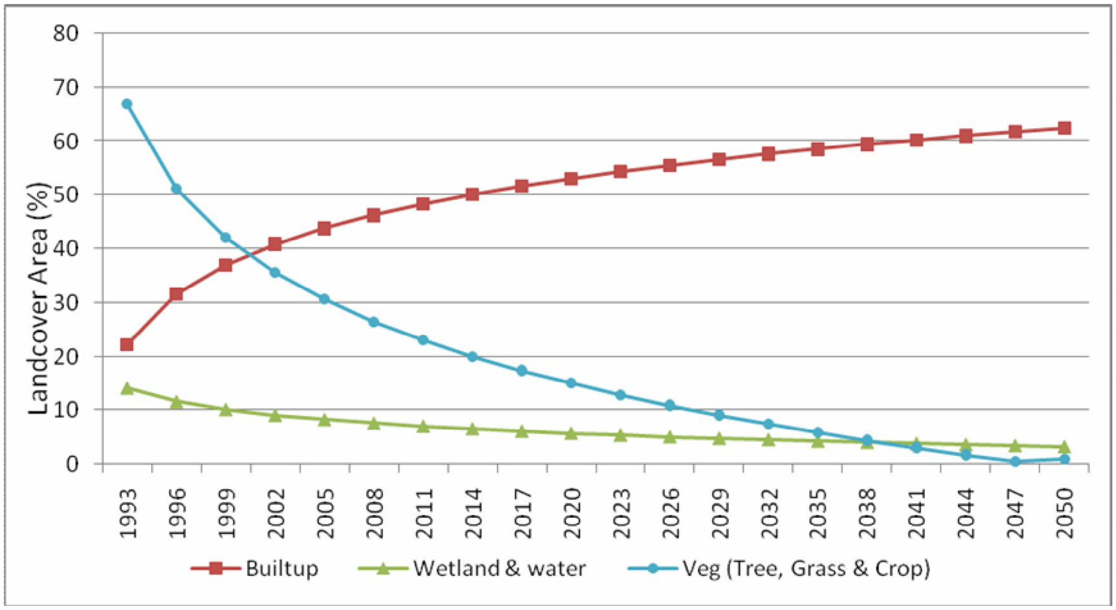


Fig. 5.24: Land use change projections within Dhaka City **(1993-2050)**

During the monsoon, flooding and water logging in the city due to river floods and above normal rainfall has occurred quite a few times in the past including in more recent years. An increasing trend in the rainfall over Dhaka city has been observed over 1950 to 2010. A large part of Dhaka is actually low land and as a result, above normal rainfall along with rising urbanization increasingly occupying low elevation land is likely to result in severe water logging. Major floods occurred in Dhaka whenever above normal rainfall combined with overflow of the surrounding rivers. Among these, the 1988 and 1998 floods were catastrophic.

The daily rainfall was above normal in the months of July, August and September during the flood of 1988. Rainfall on 18 September 1988 was 108.62 mm above the normal trend. The rainfall was again significantly above normal during September 2004 with very high deviation of 151.17 mm and 334.48 mm on 13 September and 14 September 2004 respectively. Again, 1 day maximum of 448 mm of rainfall was recorded in July 2009 which was responsible for flooding and water-logging in Dhaka.

Figs. 5.25 and 5.26 depict the flood/water-logging situation in 1998 and 2004. The two maps show interesting differences. In 1998, the flooding was on the unprotected side of the city. In 2004, it was far less extensive but was concentrated more towards the protected side. This means that even when river flood water does not enter the city, it may still have flooding inside possibly due to more of built-up areas obstructing normal flow of water.

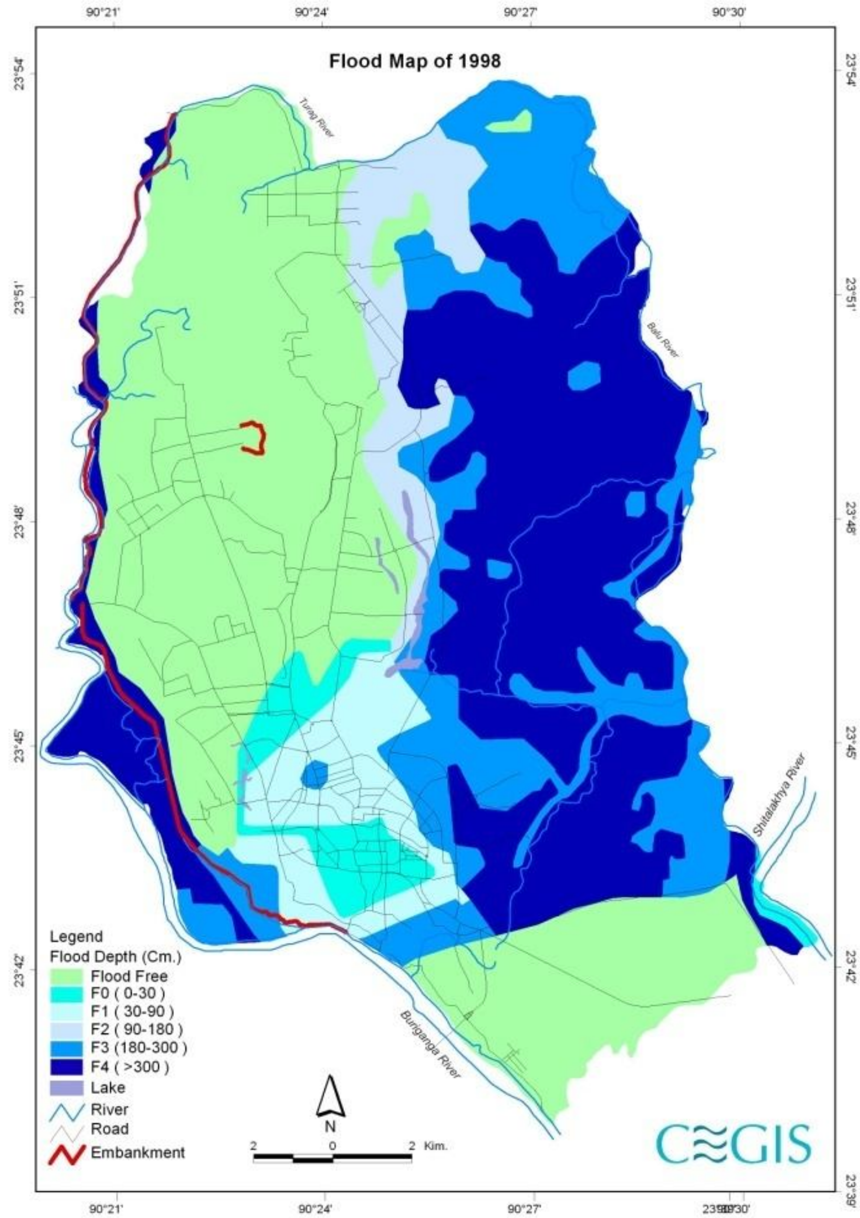


Fig. 5.25: Flood map of Dhaka City, 1998,*Source:* IWM

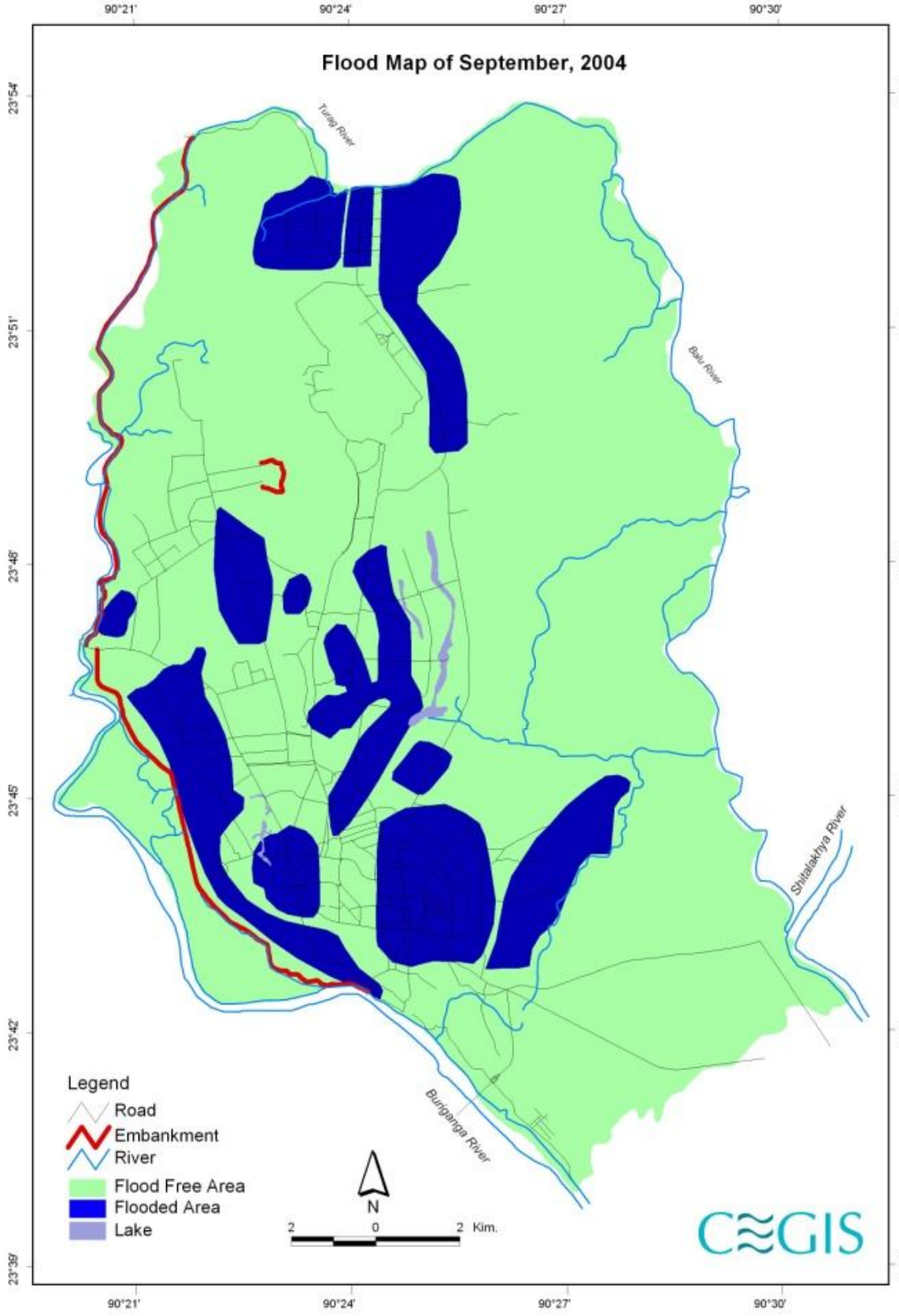


Fig. 5.26: Flood map of Dhaka City, 2004
Source: IWFM, BUET

Chittagong city: Chittagong, the second largest metropolis in Bangladesh is bounded by hills and forests to the north, the Halda river valley to the northeast, the Bay of Bengal to the west and the Karnaphuli River to the southeast. The Chittagong City Corporation covers an area of 155 square kilometres with a population of 1.99 million. The population growth in the last decade is estimated to be about 4.4% per annum, which is much higher compared to the national growth of about 1.6%.

Annually on an average 3,000 mm of rainfall has been observed, of which the major part of about 2,400 mm occurs during the monsoon. The existing problems for the city of Chittagong include flooding (flash flooding), water logging, storm surges, cyclone and tidal surges, salt water intrusion, sedimentation, land and mud slides. Landslides particularly has become more frequent due to haphazard hill-cutting and high rainfall easily washing away the soil and leading to mud slides often causing death and injury to people.

The landslide on June 11, 2007 which killed 127 people and injured many was triggered by unusual heavy downpour estimated to be 348 mm for a period of around 12 hours. The flood inundated around two-thirds of the city followed by high tide which slowed the discharge of rainwater into the river system.

Khulna city: Khulna, located in the southwest of the country is the third-largest city in Bangladesh. The land use pattern of Khulna has been substantially influenced by the flow of the Rupsha and Bhairab rivers. As a deltaic plain the land is flat and poorly drained. The whole metropolitan area is approximately 2.5 m above the mean sea level. Downstream of Khulna City, the Rupsha River meets the Kazibancha-Pussur River that travels more than 100 km and then falls into the Bay of Bengal. Tidal flow from the Bay has daily, seasonal and annual variations. The effect of this tidal flow is observed throughout the system. Salinity is a major problem. In the year 2007, the highest level of salinity in 32 years was recorded.

5.12.2 Climate Induced Vulnerabilities in the Selected Urban Centres

The hazards or extreme events that already exist such as flooding, cyclones, and temperature rise will be aggravated under the climate change conditions. In the meantime, new hazards like sea level rise will emerge. The vulnerabilities of urban areas specially the cities due to the climate change hazards will increase as discussed below.

Dhaka city: Increases in built up area will exacerbate the future flooding condition if adequate flood control and drainage measures are not taken. Water related problems during floods in terms of both quality and quantity pose a huge threat to the daily life of city dwellers. The risks of some diseases during and after flood include vector-borne diseases like malaria, dengue fever and waterborne diseases like diarrhea.

In the cities 'Heat Island' effects due to dense urbanization and lack of vegetation areas are usually visible. A trend analysis of temperature data of Dhaka district from 1953 to 2008 shows An increasing trend of both minimum and maximum temperatures. But due to lack of detailed analysis it is difficult to segregate the influence of climate change on temperature rise from the 'Heat Island' effect. Further analysis needs to be carried out to determine the factor of influence to determine climate change impact on temperature rise within Dhaka and other cities. Anyway, with or without climate change increasing heat stress will be another major risk for Dhaka along with increased frequency of floods/drainage congestion (Alam and Rabbani, 2007).

Chittagong city: Chittagong may face increased frequency and extent of flooding (particularly flash flooding), higher flood levels, storm surges, increased intensity and frequency of cyclones and tidal surges, salt water intrusion and sedimentation as well as land and mud slides during heavy rains. Also, as cyclones and storm surges are expected to be more frequent and intense in future, Chittagong will fall within the high risk zone. At current conditions 68.63 sq.km of

Chittagong city corporation is at high risk of cyclone and in the year 2050 around 33.5 sq.km of additional area may be at risk (Tanner *et.al* 2007a).

Khulna city: Increase of extreme rainfall events under the A2 scenario by 2050 is observed through analysis of climate change scenarios. Changes in the extreme rainfall events are expected to be higher during 2041-2060. More than 50 mm of rain in 6 consecutive hours at Khulna is likely to occur almost 6 times a year over 2041-2060 compared to just over 4 times a year in recent history (2003-08). The probability of occurrence of an event of 150 mm rainfall in 6 hours is 0% (no occurrence) at present (2003-2008). This may rise to 24% (once in every four years) (ADB, 2010) by 2050. Figs. 5.27 and 5.28 represent 1 in 10 year flooding extent for 2030 and 2050 respectively for A2 scenario. As the maps indicate the occurrence of floods will increase over time and would cover practically the whole city by 2050 if no intervention is made.

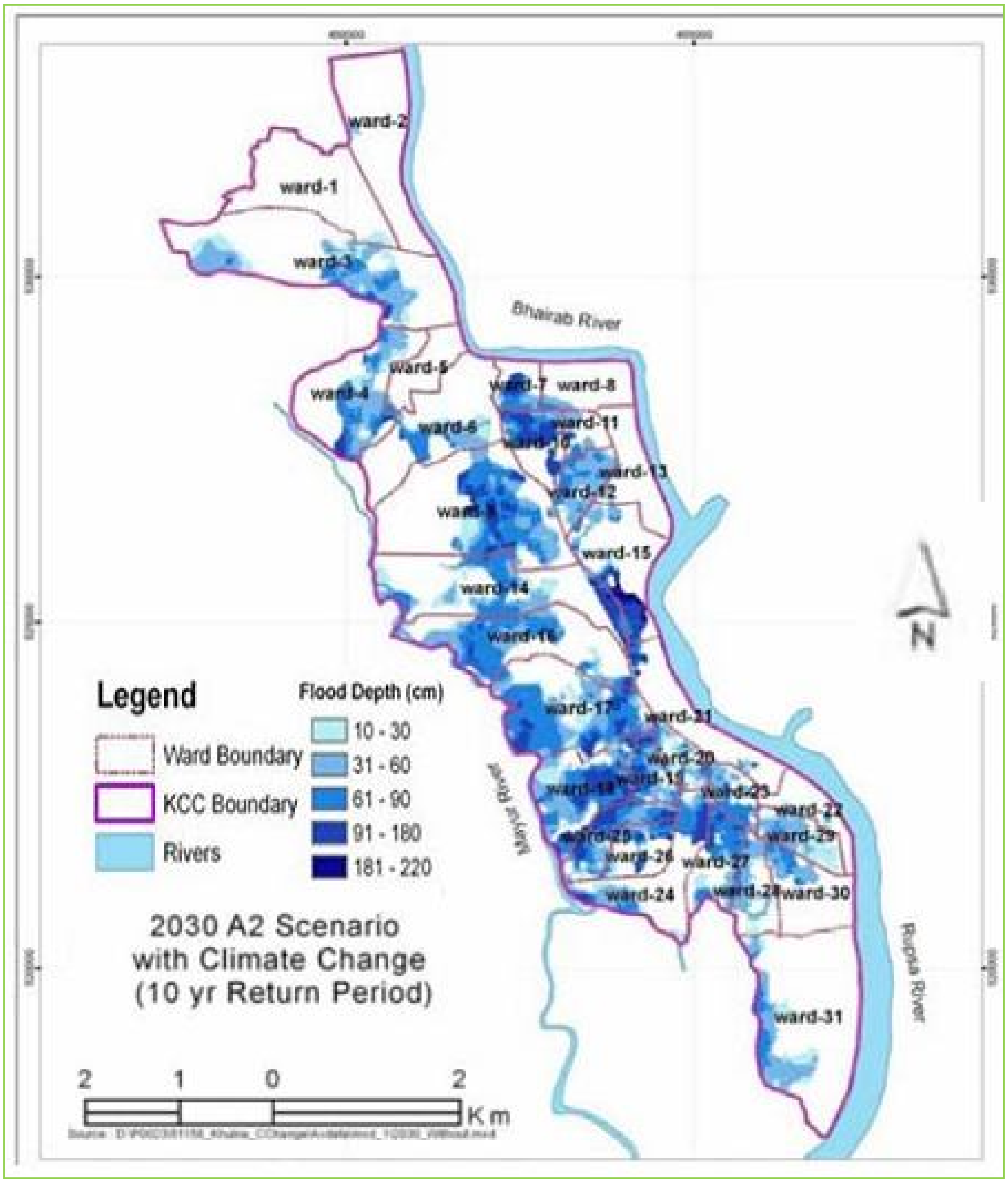


Fig. 5.27: Khulna City Map Showing Area Flooded with 10 Year return Period in 2030

(Scenario A2)

Source: ADB, 2010

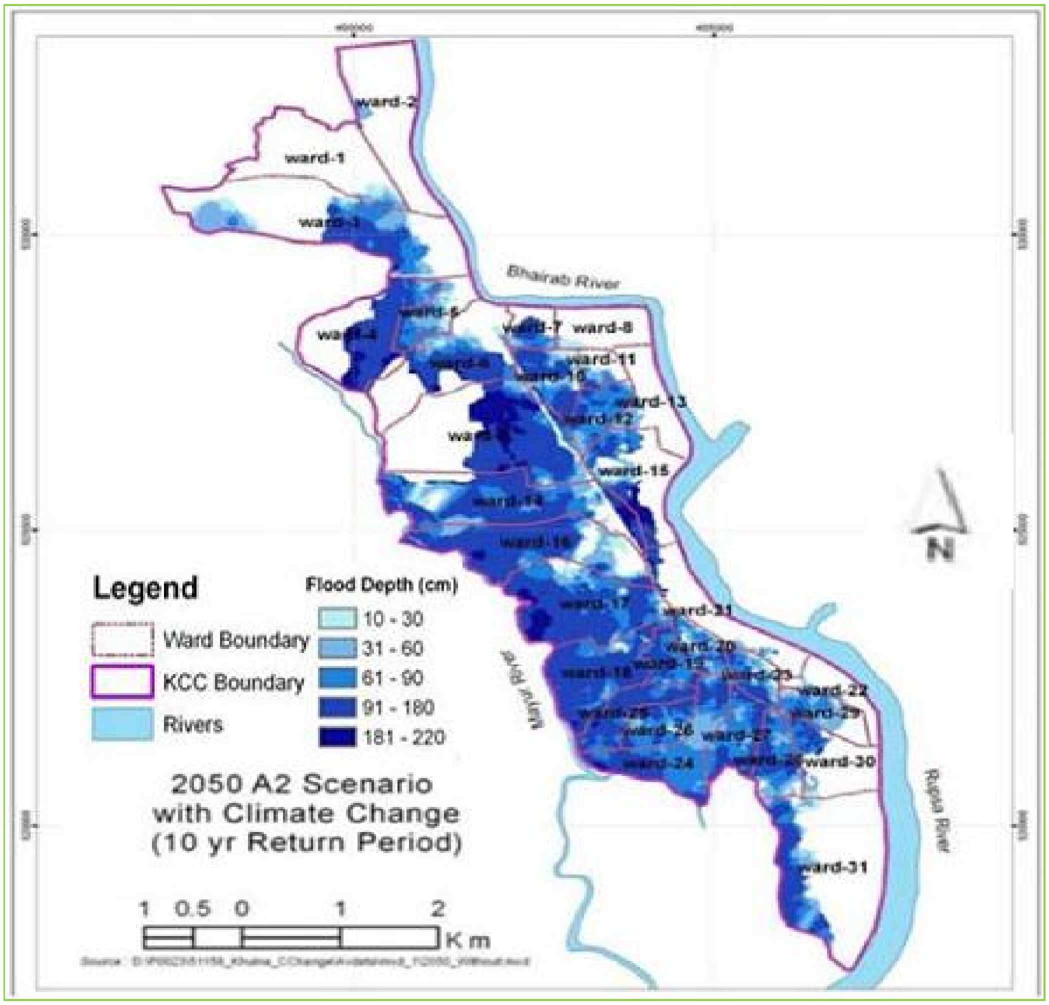


Fig. 5.28: Khulna City Map Showing Area Flooded with 10 Year return Period in 2050

(Scenario A2), *Source:* ADB, 2010

5.12.3 Impacts due to Climate Change

Impacts of climate change induced urban flooding, cyclone and temperature rise are multifaceted and these problems will be further exacerbated with the increasing trend of urbanization and population growth. The effects of flooding and cyclone are enormous and manifold such as damage to infrastructure and facilities like roads, houses, water supply, effect on health and hygiene, water quality and the environment. Poor urban people are likely to be amongst the worst sufferers of climate change as it affects their livelihoods, damages assets, causes health problems etc.

<u>Heat Island Effect</u>

Apart from all these, temperature rise due to climate change will enhance the existing heat island effects in urban areas. The heat waves during summer can cause heat stroke, dehydration and aggravation of cardiovascular diseases in elderly people (WB, 2000), while climate-related disturbances in ecological systems, such as changes in the range of infective parasites, can indirectly impact the incidence of serious infectious diseases.

Infrastructure

Flooding in urban areas already creates huge economic damage. With the probability of increased flooding and cyclones in the future, the cities will continue to suffer infrastructural damages if proper initiatives of building climate proofing structures are not taken.

Water Supply

Water supply is hampered during floods and drinking water is contaminated as the production wells, distribution network, street side taps, groundwater reservoirs are submerged. The level of fecal contamination of drinking water was very high during the flood of 1998 as flood water submerged delivery and drainage pipes and mixed drinking water and sewage. If frequency and severity of urban flooding increase under climate change in future, the water quality will deteriorate severely.

In the coastal areas, due to increase of salinity, 22 million people will be affected in the year 2050 under A2 scenario, and about 15 million people will be affected in the year 2050 under scenario B1 (IWM and CEGIS, 2007). In Khulna, climate change will increase the maximum river chloride levels exceeding the 1.0 ppt chloride limit for water supply. Due to climate change, the number of days the river salinity would exceed 1.0 ppt at the proposed Mollarhat intake point by 1 day (up from the present 41 days) by 2030 and 24 days by 2050 (ADB, 2010).

Sanitation

Sanitation will be a major problem as normal practices of sanitation changes as a result of failure of sanitation system during flood and cyclone. People do not get access to proper sanitation facilities as houses are damaged or submerged, and people are often displaced from their homes. People resort to all kinds of unhygienic sanitary practices when their homes and area get submerged for prolonged period causing severe insanitary conditions with major risks of outbreak of diseases. The health system may face major stress as happened during 2007 when hospitals ran out of intravenous saline in Dhaka. In any case, major outbreaks of diseases are highly likely.

Health

Heat stress, precipitation changes, frequent floods and sea-level rise along with insanitary conditions in the future under CC as well as insanitary conditions and practices will degrade the water quality and may lead to more water-borne as well as infectious diseases such as gastrointestinal, dermatosis, cardiovascular diseases and diseases. Flood-related damages increased by about three to eight times in the 1990s relative to those in the 1980s and 1970s. These trends are likely to persist in the future. (Cruz *et al*., 2007). Mosquitoes may have more favourable breeding ground and malaria and dengue may be more prevalent.

Livelihood

The people's daily lives are impacted adversely due to the weather-related urban problems. Particularly continued water-logging is expected to create problems in transportation for those going to schools, working place or hospitals. Heavy downpour resulting in quick water-logging due to drainage capacity limitations also result in vehicles being stranded on roads. A study has found that up to 20% working hours are also lost due to such problems while the costs of daily expenditures also rise for poor groups in urban society.

Cyclonic storms are expected to create major adverse impacts on livelihood of people in the coastal districts. So they shall in the coastal cities such as Chittagong and Khulna, although the categories of people whose livelihood will be so affected will be different in the cities compared to the countryside. For example, under A2 scenario for 2050, adverse impacts will fall mainly on livelihoods of groups such as fishermen, farmers and women. Obviously in cities the impact will be on groups whose livelihoods are linked with those outside. Thus traders in and processors of grain, food in general, and fish , particularly in Chittagong and Khulna will be affected indirectly.

Migration

Many victims of natural hazards such as floods, cyclones, and erosion, particularly the poor, migrate into cities in search of new jobs, shelter and livelihood and finally end up in slums or in the streets. The slum population in Dhaka doubled in a decade to reach 3.4 million in 2006 from only 1.5 million in 1996 following heavy rural-urban migration (CUS, 2006). According to the Climate Change Cell of the DoE, about 45 cm rise of sea level along the Bangladesh coast may inundate 10-15% of the land by the year 2050 creating over 35 million climate refugees or environmental migrants from the coastal districts. Many will end up in the major cities putting further stress on the living conditions and facilities therein.

5.12.4 Adaptation Measures

Adaptation in the urban areas due to climate change is somewhat similar to though not entirely elsewhere within the economy and the country. The basic difference is that the built-up environment and the density of population create specific difficulties in implementing them. Secondly, urban areas are also a focal point for mitigation activities due to high level of use of mechanized transports and other factors such as industrial location. Third, urban areas in general may suffer due to heat island effects.

While these generic similarities and differences exist, each city may have unique problems due to its historical evolution and location by the river front or along the coast. Dhaka particularly poses a problem because it is actually surrounded by several rivers. Having intimate knowledge of the peculiarities of each city is therefore absolutely important for dovetailing adaptation measures and their specificities in each context.

Urban Planning Needs under CC

A kind of urban planning exists in the country which is likely to be inadequate to take CC into account. First and foremost each city therefore must be studied carefully as to its built-up areas, their elevation, drainage systems, open spaces and the like to find out impediments to free surface flow of water, and remove them as the initial measure. Secondly, the present area plan if it exists needs to be redesigned if necessary to take into account the possible CC impact on the city and its surroundings.

- If the present planning appears to be adequate for the time being, properly implement the existing policies and plans for building construction, landscaping, preservation of green space, and water bodies
- Mainstream 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;

Built environment

There are three ways to improve the living environment for the urban people, particularly the poor in building design, in settlement planning and design as well as in general urban planning. Important considerations for planning and designing will include housing standards, environmental sustainability, economic affordability, number and types of structure as well as aesthetics by type of structures. There are also issues like infrastructure development, upgrading and designing community facilities that influence the living environment of urban people in general and specifically for the poor. Zoning regulations, development control and urban planning can provide appropriate and safe locations for households. (Jabeen and Mallick, 2009)

The adaptation measures for buildings including houses, offices and institutions in city areas may include:

- Urban greening programme to increase vegetation covered area
- Revision and implementation of building codes with considerations of climate change
- Installation of alternate sources of water supply systems like rainwater harvesting, grey water systems etc

To alleviate heat island effect, gardens on the rooftops of high rise buildings may help. So shall paint them white which can reflect back sunlight. Such roof and pavement gardens, wherever possible, may have important co-benefits such as providing shade, improve air quality through removal of particulates, and reduce power plant emissions due to reduced energy consumption. Training and necessary logistics for roof gardening and horticultural development may be provided.

Climate change should be one of the prime considerations for the development of roads in general and urban roads in particular. Suitably designed roads can help reflect solar radiation and wherever possible should be so constructed. Parking lots made with brick pavements can also help reduce the storm water load due to its permeability.

5.13 Summary of Sectoral Vulnerability and Adaptation

The sectoral vulnerabilities discussed in the previous sections along with the possible adaptation measures have been summarized in Table 5.21.

Table 5.21

Summary of Sectoral Vulnerability and Adaptation

Sector	Vulnerability	Adaptation measures
1. Water Resources	• Water stress will be increased. • Water availability will be decreased in dry season and the northwest and southwest regions likely to be suffer the most • Flooded area will be increased by 6% in 2030s and 14% in 2050s respectively • The western parts of the country will be at greater risk for droughts, during both the Kharif (January – May) and pre-Kharif (June – October) seasons due to the effects of climate change • The coastal areas of Bangladesh face salinity intrusion and fresh water scarcity during the dry season which will aggravate due to sea level rise. • From the base condition additional 7% (>5 ppt) area will be increased in the coastal area. Among the coastal district Bagerhat, Khulna, Satkhira, Barisal, Patualkhaki and Bhola will be more affected. • Additional 7.6 million people will be exposed to high salinity (>5 ppt). • About 0.1 million people become homeless every year in the country due to river erosion	• Revisiting andappropriate strengthening of embankment systems along the coastal zones based on future vulnerability • Implementation of proper tidal river management in the longer 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 committee and using indigenous knowledge and practices to solve water related problems • Strengthening local disaster committee. 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 hazard • Promotion of early warning and preparedness for all hazards (flood, cyclone, river erosion, drought)
2. Crop-agriculture	• Due to carbon fertilization alone Boro production might increase 9.6% with respect to base year • However, Due to temperature and precipitation change over-all production will reduce 13.9% (2050). • Aman and Aus output will reduce at the rates of 0.62% and 1.52% respectively	• More research on salt tolerant crop, short duration , submergence tolerant, drought and low moisture and other relevant climatic stress tolerant varietal development • Develop water management innovations, including efficient irrigation, to address the risk of moisture deficiencies and increasing frequency of droughts. • Promote diversified crop production, including crop substitution, to address the environmental variations and economic risks associated with climate change

Sector	Vulnerability	Adaptation measures
3. Fisheries	• Culture fish production (pond fish) would be decreased due to overtopping of flood water • Capture fisheries especially floodplain fish production will be increased by 9% for A2 emission scenario and 7% for B2 emission scenario in 2050 • Sea level rise could also push saline water further into the Ganges-Brahmaputra-Meghna (GBM) delta, reducing habitat for fresh water fish.	• Protection and improvement of floodplain capture fisheries habitat through excavation of silt from beel, river and canal bed, sanctuary establishment, and connectivity improvement • Enhancement of culture fisheries by retaining water for longer period 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 flood • Acreening 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 livelihood during fish breeding
4. Livestock	• The increasing temperature and humidity due to climate change will make livestock, especially cattle, more vulnerable • According to model results, there will be around 2.5% decrease in annual milk production by 2030s and by around 5% in the 2050s due to heat stress. • Animal protein output such as milk and meat may fall and consequently livelihood of the rural community will be adversely affected. • In the coastal area, livestock are most vulnerable to cyclones and storm surges along with tidal flooding. • About 20% of present area suitable for livestock will be reduced in 2050 for livestock due to sea level rise	• Use feeding and water drinking management practices to minimize 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 farmer to enhanced climatic disasters

Sector	Vulnerability	Adaptation measures
5. Human Health	• Total malaria affected area will increase • Some new areas not currently vulnerable to malaria may become so exposed • Spatial distribution of malaria infestation will change and low risk areas will increase. • In 2050 the central, eastern and southern parts of Bangladesh will be highly vulnerable to diarrhoeal incidence • Seasonal cholera disease can become a regular phenomenon in future • Incidence and severity of heat stress related diseases may increased • Increased salinity in drinking water will limit the access of people to safe drinking water •	• Enhancing the capacity of the 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 massive awareness to reduce diseases related with floods, cyclones, heat wave, cold spell etc. • Raising levels of hand tube well, sanitary latrine to reduce the threat of water contamination • Research on vectors, parasites and virus mutation and adaptation to changing climate for future health support system strategy
6. Ecosystems and Forests	• The ecosystem and biodiversity of Sundarbans, haor and beel wetlands along with fish and other aquatic life are in most threat due to climate change induced hazards • Main economic products such as Sundri and Gewa timber output will decline drastically with increase in sea level rise • Sal forest ecosystem at the Madhupur and Barind tract might be affected due to moisture stress during dry period • Chapalish (Artocarpus chaplasha), Garjan (Dipterocarpus spp) will increase 2-7% (in 2030s) and 7-10% (in 2050s) due to increased precipitation. • Climate change induced additional flood will adversely effect jackfruit trees and lower nutritional status of particularly low income people who eat these nutritious fruits	• Development of a National Strategy for integrated water resources management to protect aquatic plants and animals • Maintaining critical ecological zones • Conservation of threatened species • Creating buffer zones or migration corridors for ecosystems • 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 • Conservation of and afforestation in the reserve forest areas, coastal areas, swamp forest in the wetland (haor, baor and beel).
7. Infrastructure	• 50% of national highways are under medium vulnerability while another 8% are highly vulnerable by 2050 due to flooding. • 10% of regional highways and 8% of railways are under high vulnerability by 2050 due to flooding.	• Redesigning and improvement of road, rail line, embankment, and other infrastructures keep them functional during flood • Increase number of openings (bridge, culvert) to improve drainage congestion

Sector	Vulnerability	Adaptation measures
		• 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
8. Urban Area	• Urban flooding caused water logging and drainage congestion due to frequent and excessive rainfall • Flash flood and landslides due to hill cutting and excessive rainfall is a continuous threat for the people living in cities and towns of the hilly areas • Cyclone storm surges accompanied flooding will inundate coastal cities • Heat island effects in the urban area is another major threat for people impairing their health and raising morbidity and also mortality • Poor people specially the slum dwellers will be more affected directly and also will have income losses due to morbidity and loss of income. • • Quality of water (surface and drinking) will deteriorate due to flood, cyclonic storm surges and salinity intrusion •	• Properly implement the existing policies and plans for development of built-up areas and redesign urban planning keeping CC 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 CC consideration • Urban greening programme including roof top gardening • Preservation, maintenance and improvement of the 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

5.14 Livelihoods and Climate Change Impacts

5.14.1 Links between CC and Livelihood Changes

Issues

The key issues in climate change and adaptation strategies to minimize its adverse effects are related to reducing vulnerability to climate-induced change and to sustain and enhance the livelihoods of people. These strategies consequently need to be rooted in an understanding of how the people and vulnerable groups sustain their livelihoods, the role of risk and vulnerability in livelihood activities and the scope for adaptation actions that reduce vulnerabilities and increase the resilience of people, in general, and the poor in particular. This is not as straightforward as it sounds, as the effects of climate change are just one of the many factors that influence people's livelihoods.

Earlier in Chapter 2 a broad description has been provided regarding the livelihood issues of the people in the country. Here an attempt has been made to provide the link between livelihood and weather and climate-related factors and impacts.

There are two types of livelihood issues depending whether one is examining slow or fast on-set events. Slow onset events may be reduced productive capacity of land due to changes or impacts on soil, natural resources or agriculture as a whole. In such cases, people experience erosion of livelihood options slowly, and they also adjust slowly and may try to claim back some of their earlier livelihood options. For example, as soil desiccates slowly due to continued drought, people may try to go for more irrigation, if possible or may introduce hardier crops. But the changes mean that some people may no longer be employed in the particular occupation. If they cannot get employed elsewhere, their poverty may increase, they may sell whatever assets they have to buy food or if nothing else works, some or all members of the family may migrate. Some may even turn to criminal activities to earn their livelihood.

Fast on-set events are basically disasters such as flood, flash flood, drainage congestion due to heavy rains, cyclones and storm surges, land and mudslides. While employment and incomes may fall this happens because the natural disasters usually put the various systems into temporary but immediate disarray. More immediate impacts fall on chances of survival as many may die during or in the immediate aftermath of the events. Other areas which may be adversely affected include habitation, housing, health, availability of safe drinking water, infrastructure necessary for rehabilitation and relief works and on access to various necessary services including transport of food and ultimately on food security.

The impacts of these changes whether due to slow or fast on-set events fall disproportionately over groups in society as well as spatially. Coastal areas are far more vulnerable to cyclones and storm surges while the inland districts are more vulnerable to river flooding and in hilly areas to flash floods. The impacts also fall disproportionately on men and women, children and the old and the poor and the non-poor. Women particularly are vulnerable due to cultural factors as well as the events. They prepare the food, carry the water home and ten for the children and yet, as studies have shown they suffer probably the most during and after disasters. Even in case of cyclonic storms when they get to shelters they find inadequate facilities for personal hygiene such as toilet putting them in more difficulty and expose them to urinary tract diseases.

The poor and the non-poor suffer differently because of the wider livelihood options for the non-poor and their better adapting capacity. In general the disadvantaged groups in society may become more disadvantaged.

There are several issues to livelihood vulnerability: what happens and will happen to employment, income and poverty; what happens and will happen to gender-based division of resources, food access and others; what happens and will happen to habitation pattern and migration; what happens and will happen to people in the coastal areas and non-coastal areas and between plains and the hills. Also we shall have to think wherefrom or through which the shocks will emanate. Very few of these can be quantified at this stage as we have but little work done on these issues including macroeconomic ones of growth, employment, income and poverty. What we shall try to do therefore is to briefly draw upon the earlier sections which described the potential impacts of shocks and try to deduce qualitatively what might happen in future.

Employment

Agriculture, despite its substantially lower contribution to GDP at present is still the mainstay of the Bangladesh economy and the source of food, and major part of employment and livelihoods for its people. The agriculture sector provides employment to 52 percent of the total labor force. The crop sector, providing major livelihoods to people, accounts for almost 12 percent of the GDP and 56 percent of the agricultural value added.

It has been seen earlier that crop agriculture will have a reduction in yield as well as output due to climate change impacts, apart from losses that it might suffer due to floods and other natural hazards. In any case this means a diminution of the available output for food security while there will also be employment reductions from the baseline. How much reduction there will be in employment will of course depends on how much labour it takes to produce a unit of crop output. It has been observed earlier that there will be substantial loss in case of boro output. However, the actual employment loss will be not simply due to the loss in output but also due to indirect losses elsewhere within the economy caused through linkage effects. All sectors which purchase price for production purposes and all sectors supplying inputs into rice production will incur some losses. All of these together will have multiplier effects. A dated report (Asaduzzaman: 2001) shows that there will be up to 50 units of employment loss as a whole for the economy for each mn taka of output while for losses in wheat, livestock and poultry the losses will be more than 50 units of labour per mn taka of output loss. These are very large losses indeed.

The aggregate losses in employment will be for output losses due to CC and additionally due to natural hazards such as flood, cyclones and storm surges. Rice crop alone suffers losses of 3.7 percent of potential output on an average every year.

According to an estimate (BBS, 2006) the projected labour force in 2030 and 2050 will stand at 9.5 million total (males: 6.6mn, females: 2.9 mn) and 12.0 mn (males: 7.8 mn, females: 4.2 mn). Work will have to be found for all of them. If production disturbances occur due to climate change impacts, this is going to be hard.

Employment losses will also occur due to the losses in other non-agricultural sectors. For example, transport services which are often hampered due to floods and similar hazards, have a multiplier of up to 50 units of employment meaning that every mn taka worth of services lost result in up to 50 units of employment loss.

All these assume that there is or will be no intervention. But some kind of adaptation intervention will be there and if properly implemented, the losses will be correspondingly less.

Food security

To understand the implications for food security, first note that theconsumption demand for staples such as rice has been projected to be 32.5 mn mt in 2030 and 38.3 mn mt in 2050. Including wheat the demand for cereals will be 33.5 mn mt and 40.7 mn mt in 2030 ande 2050 respectively. It has been estimated in a study that over 2005-2050 a total cumulative loss of 80 mn mt of rice may occur. But weather variability and future climate change may make it difficult to domestically produce the projected demand of cereals.

The demand for other food will also increase. Demand for milk for example is expected to rise from less than 5 mn mt in 2010 to nearly 12 mn mt by 2030 and 16.5 mn mt by 2050.

Given the losses that crop agriculture and livestock may suffer particularly dairy cattle, it would be difficult to meet these demands unless measures are taken to prevent these losses.

It is true that incomes will fall for many, if not all due to the CC and its impacts. This will restrict access to food. Non-crop food supply may also be restricted lowering very possibly nutritional status of the people in general and the consumers who no longer can afford possibly pricey but nutritious food.What all these mean is that in future food security will be under grave threat unless appropriate measures are undertaken.

Income

Production and employment losses will immediately mean income losses which also mean food insecurity for those such as agricultural wage labourers who depend on agriculture and also have to purchase their food. Again such income losses will be both direct and through linkage effects. Earlier analyses indicate that for every unit of output loss there will be at least 0,75 units of loss in value added in case of paddy, poultry, livestock, many other agricultural products, transport services etc. As we know all of these are going to be seriously adversely affected due to climate change and the second round of physical impacts. Thus, the loss of a mn dollar worth of paddy output will mean at least 7.5 hundred thousand dollars' worth of value added or income. And obviously this income loss will be experienced by those who had lost in production and employment, among farmers the marginal and the poor ones mainly, agricultural and non-agricultural rural labourers, small entrepreneurs, transport service providers etc.

Poverty

If the economy grows in the normal manner, poverty may fall over time particularly if the rate of growth picks up to reach 8-9% per year by 2050 or thereabout. If by 2030, the growth rate accelerates to more than 7% per annum, the poverty incidence may fall to 13-14% of population. Question is if such a growth rate would be achievable under CC impacts. If some recent exercise is a guide, it may not happen that way.

If only rice output losses are accounted for output may fall by a cumulative 80 mn mt between 2005 and 2050 or nearly 4% per year. Future climate change will exacerbate the existing impact of climatic variability. The loss in agricultural GDP as deviation from the baseline over 2005-2050 (discounted) is US$ 26 bn. Including the linkage effects within the economy this may be up to US$ 121 bn (or US$ 3 bn/year). This is a deviation of 5% below the baseline scenario. All of these may mean a reduction of the over-all GDP by 1.15% per year. That is the expected 7-8% growth rate may be less by at least 1 percentage point due to the fall in output in only one crop. Consider now that there are damages to other crops, sectors and sub-sectors due to flood and other hazards. For example, in 2004, industrial losses due to flood was nearly 5% of total damages while infrastructure loss was nearly 40%. The expected growth rate will be extremely difficult to be achieved if such shocks become more frequent than these are now. Poverty therefore may not diminish much or even if it does, there is a grave chance of the poor sliding down the income ladder at times of major natural hazards.

Habitation and housing

Habitation losses may occur temporarily due to flood or permanently due to sea level rise and consequent water logging and inundation. This may be severe in case of urban areas particularly if low elevation land is used as built up area. Naturally, housing and property losses will also occur. As these types of areas are often inhabited by the poor, it is them who will suffer more than others.

Health, morbidity and mortality

Health impairment under CC and its impacts may be due to several factors, some or all of which may combine at any given time period. Food availability problems may lead to under-nutrition and malnutrition while direct impacts of temperature rise and precipitation changes may make the environment favourable for vectors and parasites and viruses causing diseases, temperature rise itself may create specific health problems. All these may be exacerbated by drinking water problem which may also arise in certain areas. Natural hazards accentuate some of these problems while they may also be the direct causes of death as happens in case of cyclones and storm surges.

In general morbidity is expected to rise which may also lead to erosion of income and may further put stress on households, particularly the poor. Lower income also impairs their capacity to seek medical help unless free medical services are available.

Spatial aspects of livelihood

From a spatial distribution of adverse effects, one finds that people living in the Southwestern region will face multiple livelihood stresses under climate change (Ahmed and Hussain, 2010). Management of increasing salinity, given the limitations of the present water resources management plans and practices without adequate provisions for sediment management and the dilapidated and faulty embankment system along the coastal reaches, has the potential to wreak havoc in the coastal areas at times of cyclones and storm surges and affect the livelihood of the people in all its aspects.

The coastal charlands in the central southern region are facing the risk of embankment failure and subsequent saline regime. The latter will tend to reduce crop agricultural potential. This region will also tend to face SLR and stronger and higher surges. The increasing frequency of rough seas will tend to discourage fishermen from going out to deep sea for maintaining their already threatened livelihoods (Ahmed and Neelormi, 2007).

There are specific CC hotspots in the non-coastal areas. The barind tract is susceptible to drought while the haor areas in the north-east face flash floods and related hazards. The livelihood of the people in these areas may face severe stress over time. So will be that in the hill areas in the south-east and also the central north.

Habitation, housing, health, food supply, and urban areas will face various types of stresses in future. While both rural and urban areas will face the problems, these will be much accentuated in the urban areas due to lack of spatial leeway, so to speak and high density of people.

Gendered dimension of livelihoods stresses under CC

The patriarchal system in place in Bangladesh controls women's roles and responsibilities, mobility, and sexuality. Women's status tends to be derived from their family, and they are generally seen as economic dependents, while high value is placed on sons as potential family providers and perpetrators of family names (Goetz and Gupta, 1996).There is an emphasis on women's reproductive value and consequently access to higher education for girls is more limited than boys.

The responsibilities of women tend to focus on family maintenance and the existence of succeeding generations (Jahan, 1975). Within the household, decision-making and control of resources are generally in the hands of men (Kabeer, 1991). They have limited access to resources, property, education, and income-earning opportunities. Climate change adds on to the existing gendered inequities and accentuates the plights of women in general compared to men.

There have been only a few explorations of the link between gender relations and climate change (Ahmed *et al*., 2007a; Ikeda, 1995; Neelormi, 2010). As men and women in a society as that in Bangladesh have distinct social and familial roles and responsibilities, these give rise to differences in vulnerability and ability to cope with climate change and its impact.

The contexts of vulnerability to climate change in Bangladesh for women are somewhat different for women compared to men. Women biologically as women may face certain bio-physical stresses due to CC and its impacts. These are some time accentuated by their social, reproductive and care-giver role in the family as well as their social differentiation (or discrimination) that they may face. And thirdly, they face the same or similar stresses of CC and its impacts as men do. Such stresses do get compounded when most climate change issues, policies and programs are not found to be gender sensitive.

5.14.2 Adaptation measures for secure livelihood

The basic adaptation measure for a secure livelihood has to be against the sources of the primary vulnerability about which analysis and description have been given in earlier sections. Here we provide ideas about measures which may not have been covered elsewhere. These include among others;

a. Various income-supplement programmes such as social safety net programmes for those who may have become temporarily or permanently unable to secure an income ;
b. Various insurance as well as micro credit programmes;
c. Rehabilitation programmes for agriculture and small scale enterprises in the aftermath of disasters including credit, technological up gradation and marketing support;
d. Revision of relevant policies to make them gender-sensitive;
e. Make all CC and impact related interventions gender-sensitive;
f. Food assistance and nutrition programmes in case of emergencies

5.15 Adaptation Strategy

5.15.1 Preamble

Bangladesh has a Climate Change Strategy and Action Plan (BCCSAP) formulated initially in 2008 and slightly revised in 2009 (MoEF, 2009). This clearly sets out the over-all strategy and the actions that need to be undertaken. At the same time or even prior to that there has been other non-state attempt to initiate climate change adaptation in certain hotspots in the South-western region of the country. This paved the way for a community-based adaptation strategy. As its happens, the BCCSAP is a over-all guideline strategy and has left space for all kinds of actors on the scene although it was envisaged that the State will play a major role. For ease of understanding of these two approaches to adaptation we first provide a description and review of the programme called Reducing Vulnerability to Climate Change (RVCC) and then move on to the BCCSAP.

5.15.2 The RVCC Innovation

The people in Bangladesh face various kinds of climatic events throughout the year including ones which are also sometime life-threatening. Yet, they have survived because of their traditional knowledge regarding how to survive in such situations. CARE Bangladesh administered a project, calling it Reducing Vulnerability to Climate Change (RVCC), in association with 16 partner NGOs and a few regional/national institutions (CARE-RVCC, 2003).

The project aimed among others on tapping the people's first hand experiences on how to tackle impacts of climatic events.

RVCC innovated a participatory methodology to assess vulnerability of a few communities living in climate change hot spots in the SWR region of the country. Local people identified their climate and non-climate contexts of vulnerability and discussed plausible response modalities (i.e., adaptation). Following an analysis of capacity of the communities involved, socio-culturally appropriate adaptation modalities were identified for both household and community levels (Ahmed and Scherer, 2004). Moreover, a few institutional adaptation modalities were also promoted that involved exercising planned adaptation involving Local Government Institutions (LGI), promotion of school curricula on climate change, grassroots advocacy on water rights, and social mobilization towards responding to climate change at local levels (Ahmed, 2008). Table 5.22 provides a bird's eye view of various adaptation modalities implemented at household levels. Table 5.23 highlights adaptation modalities which were tried out at the community-based institutional level.

Table 5.22: Strategic Approaches for Increasing Household Adaptive Capacity

Strategy	**Measure**	**Brief Description of the Measure**
Household-level strategies		
Increase food through agriculture	Drought tolerant crops/vegetables	Introduction of drought tolerant crops such as groundnuts, watermelon, etc. that can be grown under drought conditions
	Embankment cropping	Cultivation of beans, gourds, okra and other vegetables on the embankments between prawn ponds
	Floating gardens	Cultivation of vegetables on floating beds of water hyacinth (hydroponics)
	Homestead gardening	Cultivation of vegetables and fruits on homestead plots for consumption and market
	Low-cost irrigation	Demonstration of treadle pump and other simple technologies for irrigation
	Saline tolerant non-rice crops	Introduction of saline tolerant varieties of chili, mustard, maize and potato
Increase income through alternative livelihoods	Apiculture & honey processing	Beekeeping and processing of honey for market
	Cage aquaculture	Small-scale fish farming in cages, implemented in household ponds or common water bodies
	Cattle rearing	Raising cattle for consumption and market
	Cottage industries	Production of *mele* (reed) mats, recycled paper bags and bamboo baskets for market
	Crab fattening	Collection, rearing and feeding of crabs for a period of 15 days to increase their market value
	Drought-resistant tree plantation	Homestead planting of drought-resistant fruit and timber trees for longer term income generation
	Duck rearing	Raising ducks to produce meat and eggs for consumption and market
	Goat rearing	Raising goats for consumption and market
	Mele (reed) cultivation	Cultivation of reeds that are used to produce mats that are widely used for sitting and sleeping on
	Nursery & homestead afforestation	Establishment of community nurseries and distribution (with handling instructions) of indigenous varieties of tree saplings (mango, coconut, *sofeda, korai*, guava, *mehaguni*, neem, *kewra*, etc.) to beneficiaries for homestead planting

Strategy	Measure	Brief Description of the Measure
	Pig rearing	Raising pigs for consumption and market
	Poultry rearing	Raising chickens to produce meat and eggs for consumption and market
	Prawn fish poly-culture	Prawn and fish culture in fresh-water *ghers* (ponds)
	Saline-tolerant tree plantation	Planting of saline tolerant fruit and timber trees for longer term income generation
	Shrimp fish poly-culture	Shrimp and fish culture in salt-water *ghers* (ponds)
Increase food availability/ storage	Improvement of food storage	Promotion of indigenous techniques for protecting food stores from flood
	Introduction of cooking stoves	Promotion of flood-proof cooking stoves made of local materials
Improve health and personal safety	Improvement of hygiene and sanitation	Raise awareness about personal hygiene and sanitation and promote use of hygienic latrines
	Protection against cyclones	Work with communities to allow minority groups to access existing cyclone protection facilities
Increase access to safe water	Deep Tube Wells	Drill deep tube wells to provide safe water to households for cooking and drinking
	Household pond protection	Promote protection of small ponds to provide safe water for cooking and drinking
	Indigenous methods of water collection	Collection and sanitary storage of rainwater in earthen pots
	Pond sand filters (PSF)	Construction of pond-sand-filters to provide safe water for cooking and drinking
	Rainwater harvesting	Improved technology for rain water collection from roofs and storage in a tank
	Safe water & sanitation	Raise awareness about methods for collecting & storing safe water and sanitation
Improve safety of housing and other property	Safe havens for domestic animals	Establishment of safe havens for animals to protect from flood, storm and cyclone
	Storm-resistant housing	Promotion of storm resistant construction features, including local technologies
	Wind break tree plantation	Promote plantation of trees for protection against storms and cyclones

Source: Schaerer and Ahmed, 2004.

Table 5.23: Strategic Approaches for Increasing Community-Level adaptive Capacity

Strategy	Measure	Description of Measure
Community-level Strategies		
Increase access to common property resources	Access to common property regimes within the water-logged areas	Negotiations with locally-elected bodies and influential people to allow access by beneficiaries to common water bodies
Reduce threats through community-based initiatives	Canal excavation	Promotion of canal excavation for improved drainage to reduce water-logging/flooding
	Cyclone preparedness	Raise awareness about cyclone preparedness and promote the construction of cyclone shelters
	Raise height of embankments	Promote the raising of height of embankments in order to protect from flooding
	Tidal River Management (TRM)	Promote tidal river management to protect from water-logging

Source: Schaerer and Ahmed, 2004.

The RVCC project initiated a massive awareness campaign in the SWR region of the country. Folk media was chosen carefully to spread the necessary information regarding climate change. Local grassroots actors were drawn into this folk-media based awareness campaign which was particularly useful for reaching out to illiterate people.

RVCC paved the way for intensification of Community Based Adaptation (CBA) in the country. The project offered capacity building training to hundreds of people throughout the SWR region who had been implementing various adaptation modalities in the region and beyond. Local institutions were particularly successful in replicating the simple ideas generated by RVCC and became local adaptation champions. As a consequence, a few adaptation modalities were replicated elsewhere by other inspired NGOs. The RVCC methodology was particularly useful towards assessing community adaptation needs and capacities (Ahmed, 2000).

5.15.3 The post-RVCC CBA: Interaction with State Actors

While NGOs were involved, collectively and/or individually, in advancing CBA primarily in the SWR, a good number of nationally active public institutions have been drawn and engaged in research–mostly action research–to test adaptation modalities in areas other than SWR in association with the non-State actors..

For example, CARE took the newly developed BRRI-40 and BRRI-41 paddy varieties to the field for testing their farmer level trials. This was done in collaboration with the Bangladesh Rice Research Institute (BRRI). While the two varieties were found to be useful for avoiding adverse impacts of salinity in the monsoon rice season up to 10~12 ppt in Satkhira, the BRRI produced a new variety, BRRI-47, which could sustain up to 12 ppt salinity during dry season. Before extension, all these varieties and other non-rice varieties such as chilli and tomato were field tested by CEGIS in collaboration with the BRRI and the Bangladesh Agriculture Research Institute (BARI). It was found that such new varieties would be highly useful for adapting to high salinity under climate change (Ibrahim *et al*., 2009).

The Center for Natural Resources Studies (CNRS) also field tested a few vegetables and other crops in the haor basin (Rahman *et al*., 2009). BARI was once again the technical supporting institution that collaborated in the action research. Following the research phase, efforts have been made to popularize the most suitable (i.e., adaptable) varieties in the haor region.

The floating garden was successful in the SWR and also in floodplains such as Gaibandha. Practical Action promoted the idea of making Aman seedbeds on floating gardens in order to avoid late flood induced production loss and subsequent food insecurity. Since Gaibandha district has been facing three phases of peak flood in a single monsoon and the late flooding being particularly damaging to seedlings of Aman paddy, farmers happily accepted the idea and replicated the floating garden even when project-based incentives were pulled off.

In the drought-prone region, the FAO initiated a research programme that identified a few adaptation modalities in the greater Rajshahi region including the Barind Tract (Selvaraju *et al*., 2006). The study prompted a number of projects to promote adaptation modalities. CARE Bangladesh, in association with its partner NGOs, has been particularly promoting such alternative crops in anticipation of occurrence of acute drought in the Barind Tract. A few NGOs have been trying to promote, as a part of autonomous adaptation, water retention ponds and excavation of local ponds and kharees in the area. However, most of such promotional efforts have been approached without any project format.

CARE Bangladesh promoted a number of aspects of disaster risk reduction in order to enhance resilience of local communities living in climate hot spots. CARE Bangladesh in association with its partner NGOs, promoted adaptation modalities such as raising the plinth height to avoid flooding, creating wave-breaks in haor areas to safeguard villages from erosion, charland resettlement areas, cyclone shelter refurbishment/building with modified design, etc (CARE, 2009).

Recently, two other noteworthy organizations have become involved in promoting CBA: the Bangladesh Rural Advancement Committee (BRAC) and Hellen Keller Institute (HKI), Bangladesh. While BRAC has been promoting alternative agriculture to avoid crop loss due to high salinity, the HKI has been popularizing common practices such as raising the plinth height of flood-prone dwellings, pit production of vegetables, crab fattening, establishing nursery, apiculture, etc.

5.15.4 BCCSAP: A Broader Framework for National Level Adaptation

The early experiences of the RVCC clearly inspired all concerned that the CBA could be one of the major mechanisms to address climate change. But over time it became apparent that without a broader national framework, local, community based adaptation has its limits. Organized approaches are necessary to ameliorate these limitations by means of involvement of organizations at all tiers, policies, norms and practices, governance processes, etc. General strategies and time-bound plans are manifestations of organized approaches for addressing relevant issues. The answer to this need was given by the Bangladesh Climate Change Strategy and Action Plan (BCCSAP). Chapter 6 provides a brief introduction to the over-all BCCSAP. Here we concentrate mainly on its analysis. The relevant sections in the two chapters may have to be read together, however, for a fuller understanding.

The BCCSAP called for enhancing risk-related knowledge, through modeling and continued education and sharing (MoEF, 2009). There has been renewed emphasis on enhancement of early warning system (EWS), by involving national institutions. The success of the Cyclone Preparedness Programme (CPP) is largely attributed to the robustness of the early warning system, the issuance of warnings through a unified signaling system, and the dissemination of information from door to door by about 62,000 volunteers of the Bangladesh Red Crescent Society.

A brief analysis of the BCCSAP provisions and recommended adaptations

The BCCSAP highlights adaptation as well as low carbon development. There are 44 programmes, 28 of those have specific relevance to adaptation. The programmatic approach to adaptation is organized under four major issues: (a) food security, social protection and health, (b) comprehensive disaster management, (c) infrastructure, and (d) research and knowledge management. The fifth major issue involving capacity building and institutional strengthening also has elements that deal with adaptation in addition to mitigation and low carbon development.

The programmatic approach to adaptation focuses interventions in all tiers of the governance system. The primary emphasis is on institutionally driven adaptation. However, the importance of Community Based Adaptation (CBA) and emergency responses has also been considered under the BCCSAP. Since the BCCSAP has been formulated following the rich experiences of CBA initiatives such as RVCC, and other such experiences, all the adaptation modalities involving local communities find direct relevance with the provisions created by the BCCSAP. The latter also provides for justification of the projects highlighted in NAPA, In most of the CBA, it is found that NGOs find livelihoods enhancement, especially through diversification of agriculture and adopting alternative production system in changed hydro-geophysical conditions, and small scale disaster risk reduction (DRR) efforts as the primary generic modality to address adaptation (Ahmed, 2010). The BCCSAP creates space to plan for a combination of the two different approaches to adaptation, which has significant potential to reduce adverse impacts in agriculture-based production system and thereby contribute towards reducing overall food insecurity.

Indeed, the needs for adaptation in the agriculture sector highlighted in an earlier section in this chapter find strong relevance to BCCSAP (Programme T1P2, T1P3, T1P4, T1P5, T1P8, and T1P1). Similarly, the perceived/recommended adaptations in disaster risk reduction, as highlighted in an earlier relevant section compliments programmes indicated in BCCSAP (viz. T2P1, T2P2, T2P4, and T2P3).

It is well understood that the investments of today need to be safeguarded against climate induced extreme weather events in the longer term (Ahmed, 2007), and the country must embark upon a new paradigm of 'climate resilient development' (Uddin *et al.*, 2006) by accommodating concerns of climatic hazards in large capital investments, such as in infrastructure. Simultaneously, infrastructure can also be considered to be a complimentary factor to promote/strengthen adaptation (such as strategic embankments, cyclone shelters, etc.) (World Bank, 2000; Agrawala *et al.*, 2003). The recommendations provided for adaptation in infrastructure find strong complementarity with the provisions created by BCCSAP, especially through programmes such as T3P1, T3P5, T3P6, T3P7, T3P2, T3P3, T3P4, and T3P8.There has been certain demand in the literature which highlighted the need for knowledge-driven well-planned adaptation (Agrawala et al., 2003; Ahmed, 2004; Ahmed 2008, and Ahmed, 2010). It is also argued that the current thrust to sustainable development cannot be sustained unless the management system fully understands the potential risks from climate related extremes and new thresholds. For example, a change in cropping pattern will only have a lasting impression if the extent of change is well understood and the proposed 'new cropping pattern' takes into consideration of such changes. The BCCSAP duly emphasized on research and knowledge management, and created provision for knowledge driven adaptation by means of programmes such as T4P1, T4P2, T4P3, T4P4, T4P5, T4P6 and T4P7. Such programmes resonate well with some of the adaptations recommended in the earlier sections. It is also widely recognized that one of the obstacle to implementing climate smart development lies in the limited capacity within various relevant national institutions. The importance of clear understanding regarding climate related threats has been highlighted. Currently, there is a policy void towards dealing with climate smart development, integrating adaptation concerns. The BCCSAP clearly highlights the need for capacity building and pronounced programmatic approach to deal with low levels of institutional capacity. A few similar specific recommendations have also been placed in earlier sections

5.15.5 Strengthening the Institutional Processes

As indicated earlier building capacity is an urgent need if CC and its impacts are to be managed well. The Government of Bangladesh (GoB) has taken firm steps towards strengthening the institutional approaches and capacity to climate change, especially adaptation. As an apparent interim arrangement, a Climate Change Cell (CCC) was established in 2005 [as a part of a major programme titled Comprehensive Disaster Management Programme, CDMP]. It has undertaken a good number of steps towards strengthening the national institutional processes. Later, the MoEF has established a Climate Change Unit (CCU) within it. It is intended that the primary role of the CCU will be to foster adaptation and low carbon growth in the country. Considering the inadequacy of financial flows through international climate change process to address activities at the ground, government established Bangladesh Climate Change Trust Fund (BCCTF) to start the implementation of the Bangladesh Climate Change Strategy and Action Plan. During the

2009-2010, 2010-2011 and 2011-2012 financial year (which begins in July and ends in June next year), government allocated US$ 300 million from its own resources. A 15 member trustee board has been created to administer the fund. A Climate Trust Act 2010 has also been enacted to provide a legal footing for the fund.
It has been estimated that a total of US$ 5 billion will be required to implement the BCCSAP. Alongside Bangladesh government initiatives, Development Partners came forward to support the implementation of our BCCSAP. They have established a Bangladesh Climate Change Resilience Fund (BCCRF) worth US$ 125 million.

Mainstreaming efforts

The BCCSAP was approved at the highest level of the Government. Later it became an integral part of the Sixth Five Year Plan (2011-15). The BCCSAP consists of six pillars encompassing all major aspects of lives where adaptation would be necessary. This provides a framework to determine adaptation needs and to implement adaptation up to 2015.One of the major directives provided by the BCCSAP is to mainstream CC and adaptation concerns in all economic and social aspects of governance. BCCSAP highlights the involvement of various key institutions to implement it. Also while the Sixth Five Year Plan has included it there is now an attempt to actually prepare a procedure for integrating CC and its impacts into project designs of all public investment projects.

To steer BCCSAP related activities, a high powered ministerial committee was formed in early 2009. With active guidance, the proposed CCU within the MoEF is has a mandate to translate the BCCSAP into actions.

Financing Adaptation

The GoB has allocated financial resources from its public exchequer since the financial year 2008-2009 in order to facilitate adaptation related activities in Bangladesh. With the first allocation, the GoB called for project proposals from both public institutions and NGOs to implement a few adaptation projects. While the processes of selection of appropriate projects were underway, the GoB allocated further finance in the next year's budget in order to further advance adaptation related activities. Moreover, the GoB expressed its firm commitment and requested international agencies to provide financial support to foster adaptation in Bangladesh. Only recently, a Climate Change Resilience Fund (CCRF) has been established. Bangladesh's development partners have committed funds as initial support to the CCRF.

5.15.6 Implementing the BCCSAP

Many ministries of the government as well as many non-state actors are involved in adaptation and other CC and impact areas to manage climate change. There is still no firm implementation framework yet, however. This needs to be set up. In the meantime, the government has established a Climate Change unit in the MoEF. A Department of Climate Change (DCC) has been approved to be established as an operating arm of the ministry. Hopefully this will give impetus to the establishment of a climate change management framework with ministries as well as non-State actors.

In the meantime it may be noted that the BCCSAP actually has assigned ministries and agencies to various programmes to be implemented by them Table 5.24 shows these assignments of public and other institutions. There is no bar on the ministries in carrying out these assignments provided they can generate funds for the purpose.

Table 5.24: BCCSAP Programmes

BCCSAP Programmes	Suggested Institutions
Institutional capacity and research towards climate resilient cultivars and their dissemination	BRRI, BARI and other NARS organizations
Development of climate resilient cropping systems	Ministry of Agriculture, NARS
Adaptation against drought	Ministry of Agriculture and Ministry of Water Resources, in association with the extension service
Adaptation in fisheries sector	Ministry of Fisheries and Livestock, Department of Fisheries, Bangladesh Fisheries Research Institute, in association with selected NGOs
Adaptation in livestock sector	Ministry of Fisheries and Livestock, Department of Livestock, Bangladesh Livestock Research Centre, in association with selected NGOs
Adaptation in health sector	Ministry of Health and Family Welfare, in association with research centres (IDCCR,B) and others
Water and sanitation programme in climate vulnerable areas	Ministry of Local Government, Rural Development and Cooperative and various local government bodies and NGOs in rural and urban Bangladesh
Livelihood protection in ecologically fragile areas	Various line ministries, in collaboration with NGOs
Livelihood protection of vulnerable socio-economic groups (including women)	Various line ministries, including Ministry of Agriculture, Ministry of Food and Disaster Management,Ministry of Women and Children Affairs, Ministry of Health and Family Welfare in partnership with NGO
Improvement of flood forecasting and early warning	Ministry of Water Resources and its various agencies; civil society organizations active in disaster management and media
Improvement of cyclone and storm surge warning	Ministry of Food and Disaster Management, Bangladesh Red Crescent Society, NGOs and CBOs (community based organizations) working in the coastal areas and media
Awareness raising and public education towards climate resilience	Ministry of Food and Disaster Management, Bangladesh Red Crescent Society, NGOs, CBOs working in the coastal areas, media (print and electronic)
Risk management against loss on income and property	Ministry of Finance and other line ministries, and the insurance sector and NGOs
Repair and maintenance of existing flood embankments	Ministry of Water Resources and its agencies
Repair and maintenance of cyclone shelters	Ministry of Food and Disaster Management, Bangladesh Red Crescent Society, private sector under their CSR programmes and NGOs
Repair and maintenance of existing coastal polders	Ministry of Water Resources and its agencies
Improvement of urban drainage	Ministry of Local Government, Rural Development and Cooperative with the Local Government Engineering Department, Dhaka WASA, Chittagong WASA
Adaptation against floods	Ministry of Water Resources and its agencies, Ministry of Food and Disaster Management
Adaptation against tropical cyclones and storm surges	Ministry of Water Resources, Ministry of Environment and Forests, Ministry of Food and

BCCSAP Programmes	Suggested Institutions
	Disaster Management
Planning and design of river training works	Ministry of Water Resources with support from IWM, IWFM, CEGIS, WARPO and RRI
Planning, design and implementation of revival of rivers and khals through dredging and re-siltation of work	Ministry of Water Resources, Bangladesh Water Development Board, Ministry of Local Government, Rural Development and Cooperative through Union Parishad, Ministry of Food and Management and Local Administration
Establishment of a centre for knowledge management and training on climate change	Ministry of Environment and Forests, researchorganizations, universities
Climate change modeling at national and sub-national levels	Bangladesh Meteorological Department, Universities, Research Organizations, FFWC
Preparatory studies for adaptation against sea level rise	Ministry of Defence, Ministry of Shipping, Ministry of Agriculture, Ministry of Industry and Ministry of Power, Energy and Mineral Resources
Monitoring of ecosystem and biodiversity changes and their impacts	Ministry of Environment and Forests, Ministry of Agriculture, Ministry of Health and Family Welfare, Ministry of Fisheries and Livestock
Macroeconomic and sectoral economic impacts of climate change	Ministry of Finance, sectoral ministries, Ministry of Women and Children Affairs, Ministry of Social Welfare, Ministry of Chittagong Hill Tracts Affairs, Universities, Research Organizations
Monitoring of internal and external migration of adversely impacted population in new environment providing support through capacity building for their rehabilitation in new environment	Ministry of Environment and Forests, Ministry of Home Affairs and Ministry of Local Government, Rural Development and Cooperative.
Monitoring of impact on various issues related to management of tourism in Bangladesh and implementation in priority action plan	Ministry of Civil Aviation and Tourism, Ministry of Environment and Forests, Department of Forest, Parjatan Corporation, Private organizations
Improved energy efficiency in production and consumption of energy	Ministry of Power, Energy and Mineral Resources, Ministry of Industry, Ministry of Agriculture, Ministry of Communications, Ministry of Finance, Universities and Research Organizations
Gas exploration and reservoir management	Ministry of Power, Energy and Mineral Resources
Development of coal mines and coal fired power stations	Ministry of Power, Energy and Mineral Resources
Renewable energy development	Ministry of Power, Energy and Mineral Resources; Ministry of Environment and Forests, private entrepreneurs
Low emission from agricultural land	Ministry of Agriculture, NARS and Agricultural Extension Services
Management of urban waste	Ministry of Local Government, Rural Development and Cooperative, private entrepreneurs
Afforestation and reforestation programme	Ministry of Environment and Forests
Rapid expansion of energy saving devices e.g. Compact Florescent Lamps (CFL)	Ministry of Power, Energy and Mineral Resources, Ministry of Environment and Forests
Energy and water efficiency in built environment	Ministry of Housing and Public Works, RAJUK, CDA, KDA, RDA, DCC, REHAB, All Private Developers
Improvement in energy consumption pattern in transport sector and options for mitigation	Ministry of Power, Energy and Mineral Resources
Revision of sectoral policies for climate resilience	Ministry of Environment and Forests, Cabinet Division

BCCSAP Programmes	Suggested Institutions
Mainstreaming climate change in national, sectoral and spatial development programmes	All relevant ministries; Planning Commission
Strengthening human resource capacity	All relevant sectoral ministries, Agencies, Private Sector, NGOs, Universities and Research Organizations
Strengthening gender capacity for climate change management	Ministry of Women and Children Affairs, Planning Commission, Ministry of Environment and Forests
Strengthening institutional capacity for climate change management	Ministry of Women and Children Affairs, Planning Commission, Ministry of Environment and Forests
Mainstreaming climate change in the media	All relevant sectoral agencies, private sector, NGOs and others

However, as recommended by an Expert Committee, for smooth integration of adaptation in sectoral development activities, a four-tier monitoring mechanism may be in place. While the line agency, the primary proponent of a adaptation mainstreaming project, will develop, pursue and implement such a project (according to their mandates), the line ministry in charge will rely on (in case it already exists) and/or form an inter-ministerial Coordination Committee with representation from a proposed high powered Steering Committee on Climate Change. The Accountant General will perform business as usual and monitor financial matters, while the IMED will monitor overall activities on behalf of the Government.

Knowledge management should be guided only by the proposed Steering Committee on behalf of the MoEF where reputed academic professionals representing research bodies, universities, and NGOs can facilitate generation of information and knowledge related to climate change. The Expert Group expressed concerns regarding the inadequate modeling efforts and opined that implementation of the BCCSAP will largely depend on accurate climate modeling outputs, without which allocation of funds for particular sectoral adaptation cannot achieve the overall goal of reducing systemic vulnerability.

Chapter 6

OTHER RELEVANT INFORMATION

6.1 Background

As indicated in the beginning of this report, the National Communication may include various information that may be thought of by the Party submitting the NC to be of relevance for understanding the climate change impacts, adaptation and mitigation by the Party. This chapter concentrates on these “Other information”. The scope of work under this activity is outlined in a template published by the UNFCCC (UNFCCC, 2007) based on the guidelines for the preparation of national communications from non-Annex I Parties (decision 17/CP.8). This chapter covers seven components, as far as available data allow to fulfill the overall information requirement as outlined in the template. The components are discussed later in Section 6.3.

6.2 Objectives of the Chapter

The over-all objectives of the NCs is to have comparable information on the activities, achievements and constraints faced by countries in managing climate change and its impacts within a national context which varies from country to country. At the same time this allows the country to have an integrated over-view of its own activities and achievements to guide the national targets towards the global goal. The present SNC has tried to do that in the context of Bangladesh. But there are specific issues which could not be discussed elsewhere within this report. These, which are important from the country perspectives and are in the main cross-cutting issues include:

- Needs assessment on awareness raising, capacity building, and education programme on climate change issues.
- Institutional advancements made in view of mainstreaming/servicing adaptation, and good practices on adaptation.
- Assessment of constraints and gaps towards the development of SNC
- Constraints and gaps, needs for technology transfer/adoption, and on assessment of technical, capacity and financial needs to be covered for institutionalizing the periodic preparation of national communication in future.

6.3 Contents of the chapter

As per the guideline provided by the UNFCCC for preparing the national communication report, different sections in the rest of this chapter are arranged in the following manner:

- Section 6.4: Steps taken to integrate climate change into relevant social, economic and environmental policies
- Section 6.5: Activities related to technology transfer
- Section 6.6: Information on climate change research and systematic observations

- Section 6.7: Research to adapt to and mitigate climate change
- Section 6.8: Information on education, training and public awareness
- Section 6.9: Information on capacity-building at the national, regional and sub-regional levels
- Section 6.10: Efforts to promote information sharing

6.4 Steps Taken to Integrate Climate Change

6.4.1 Background

In this section the following questions have been discussed and answered as far as possible:

i. How is climate change being considered in the relevant planning processes of Bangladesh?
ii. What are the sectors in which mitigation and/or vulnerability and adaptation activities may be important?
iii. What are the linkage of mitigation and adaptation activities with the national development programmes and projects?
iv. What are the national priority issues and how is climate change linked to these issues?
v. What national policies have been enacted on climate change?

The whole component is sub-divided in the four sub-groups:

- Mainstreaming 'climate change' in the national development planning process, where the answers to questions I, III and IV are covered
- Sectors related to mitigation and/or vulnerability and adaptation; the answer to question II is covered
- Mainstreaming Climate Change in the National Policies; the answer to question V is covered
- Lessons learnt and gaps in mainstreaming climate change

6.4.2 Mainstreaming climate change in the national development planning process

The overriding concern of all policies and corresponding actions in Bangladesh is poverty eradication. Various national development processes that are on-going therefore stresses this issue and some of those particularly the more recent ones mention climate change as an issue which may create impediments to the goal and thus the need for a climate smart development process.

6.4.3 Long Term Plan

<u>Perspective Plan: Making Vision 2021 a Reality</u>

The GoB has prepared the Vision 2021which is based on the principle of sustainable development. The management of climate change for sustainable development is an integral part of the Vision 2021.
The Perspective Plan provides the strategy for realizing the Vision 2021.

Adaptation to the impact of climate change is considered as a cornerstone for sustainable development in the Perspective Plan. The Plan affirms that the water and agriculture sectors are likely to be adversely affected as a result of environmental degradation and climate change. Environment and climate change concerns relate to floods, tropical cyclones, drought, desertification, water supply and salinity management, deforestation, water and air pollution, and contamination of water by arsenic, ill-planned expansion of cities and industries. Understanding these realities, the Perspective Plan has proposed appropriate adaptation measures to combat the adverse impact of climate change. Along with encouraging adaptation to climate change, the Plan proposes to undertake supportive measures like 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 the progress made against the goals and targets set in the Plan through a strategy of pro-poor, climate resilient and low carbon development, based on the four building blocks of the Bali Action Plan: adaptation to climate change, mitigation, technology transfer and adequate and timely flow of funds for investment, with in an inviolate framework of food, energy, water, livelihood and health security.

Bangladesh Climate Change Strategy and Action Plan (2009)

The Bangladesh Climate Change Strategy and Action Plan (BCCSAP) is a part of the overall development strategy of the country. Following COP 13 in Bali, 2007 the GoB first submitted its own Bali Action Plan which culminated into the BCCSAP in 2008. The BCCSAP was formulated in a participatory manner upon wide-ranging consultation within the Government as well as between the government and the civil society, development practitioners as well as development partners and the private sector. The BCCSAP was revised in 2009 to take a few programme areas under consideration. The BCCSAP outlines the core policy, strategy, and action thrusts as a mechanism to respond to and address the risks related to climate change in the country. The BCCSAP is an integral part of the Government's over-all development strategy.

The BCCSAP 2009 is offered in two parts; the first one provides background issues related to physical and climatic contexts, core socio-economic realities and policies in the country and the rationale of the vision of future development in the climate change sector. The remaining part of the plan explains a set of programmes under six priority action pillars of the BCCSAP. It is a set of 10-year programme (2009-2018) for capacity building and achieving resilience of the country to meet the challenges of climate change over the next 20-25 years. The needs of the poor and vulnerable, including women and children, will be mainstreamed in all activities under the Action Plan. In the first five year period (2009-13), the programme comprises six pillars (Figure 6.1):

1. Food Security, Social Protection and Health
2. Comprehensive Disaster Management
3. Infrastructure
4. Research and Knowledge Management
5. Mitigation and Low Carbon Development
6. Capacity Building and Institutional Strengthening.

Fig. 6.1: Six Pillars of the BCCSAP

The six thematic issues encompass 44 programmes, listed below in Table 6.1. 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.

Adaptation to the climate change impacts is the main focus. The basic approach is to address economic development and climate change issues in an integrated fashion so that the resilience of the people is increased and climate change impacts managed through effective adaptive activities.

Table 6.1: BCCSAP Programmes

Theme	Programme
T1: Food security, social protection and health	P1. Institutional capacity for research towards climate resilient cultivars and their dissemination
	P2. Development of climate resilient cropping systems
	P3. Adaptation against drought
	P4. Adaptation in fisheries sector
	P5. Adaptation in livestock sector
	P6. Adaptation in health sector
	P7. Water and sanitation programme in climate vulnerable areas
	P8. Livelihood protection in ecologically fragile areas
	P9. Livelihood protection of vulnerable socio-economic groups (including women)
T2: Comprehensive Disaster Management	P1: Improvement of flood forecasting and early warning system
	P2: Improvement of cyclone and storm surge warning
	P3: Awareness raising and public education towards climate resilience
	P4: Risk management against loss on income and property
T3: Infrastructure	P1. Repair and maintenance of existing flood embankments
	P2. Repair and maintenance of cyclone shelters
	P3. Repair and maintenance of existing coastal polders
	P4. Improvement of urban drainage
	P5. Adaptation against Floods
	P6. Adaptation against tropical cyclones and storm surges
	P7. Planning and design of river training works
	P8. Planning, design and implementation of resuscitation of river and *khals* through dredging and de-siltation work
T4: Research and Knowledge Management	P1. Establishment of a centre for knowledge management and training on climate change
	P2. Climate change modeling at national and sub-national levels
	P3. Preparatory studies for adaptation against sea level rise
	P4. Monitoring of ecosystem and biodiversity changes and their impacts

Theme	Programme
	P5. Macroeconomic and sectoral economic impacts of climate change
	P6. Monitoring of internal and external migration of adversely impacted population and providing support to them through capacity building for their rehabilitation in new environment
	P7. Monitoring of impact on various issues related to management of tourism in Bangladesh and implementation in priority action plan
T5: Mitigation and Low Carbon Development	P1. Improved energy efficiency in production and consumption of energy
	P2. Gas exploration and reservoir management
	P3.Development of coal mines and coal fired power stations
	P4. Renewable energy development
	P5. Lower emission from agricultural land
	P6. Management of urban waste
	P7. Afforestation and reforestation programme
	P8. Rapid expansion of energy saving devices
	P9. Energy and Water Efficiency in Built Environment
	P10. Improvement in energy consumption pattern in transport sector and options for mitigation
T6: CapacityBuilding& Institutional Strengthening	P1. Revision of sectoral policies for climate resilience
	P2. Main-streaming climate change in national, sectoral and spatial development programmes
	P3. Strengthening human resource capacity
	P4.Strengthening gender consideration in climate change management
	P5. Strengthening institutional capacity for climate change management
	P6. Main-streaming climate change in the Media

The GoB recognizes the need for institutional strengthening and capacity development to respond to the climate change issues effectively. Some of the relevant administrative and governance issues have already been discussed under Adaptation Strategy in Chapter 5.

As a part of facilitating the implementation of BCCSAP programmes, the MoEF has already approved 66 projects for implementation in various areas related to management of and adaptation to climate change.

Financing the adaptation and mitigation programmes outlined in the BCCSAP is a challenge. Roughly, it is estimated in the BCCSAP that $500 million will need to be initiated in years 1 and 2 and the total cost of the programmes commencing in the first 5 years could be of the order of $5 billion.

Millennium Development Goals (MDGs)

Bangladesh is committed to the achievement of the MDGs. Goal 7 on environment includes issues related to climate change. Bangladesh is on track for maintaining the forest cover at the national level, maintaining the CO_2 emission and consumption of ozone depleting CFCs at an acceptable level. But Bangladesh needs attention for meeting other indicators of progress towards the Goal 7.

6.4.3 Medium Term Plan

Five-year Plans

Environment as a concern for development was first addressed in the Fourth Five-Year Plan (1990-1995) of the country and received more emphasis in the Fifth Five Year Plan (1997-2002). The Fifth Plan strongly advocated the need for paying attention to sound environmental management for sustainable development. The major environmental issues identified and addressed in the Fifth Plan were, among others, natural disasters, pollution, health and sanitation, deforestation, desertification, changes in climatic conditions, salinity and biodiversity all of which directly or indirectly are expected to be impacted by climate change.

Bangladesh has now prepared its Sixth Five-year Plan which is expected to follow the directives for making Vision 2021 a reality. The outline of the Perspective Plan clearly states that the proposed programmes will be implemented through the Sixth (2011-2015) and the Seventh Five Year Plans (2016-2020). As a part of this, Bangladesh is moving towards mainstreaming climate change management as an integral part of its national development strategy in the Sixth Five Year Plan.

The five year plans are implemented through what are called Annual Development Plan (ADP) which is actually a collection of public sector development projects. The Government has now begun a study to examine thoroughly exactly how climate change issues may be integrated within project designs and also to understand where this must be done and where this may not be needed.

National Plan for Disaster Management

A Standing Order on Disaster was introduced in 1997 by the Ministry of Food and Disaster Management. Recently the Government has launched the National Plan for Disaster Management to be implemented during 2008-2015. The Plan addresses issues like risk reduction, capacity building, climate change adaptation, livelihood security, gender mainstreaming, community empowerment and response and recovery management. The plan states that climate change adds a new dimension to community risk and vulnerability.

"Steps towards change: National Strategy for Accelerated Poverty Reduction" (FY 2009-2011

This document the life time of which has already ended discussed among others climate change issues within the framework of poverty eradication. None of the five supporting blocks and five supporting strategies directly included "climate change" as an issue but it was implicit in all the suggested activities and policy recommendations under the strategic blocks.

For example, improved performance in the agricultural sector is proposed to be attained through among others implementing climate change adaptive technology. Similarly, climate change adaptation is considered as a key strategy for water resources development and management. Under the proposals for disaster management programmes, provisions of cyclone protection, early warning and forecasting systems with adequate lead time, flood proofing shelters, control of riverbank erosion, drought management and rationalization of groundwater resources and climate change adaptation are considered as key strategic priorities in the area. Obviously these are all parts of adaptation as discussed in Chapter 5.

6.4.4 Sectors related to Mitigation and/or Vulnerability and Adaptation

Bangladesh submitted the National Adaptation Programme of Action (NAPA) in 2005 to the UNFCCC where several sectors were identified that might be potentially affected due to climate change. Similarly, the Bangladesh Climate Change Strategy and Action Plan 2009 also identified key sectors that may be affected or is important from the view point of mitigation. Chapters 3 and 4 earlier discussed at length the sectors that are important from mitigation point of view and Chapter 5 provides details of vulnerable sectors and adaptation needs therein. BCCSAP 2008 and 2009 both indicated where investments may be needed to adapt to or mitigate climate change. Some of these are shown in Table 6.1 earlier.

6.4.5 Mainstreaming Climate Change in the National Policies

A list of policies of the Government is given in Table 6.2. Very few of these national policies directly address the climate change risks the main reason being that when many of these were formulated at that time climate change was just beginning to emerge as a major development policy concern. Yet, mandates of several policies deal with areas of activity which are directly related to or will be affected by or will affect climate change. Among these the most clear cut policy statements related to climate change has been made in the Coastal Zone Policy of the Ministry of Water Resources in 2005.

Table 6.2: Policies Reviewed in Relation to Climate Change

Coastal zone policy (Ministry of Water Resources), 2005	**National forest policy** (Ministry of Environment and Forest), 1994
Environment policy (Ministry of Environment and Forest), 1992	**National health policy** (Ministry of Health and Family Welfare), 2010
Industrial policy (Ministry of Industries), 2005	**National policy for safe water supply and sanitation** (Ministry of Local Government, Rural Development and Cooperatives), 1998
Information communication and technology policy (Ministry of Science, Information and Communication Technology), 2009	**National population policy** (Ministry of Health and Family Welfare), 2004
Integrated Pest Management policy (Ministry of Agriculture), 2002	**National Seed Policy** (Ministry of Agriculture), Undated
Land Use policy (Ministry of Land (MoL), 2001)	**National Water Policy** (Ministry of Water Resources), 1999
National agricultural policy (Ministry of Agriculture), 1999	**Renewable Energy Policy of Bangladesh** (Ministry of Power, Energy and Mineral Resources), 2008
National Biotechnology Policy (Ministry of Science and Information and Communication Technology), 2005)	**Social and resettlement policy framework** (Ministry of Planning), 2009
National fisheries policy (Ministry of Fisheries and Livestock), 1998	**Tourism policy** (Ministry of Civil Aviation and Tourism), 2009
National food policy (Ministry of Food and Disaster Management, 2006)	

The Coastal Zone Policy directly mentions that the coastal area is vulnerable to risks from climate change. It also points out that the majority of households in the coastal area are vulnerable to climate change. Indeed, a whole section is devoted to climate change in coastal areas as well as adaptation procedures and directly mentions adaptive measures towards sea level rise. The other policy which is somewhat sensitive to climate change issues is the National Health Policy. So is the Social and Resettlement Policy Framework.

On the whole the review of policies indicates the following:

i. Climate change has already been included partially in the national development planning processes, especially in the outline of the perspective plan. Bangladesh has already enacted its climate change strategy and action plan which provides the principle guideline for adaptation and mitigation planning.
ii. Sectors in which mitigation and /or adaptation is required has already been identified in NAPA and BCCSAP.
iii. Linkage of adaptation and mitigation activities with the national development programmes and projects has started to be established. But for better linkage, a road map for Bangladesh is required for mainstreaming climate change considerations across all sectors and at all levels.
iv. National priority issues have been identified in the long-term, medium term and short-term planning documents and to some extent climate change has been linked with some issues. But efforts targeting toward adapt or to mitigate climate change with overall objective of achieving the national priorities are yet to be achieved.
v. Some of the national policies have addressed climate change directly, but most of them do not.
vi. The following gaps are identified in terms of mainstreaming climate change considerations in the national development planning:
    a) Currently, most policy responses continue to address climate change, development, and disaster management without any reference to others;
    b) There certainly remains a lack of interaction and institutional overlap among policy makers; in other words, there is a need for more coordination and harmonization across different sectors, ministries and their agencies;
    c) While many of the CC adaptation policies are consistent with traditional developmental policies (especially in areas of disaster reduction), some CC implications will require changes in policies and new policy instruments, for which there is a considerable knowledge gap;
    d) There is a lack in understanding synergies in and/or obstacles to simultaneous progress in promoting enhanced adaptive capacity and sustainable development;
    e) There are gaps between spatially explicit analyses of vulnerability and aggregate integrated assessment models; and
    f) There are gaps in developing new decision support mechanisms that can identify robust coping strategies in the face of the many critical climate change uncertainties.

6.5 Activities Related to Technology Transfer

6.5.1 Policy, Legal and institutional Framework

Several policies are important from the view point of technology transfer and development. These include the Science and Technology Policy (draft), 2010, and the draft Information and Communication Technology Policy, 2009, Industrial Policy 2005, National Energy Policy 2004, and the Renewable Energy Policy 2008. Among these the draft Science and Technology Policy 2010 probably is the most important as kind of over-all guideline. It has emphasized capacity building in all spheres of technology development, transfer and adaptation and firming up an institutional framework for its implementation. Furthermore it has called for the preparation of an Action Plan for implementation of the policy. Regarding climate change related technology it has emphasized research and development activities.

The ICT Policy is a cross-cutting policy and wherever there are needs for fast data management and analysis and retrieval and dissemination, ICT can be used fruitfully. Climate change and environmental management is one such area. And the ICT Policy of the country is aware of such possibilities. Particularly it has paid 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.

The Industrial Policy 2005 recognizes the role of technology in fostering competitiveness and sound environmental management and calls for an institutional framework for over-all technology development and transfer of environment-friendly technology. The Industrial Policy is now undergoing revisions for making it more relevant. But neither the 2005 version nor the present draft version provide any clear guideline regarding the nature and context of technology development or transfer although both stressed the need for environment-friendly technology. Earlier Chapter 2 on GHG emission and Chapter 3 on mitigation have stressed the role of the industrial sector in energy use efficiency and yet, one finds little or no such reference in the earlier or the draft Policy. The Industrial policy is thus not fully geared towards the development of capacity for development, acquisition adaptation of technology.

The National Energy Policy 2004 has stressed the need for energy efficiency, calls for CDM projects, calls for the establishment of a Renewable Energy Development Agency. The Policy was explicit in its call for technology transfer and research with the following proposition:

i. Transfer of technology is to be given due consideration in developing the power sector.
ii. Efforts are to be made to substitute import by local inputs. This may include both hardware and software like engineering, design and project management. At distribution level in particular, locally produced materials and equipment are to be used to substitute import.
iii. Local industries are to be assessed in order to identify manufacturing capabilities relevant to projects of power sector. Industries, thus identified, are to be encouraged to manufacture identified items as per standards.
iv. 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 R & D institutions. Adequate funds are to be made available for implementation of the R & D programme.

The Renewable Energy Policy, 2008 of Bangladesh was adopted for, among others, to facilitate reducing global emissions for mitigating climate change. In line with this, the Policy has identified different renewable energy sources like solar, wind energy, biomass, biogas, hydro-power and other renewable energy sources include 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 also set objectives to create an enabling environment and legal support to encourage the use of renewable energy, promote development of local technology in the field of renewable energy, and promote clean energy for CDM. For institutionalizing the process, the Policy proposed establishing a Sustainable Energy Development Agency (SEDA), under the Companies Act, 1994, as a focal point for sustainable energy development and promotion, where 'sustainable energy' comprising renewable energy and energy efficiency with an overall objective to support capacity building, technology and market development. The SEDA has already been established but is going through the early teething period.

The Renewable Energy Policy also proposed to provide 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 and carbon funds and providing financing for renewable energy investments. At local level, the Policy proposed setting up a network of micro-credit support system especially in rural and remote areas to provide financial support for purchase of renewable energy equipment.

6.5.2 Priority Activities Related to Capacity-building, Enabling Environments, Investment, Technology Assessments

Bangladesh possesses only limited human and institutional capacity for understanding, analyzing, planning for and managing climate change. BCCSAP has pointed to such inadequacies but not made explicit where such capacity-building needs may lie. There are several areas where priority action is needed for preparing the country for climate sensitive and climate change resilient development.

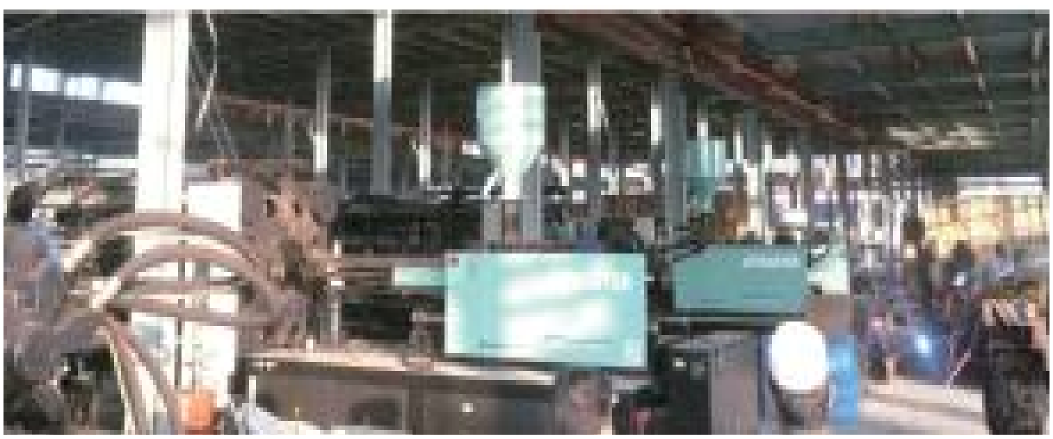
In case of capacity-building the following areas may be mentioned as important:

- Continuous monitoring of weather parameters and events and their analysis for forecasting future changes both in the near terms and long term future
- Long-range weather forecasting
- Analysis of future climate change and their 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

Building capacity is useful only when there is an enabling environment to utilize the capacity for decision-making. And here, the first issue of importance is to make all relevant policies responsive to the issues of climate change either because it has implications for GHG emission and mitigation or that it is vulnerable to climate change and its impacts and therefore needs to include adaptation activities among its mandates. Quite a few of the policies are specifically relevant for technology transfer and needs close examination. Harmonization of policies is needed so that these do not work counter to each other. Each policy must have appropriate plan of action which should be adequately budgeted for. Rules of business of various government departments, agencies and ministries must be changed accordingly. Furthermore, it must be made mandatory for all projects, investments and technology transfer and development be climate sensitive.

For investment, one needs to have clear ideas regarding not simply the costs and benefits with and without climate change, but also the costs of inaction or delay in terms of poverty and growth in the economy as well as food, water, energy and livelihood security. Perhaps the most important issue related to investment may be resource mobilization for its financing. One way is to examine various taxes and subsidies as well as pricing principles to see these may help in financing desirable activities. For example, one may think of raising taxes on inefficient technologies for production or consumption and thus subsidizing the uptake of efficient ones. The second type of activity is to prepare projects according to UNFCCC principles for funding either through fast start financing or under the Green Climate Fund. Financial rules and procedures including auditing may be transparent and harmonized with internationally accepted principles and working methods. Having said all these, one must have a clear idea of the necessary investment and financial flows that would be necessary to implement the adaptation and mitigation activities along with necessary capacity-building and consequent programmes and projects.

In a similar vein, in case of technology, the first thing to be done is to have a generalized technology needs assessment and then to look for specific technology for specific purposes. One will have to determine whether there is off-the shelf technology, whether it can be acquired domestically or internationally and whether there are IPR issues involved. If such off-the shelf technology is not available or that the available technology needs to be adapted to local conditions, research capacity within the country will have to innovate or discover the method or principle for development of the technology. Technology needs are paramount in case of weather forecasting, agricultural adaptation projects such as varietal development, health and disease control and similar other areas. The collaboration may be between Northern and Southern institutions, between Southern and Southern organizations or between the private sectors.



Standard and labeling in electrical appliances to increase energy efficiency, UNDP-GEF funded BRESEL project, 2011

Some of priority activities regarding the above issues may also be shown as under:

Table 6.3: Priority Activities

Output	Activity
Community Based Adaptation Programme	
Improved health, hygiene, housing and sanitation facilitated	Sustainable housing programme for the community people keeping in mind devastating cyclones / storms
Livelihoods and Alternative Income Generating Activities promoted	Collection and preservation of indigenous/local varieties of seeds that are salt tolerant or less water intensive and drought resistant
	Diversification of crops for better adaptation, including cultivation of medicinal plants and temperature tolerant varieties such as wheat/vegetables
	Carrying out pilot and demonstration projects on adaptation to climate change to show effectiveness of community based adaptation project and livelihood improvement
	Capacity development for CBOs (Community Based Organizations) for retention of indigenous knowledge
	Expansion of floating garden in waterlogged areas for year-round crop production
Climate Resilient Adaptation Programme	
Climate resilient adaptation programme in place	Networking and information sharing amongst agencies/departments
	Promoting the transfer of technologies for adaptation
	Develop projects to identify and assess the technology needs for different sectors
	Preparation and development of Digital Elevation Models (DEM) and maps
	Modeling in particular relation to general circulation models and their down scaling to regional and national levels for better impacts assessment. Existing institutes having experience and involved in the modeling exercise can be a starting point
Sustainable agricultural crops promoted and practiced	Promotion and replication of saline tolerant variety in the coastal area of Bangladesh
Efficiency in the Energy Sector	
Reduced GHG emissions through efficient use of energy in the energy intensive sectors	Replacement of fluorescent lamps and incandescent bulbs with electronic ballast, reflectors and compact bulbs
	Use of high-efficiency motors in industries
	Replacement of old refrigerators with new high energy-efficient models
Waste products from industries used for combustion in cogeneration processes	Converting wood waste to bio-gas
	Recovering heat from high-temperature waste sources to steam
Improved cooking stoves used in rural areas	Promotion and expansion of efficient stoves in rural homes, schools, hospitals, hostels, police barracks etc
Small scale photovoltaic plants or other renewable energy options installed in remote areas	Installation of solar panels
	Construction of small run-off-river hydro power plants
	Establishment of wind turbines in suitable areas
Promotion and expansion of more bio-gas plants in the rural areas	Use of human waste in bio-gas plants
	Use of waste from livestock and poultry firms in bio-gas plants
Efficient energy production system in place	Replacement of old technology of BPDB with new and

Output	Activity
	modern technology
	Trained manpower to operate / adapt to the new technology
Energy efficiency in the Transportation Sector	
Compressed Natural Gas (CNG) used	Conversion of car/bus engines to CNG as the principal source of fuel instead of gasoline/petroleum products
Efficient inland water transport management in Place	Efficient use of fuel Efficient disposal of waste and garbage
Promotion and expansion of Clean Development Mechanism (CDM)	
Promotion and expansion of CDM	Capacity development of the concerned departments for development of sector specific CDM Project. Capacity building to prepare good CDM proposals
	Capacity building of the members of the Designated National Authority on CDM modalities and procedures, and how it functions
Promotion of carbon sinks in the Forestry Sector	
Carbon sinks expanded through massive afforestation programme	Conserving and expanding protected forest areas
	Encourage intercropping and agroforestry
	Introduce urban forestry practices in fallow lands / roof tops/ graveyards
Increased efficiency of wood use and better utilization of wood	Improving technical efficiency of wood recovery through improved harvesting and milling techniques to reduce waste
Mitigation and Waste Management	
Methane generated from landfill sites recovered and used to produce energy	Safe handling and collection of methane from landfill sites for generation of power
Quantity of landfill waste reduced through source reduction, recycling etc.	Sorting of waste at source and recycling of wastes such as glass/paper/ plastic
Sustainable waste management in major cities established	Establishment of incineration plants in major cities of Bangladesh to produce power from the municipal wastes
	Institutional capacity building of PDB/ DESA/ DCC for establishment of incineration plants in major cities of Bangladesh to produce power from the municipal wastes
	Technology need assessment for incineration plants in major cities of Bangladesh to produce power from the municipal wastes
Mitigation through the Agriculture Sector	
Anaerobic fermentation/ production of methane from flooded rice field reduced	Construction of small-scale digesters for gas recovery and use in rural areas
	Conversion of lagoons for trapping methane by placing impermeable layer
National inventories of anthropogenic emissions by sources	
Develop, periodically update, publish and make available to concerned Agencies/Parties national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol	Initiating a programme to develop country specific emission coefficients for different sectors (agriculture, forestry, waste, etc.) including the enhancement of systematic observation and monitoring networks
	Making links with international research institutes working on emission coefficients
	Modeling, in particular related to general circulation models and their down scaling to regional and national levels for better impacts, vulnerability and adaptation assessment
Integration of climate change considerations into social, economic and environmental policies	
Integration of climate change considerations into social, economic and environmental	Dialogue and persuasion with ministry of planning, finance and sectoral ministry by the climate change focal

Output	Activity
policies and actions, and formulation and use of appropriate methods (e.g. environmental impact assessment-EIA), to minimize adverse social, economic and environmental impacts of projects or activities undertaken to mitigate or adapt to climate change	points
	Preparing policy document to facilitate discussion sand persuasion
	Preparing tools and methods for integrating climate change in national and sectoral development plans
	Engaging local government institutes in decentralized planning
	Screening of national and sectoral development portfolio
	Downscaling climate change models for different regions (coastal, drought prone, flood prone etc.)
	Providing training to planning cell in each ministry
	Demonstration of adaptation project to build capacity and increase confidence and scale up
	Capacity building for Seasonal Forecast and Application
	Carrying out pilot and demonstration projects on adaptation to climate change to show effectiveness of community based adaptation projects and livelihood improvement
	Discussion with bilateral and multilateral development partners for resources allocation for incorporation of climate change
	Link sectoral ministries to international climate change funds
Promotion and transfer of technologies to reduce GHG emissions and increase carbon sinks	
Promotion of, and cooperation in, the development, application and diffusion, including transfer of technologies, practices, and processes that control, reduce or prevent GHG emissions	Formulation and enactment of policy on renewable energy to support different types of renewable energy technologies in Bangladesh
	Encourage private sector to invest more on renewable energy application
Promotion of sustainable management, conservation and enhancement of sinks and reservoirs of all GHG gases	Promotion of afforestation programme in Bangladesh
	CapacityBuilding for data collection, analysis and preparing national GHG inventory and monitoring

Recognizing the uncertainties and inadequacies of international adaptation finance from both multilateral and bilateral sources, the Government of Bangladesh decided to establish the Bangladesh Climate Change Trust Fund (BCCTF) based on revenue from the national budget, within a legal mandate by the Climate Change Trust Act passed in Parliament in 2010. At the same time, an alternate Bangladesh Climate Change Resilient Fund (BCCRF - formerly known as the Multi Donor Trust Fund, or MDTF) was created to pool funds from the country's development partners (Khan et al., 2012).

The Bangladesh Climate Change Trust Fund is a 'block budgetary allocation' of US$ 100 million each year for three years (2009-2012, totaling up to US$ 300 million), in the form of an endowment. The Climate Change Act stipulated that 66 per cent of this amount will be spent on the implementation of projects/programmes prioritized in the BCCSAP, and 34 per cent will be maintained as a 'fixed deposit' for emergencies. The interest accrued on the 34 per cent fixed deposit will also be spent on project implementation. Funds from the BCCTF can be used to finance public sector and non-government projects, and it is not mandatory to spend the total grant within a given financial year.

Of the US$ 200 million endowed in the first two years, therefore, US$ 132 million (66 per cent) is available for use on projects and programmes. Of this amount, US$ 95.36 million has been allocated for 58 projects mainly related to agricultural research, mitigation, adaptation and disaster risk reduction, and non-government projects relating to research and knowledge generation(Khan et al.,2012).

At the First UK-Bangladesh Climate Conference held in Dhaka in April 2008, development partners expressed the urgency of establishing a 'financial mechanism' to assist Bangladesh in combating the impacts of climate change. Subsequently, at the London Climate Change Conference organized jointly by Bangladesh and the UK in September 2008, the UK pledged a grant of US $75 million towards the implementation of the BCCSAP over a period of five years. As the amount could not be directly transferred to the Government of Bangladesh, a "Multi-Donor Trust Fund" was established to manage fiduciary risk (Khan et al., 2012).

The Multi-Donor Trust Fund soon evolved into the Bangladesh Climate Change Resilience Fund (BCCRF), with contributions from four main donors: the UK, with a contribution of US$94.6 million; Denmark, with a contribution of US$1.8 million; Sweden, with a contribution of US$13.6 million; and the EU, with a contribution of US$11.7 million. Switzerland has subsequently contributed US$ 3.8 million.

The BCCRF has two funding windows: an "on-budget" window for public sector projects, and an "off-budget" window for civil society and private sector projects. The off-budget window, which currently receives 10 per cent of the total funding, supports the development of grassroots mechanisms for communities to increase their resilience to the impacts of climate change and to support applied and/or action research to strengthen the capacity of the community for climate resilient planning. It is administered by a Government-designated implementing agency (the Palli Karma Sahayak Foundation, PKSF).

As of November 2011, the fund has approved one project of US$ 25 million for building multipurpose cyclone shelters. Two others have been approved for development into full project proposals: a US $22.8 million proposal submitted by the Ministry of Agriculture on 'Agricultural Adaptation in Climatic Risk Prone Areas of Bangladesh - Drought, Flood and Saline prone areas; and a US$ 24.95 million proposal by the Ministry of Environment and Forests, on 'Afforestation and Reforestation for Climate Change Risk Reduction in Hilly and Coastal Areas' ((Khan et al., 2012).

6.5.3 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 (sub)sectors and/or areas, and prioritizing technologies for these (sub)sectors and/or areas. In this process, TNA offers support for conducting multi-criteria assessments in a stakeholder context.

Bangladesh is making its own TN Assessment in line with the BCCSAP, 2009. In the inception report for the TNA, the Consultant (firm) has proposed to consider following sectors for adaptation and mitigation measures:

- *Adaptation measures (Non energy sectors)*

o Agriculture
o Water
o Disaster risk
o Environment
o Local Government
o Works (urban development and housing)
o Fisheries and Livestock
o Health

- *Mitigation measures (Energy Sectors)*

- Transport
- Industry
- Forestry

Moreover, the inception report has also proposed the following criteria while implementing the TNA process:

- Development benefit e.g. food security, livelihood, market potential – investment consumption
- Environmental benefits – mitigation of GHG and other environmental mitigation and adaptation, amendable to build on current programs with government support
- Ease of implementation
- Likely to overcome barrier

The TNA process aims at achieving the following outputs:

- Technology needs assessment
- National policy development for technology
- National Strategy and technology action plan (components to be decided)
- Project formulation for technology development and transfer
- Identification of technology transfer community organization and capacity building needs
- Institutional framework development of a national technology research and development center

6.5.4 Pilot programmes on technology transfer relating to climate change

To date, no such pilot programme has been implemented in Bangladesh on technology transfer relating to climate change. However, the Ministry of Environment and Forest and the recently established Climate Change Unit have approved several projects on 'Mitigation and Low Carbon Development' thematic area under the BCCSAP where the technology transfer component might play an important role in implementation of projects.

6.5.5 Existing and planned climate-related technology transfer programmes/projects

To date, no such pilot programmes have been initiated that directly address the technology transfer component relating to climate change. But Clean Development Mechanism (CDM) projects, although not directly related to technology transfer, can be taken as a good example where the technology transfer need is crucial. In this regard, under the following sub-sections the existing status of the CDM projects in Bangladesh and barriers of implementing CDM project are discussed elaborately.

Current status of CDM projects

The CDM project portfolio of Bangladesh is shown in Table 6.4.

Table 6.4: CDM Project Portfolio of Bangladesh

SL. No.	Name	Estimated Emission Reduction Tons of CO2e/ Yr.
1	**Registered Projects (2)**	
	Landfill Gas Extraction and Utilization at Matuail Landfill Site, Dhaka	80,000
	Composting of Organic Waste in Dhaka (700 tons/day)	89,259
2	**Under Validation (2)**	
	30,000 Solar Home Systems in Non- Grid Areas	10,000
	Promotion of 1,00,000 Compact Fluorescent Lamps in Rural Areas	5,000
3	**Project Being Submitted for DNA Approval (3)**	
	Bundled Co-composting Projects in Eight Secondary Towns of Bangladesh	13,500
	Landfill Gas Extraction and Utilization at Raufabad Landill Site, Chittagong	25,000
	Composting of Organic Waste in Chittagong (200 tons/day)	17,250
4	**Projects in Pin Stage (1)**	
	Industrial Co-generation Project at Monno Fabrics (11 MW)	8,000
	Total Emission Reduction from 8 Projects	2,48,000

Apart from the aforementioned projects, the following projects are under development:

- Bundled Efficient Brick Kiln Project (Fuel Switching/ Energy Efficiency)
- Poultry Waste Management Project (Waste Sector)
- Use of SPV Pumps for Irrigation (Fuel Switch)

Barrier to implementing CDM Projects

The CDM is, by and large, an unfamiliar concept for many of the prospective CDM project developers. It is, however, worth pointing out that in the context of Bangladesh at the present time, the CDM in the energy sector suffers from the following three shortcomings:

1. The potential for renewable energy technologies other than PV has been identified to be low;
2. All large energy consuming industries are in the public sector where the incentives for implementation of innovative ideas such as CDM is limited;
3. The small-scale nature of many energy consuming activities in the private sector implies that these have to be bundled to have a project of reasonable size.

6.5.6 Role of the various stakeholders, particularly the private sector and research and development institutions

The existing institutional framework in Bangladesh, which can facilitate CDM, includes one ministry and several national committees. The Ministry of Environment and Forests (MoEF) of the Government of Bangladesh is responsible for climate change policy. The Secretary of this Ministry is the focal point for the UNFCCC. Already the Climate Change Unit under the Ministry of Environment and Forests has been set up and the Department of Environment has established a Climate Change Desk that has a director in charge. A National Climate Committee was established in 1994 to give policy guidance and oversee the implementation of the obligations under the UNFCCC. It comprises members from a range of government ministries and NGOs.

A number of governmental, autonomous, non-governmental institutes and NGOs are trying to adopt existing technologies for the local context and develop new technologies. A synopsis of the capacities of different institutions and networks is given below:

Table 6.5: Synopsis of technical capacity of different organizations

Sl. no.	Organization	Area of technical expertise	Involvement
1	National Agricultural Research System with nearly 15 research organizations and Bangladesh Agricultural Research Council (BARC) as the apex body	Development of new technology in crop, livestock, fisheries and forestry; analysis & modeling of impacts, vulnerability and adaptation of agriculture to climate change, Modeling done on major crops (DSSAT)	US Climate Change Country Study; NAPA Development of shorter maturity, drought, flood and salinity tolerant crop varieties
2	BangladeshUniversity of Engineering and Technology (BUET)	GHG Inventory; Future Scenario Development and Mitigation Strategies (LEAP); GCM-based analysis	US Climate Change Study; ALGAS
3	Center for Environmental and Geographic Information Services (CEGIS)	Modeling of Water Resources; Salinity Intrusion; Impacts on livelihoods	NAPA, CDMP, EIA,SIA,EMP; SNC
4	Water Resource Planning Organization (WARPO)	Policy and Planning Impact Assessment (IA)	NAPA; Coastal Zone Impact of CC
5	Bangladesh Institute of Development Studies (BIDS)	Economic assessment of impacts and adaptation; Life cycle analysis of GHG emission in agriculture; Rural energy; power sector analysis; Economic costs of adaptation; gender dimensions of climate change impacts; Integrated analysis of water and socio-economic change; Livelihood impacts; GHG and model-based mitigation strategies (MARKAL)	ADB ALGAS study; US Climate Change Study; NAPA; Initial NC; SNC
6	Bangladesh Centre for Advanced Studies (BCAS)	Climate Change Scenario Generation using General Circulation Model (GCM) Design and Development of CDM Projects Community Based Adaptation Projects	National studies on climate change impacts and adaptation; CBA Workshop
7	Bangladesh Unnayan Parishad (BUP)	Water Policy Vulnerability and Adaptation Assessment Scenario Development using RCM and GCM	US Climate Change Study; ALGAS; NAPA
8	Institute of Water Modeling	Modeling of Water Resources Salinity	Modeling of Water

Sl. no.	Organization	Area of technical expertise	Involvement
	(IWM)	Intrusion	Resources Programme
9	Waste Concern	Design and Development of CDM Projects New Methodology Development for CDM	Establishment of DNA
10	IUCN	Policy, Planning, Programming, Reporting	NAPA; NatCom;NBSAP; NCSA
11	ICDDR'B	Capacity of international standard in health	Research on climate change & health issues
12	NIPSOM	Capacity of international standard in health	Research on climate change and health issues
13	CNRS	Community participation	Working for CC and adaptation research and LDRRF
14	FEJB	Public awareness, media sensitization	WSSD Workshops; NAPA Workshops
15	Deptt. of Environment Sc. And Management, NSU	Climate change negotiations Economic assessments of impacts & adaptation	Micro-insurance campaign

Beside the above 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 have their own capacity on technology exploration and utilization.

6.5.7 Technology and technology enabling activities

The technology transfer needs are not prioritized nor are any priority programmes planned focusing on technology transfer related to climate change. However, under the thematic area 'Mitigation and low Carbon development' of the Bangladesh Climate Change Strategy and action plan a number of propositions have been made the implementation of which will have to include technology transfer components. Those are as follows:

Table 6.6: Mitigation Propositions in BCCSAP with Possible Technology Transfer Components

- Improved energy efficiency in production and consumption of energy
- Gas exploration and reservoir management
- Development of coal mines and coal fired power stations
- Renewable energy development
- Lower emission from agricultural land
- Management of urban waste
- Rapid expansion of energy saving devices
- Energy and Water Efficiency in Built Environment
- Improvement in energy consumption pattern in transport sector

6.5.8 Linkages between technology transfer activities, programmes and projects with national development planning processes.

This part has already been covered in an earlier section.

6.6 Climate Change Research and Systematic Observation

6.6.1 Status of National Programmes

Human and institutional capacity for conducting research, generate requisite data or monitor climate related phenomenon are in general limited in the country, but not entirely, nor in all spheres of related activities. Let us first look at the meteorological, atmospheric, hydrological and oceanographic research.

Meteorological, atmospheric, hydrological and oceanographic research and observations

Presently, the Bangladesh Meteorological Department (BMD) collects meteorological data viz., evaporation, humidity, solar radiation, rainfall, sunshine hours, temperature and wind speed from their 36 data collection stations all over Bangladesh. The Bangladesh Water Development Board (BWDB) collects hydrologic information such as rainfall, water level and discharge data. Furthermore, the Bangladesh Inland Water Transport Authority (BIWTA) collects water level data from 43 tidal stations. 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 6.7. The spatial distribution of hydro-meteorological network in Bangladesh is shown in Figure 6.2.

In addition, the air quality data and salinity data are measured by the DoE and the BWDB on a daily and fortnightly basis along the coastal region of Bangladesh. Local level salinity measurements are also done by the Khulna Newsprint Mills, Mongla Port Authority and Chittagong Port Authority. Additionally data can be collected on a project basis for defined periods and can be used for historical trend analysis.

Table 6.7: Hydro-meteorological Stations and Record of Data in Bangladesh

Organization	Data type	Data availability	No of station
BMD	Evaporation	1983 to 1996	12
BWDB	Evaporation	1964 to 1998	47
BMD	Humidity	1948 to 2008	34
BMD	Solar radiation	1983 to 2008	10
BMD	Rainfall	1948 to 2008	34
BWDB	Rainfall	1957 to 2008	312
BMD	Sunshine hours	1961 to 2008	34
BMD	Temperature	1948 to 2008	34
BMD	Wind speed	1980 to 2008	34
BWDB	Discharge	1934 to 2003 (Non Tidal), 1964 to 2000 (Tidal)	134 (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 2002 (Tidal)	43 (Tidal)

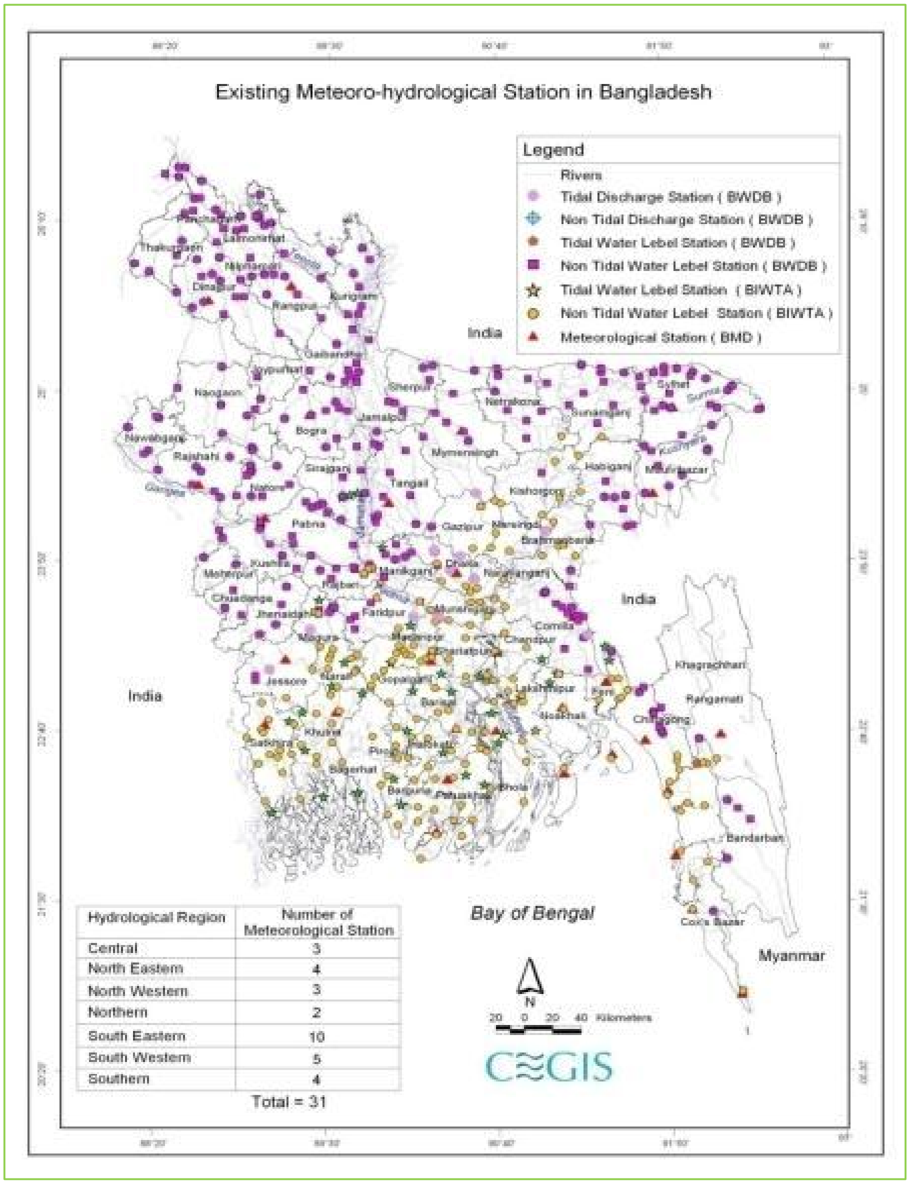


Figure 6.2: Locations of Hydro-meteorological Stations in Bangladesh

6.6.2 Level of Participation in the Global Observation Systems

The Bangladesh Meteorological Department (BMD) is connected with the World Meteorological Organization (WMO). Meteorological observations are transmitted and received globally through Global Telecommunication System (GTS). Other than this it is also associated with PTWC and JMA through BMD's GTS link, Fax, Telephone and Internet to get Tsunami advisory/ warning and Tsunami watch information. As a part of global cooperation, WMO has provided help to Bangladesh in 2008 to improve the current national agro-meteorological station network to ensure timely delivery of agro-meteorological information and products.

6.6.3 Research Initiatives on Climate Change Scenario Generation and Physical Processes

In Bangladesh, since the early nineties efforts have been made to develop climate change scenarios of various sorts as well as analyzing underlying processes. These were based on data that have been collected by the organizations as stated in the previous sub-section as well some time data existing since the British period. Work has been carried out both as part of individual academic purposes and also as institutional efforts. Most research date since the 1990s. Such researches include early speculative studies to modeling of increasing sophistication and complexity as well as applicability to ever smaller grids. The model building was helped by many studies which tried to understand the various underlying processes of climate change and its physical impacts. At the same time, another strand of analysis was pattern recognition from observed data on climate variables and other related natural phenomenon.

6.6.4 Needs and priorities for climate change research and systematic observation

Climate change scenario generation at local scale

The IPCC projected climate change scenarios for South Asia are very coarse (at 250-350 km grid) and therefore unsuitable for any micro-level impact assessment and adaptation planning. In this regard, climate change scenario generation at the local scale through downscaling using the regional climate model may be initiated as a priority basis for proper understanding and dissemination of climate change information at the national level.

Need for systematic observation

Given the advances in the monitoring system of the hydro-meteorological parameters, the overall picture of the existing hydro-meteorological observation network is still somewhat scattered and often lead to confusions in selecting the most representative observation dataset for classifications of homogenous regions for impact assessment and monitoring. Moreover, the quality of dataset of the existing observatories is often disturbed by human interventions. Now-a-days it is imperative to verify results of climatic forecasts and observations on a grid-by-grid basis, as the model simulated climate change scenarios are only available at some specific grid points. It is also important to track the extreme events (like cyclones) for efficient dissemination of early warning messages. Monitoring the hydrometric parameters related to climate change viz., sea level rise, temperature in the urban areas is still lacking. The existing tidal water level stations in the coastal region are not adequate to indicate the amount of net sea level rise on a reliable basis, as those are not free from natural and human induced disturbances. Moreover, existing temperature stations in and around the urban mega cities are grossly inadequate and do not effectively address the effect of urbanization on the precipitation and temperature anomalies (heat island effects). In this regard, a monitoring protocol is urgent for collection, monitor and dissemination of climate change information at local scale.

Monitoring of temperature and rainfall

At present BMD monitors temperature and rainfall at 34 rainfall and temperature stations in eight hydrological regions spread all over Bangladesh. One of the key activities for establishing an effective monitoring protocol is to delineate the whole of Bangladesh into meteorologically homogeneous regions. For example, key hydro-meteorological stations could be identified for each of the hydrological regions through Hierarchical Cluster Analysis which aims to build a hierarchy of clusters among homogeneous hydro-met stations.

Monitoring Sea Level Rise (SLR)

Out of the 181 tidal water level stations of the BWDB, around 25 can be used for measuring the rise of sea level along the coast of Bangladesh. But these stations may not represent the true sea level rise due to various natural phenomenon or human intervention/activity which may create artificial high or low readings. Thus, applying such screening appears to leave us only three stations. The number is quite obviously inadequate for proper measurements.

Monitoring water level and discharge

At present, the Flood Forecasting and Warning Center (FFWC) of the BWDB monitors flood in 105 non-tidal and tidal water level stations. However, monitoring of the 105 stations for investigating the effect of climate change will be highly expensive in terms of cost and time. In the final stage of monitoring, flood forecasting stations may be selected on the basis of availability of long period data sets and on statistical homogeneity.

Year round daily water level and discharge data are adequate enough for the general purpose of flood frequency analysis. However, for early warning system and message dissemination hourly data is crucial and hence it is better to collect hourly data from a number of selected (homogeneous) stations for effective flood monitoring.

Monitoring salinity

Salinity and its seasonal variation are dominant factors for the coastal eco-system, fisheries and agriculture, and are expected to be exacerbated by climate change and sea level rise. Therefore it is essential to study the spatial and temporal variation of salinity at different places in the coastal region of Bangladesh.

Saline water intrusion is highly seasonal in Bangladesh as well as determined by locational factors. The choice of salinity measuring stations thus needs to be made accordingly.

In order to study salinity, the coastal region can be divided based on the hydrological regions of Bangladesh,

To understand the spatial variability, salinity monitoring stations need to be identified at shore locations, and also in upstream locations of the rivers in the region. Based on these considerations the actual locations of measurement stations may be recommended.

Measurement of salinity at these stations should be done at least on a daily basis. However, it is important to note that the mechanism for movement of water and salinity front in the dry season is very much dependent on the tidal activity. The tides in the coastal and estuarine areas are semi-diurnal with two high and two low periods per day and have a maximum amplitude of 3-4 m at spring tide. As a result measurement time is also important, and during low or ebb tide salinity is usually the lowest.

Monitoring Cyclone and Storm Surge

At present all the data except surge height data that are required for the monitoring of cyclone and storm surge are collected by BMD (at Kuakata, Cox's Bazaar and Dhaka) on a daily basis. Surge height in coastal rivers is monitored by the BWDB. Wind speed and other relevant data should be monitored at short intervals for effectiveness.

6.6.5 Institutional responsibilities for monitoring network

The GoB recognizes that tackling climate change requires an integrated approach involving many different ministries and agencies, the civil society and the business sector. Thus the monitoring of climate change impact also needs multi-disciplinary involvement. At present, the main ministries of the government involved in climate change are the Ministry of Environment and Forests and its agencies (e.g. the Department of Environment, the Department of Forests and Food and Disaster Management, which includes the Disaster Management Bureau (DMB) and the Comprehensive Disaster Management Programme (CDMP). The Hydrology Directorate of the Bangladesh Water Development Board (BWDB) is responsible for hydro-meteorological data collection like water level, discharge, sediment sample, surface water quality, rainfall and evaporation etc. The responsibility of BMD is to observe different meteorological parameters , analyze all weather charts and to make interpretation on the basis of analyses, provide weather forecasts, issue warnings for severe weather phenomena such as tropical cyclones, tornadoes, nor'westers, 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 is 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 Soil Research and Development Institute (SRDI) is responsible for measuring soil salinity level and so on. Thus it is clear that the 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 Bangladesh Government has already formed a Climate Change Cell in the Department of Environment under the administrative jurisdiction of CDMP, which ended its project tenure in last year. It can however play a significant role in establishing a national level climate monitoring centre. SPARRSO, BCAS, CEGIS, IWM are other government and independent institutions that have a significant role in doing research about climate change and global warming.

6.7 Research Programmes

6.7.1 Background

The information provided in this section builds on the information provided in the earlier chapters and sections on greenhouse gas inventory, mitigation, vulnerability and adaptation. The contents include specific research programmes that have been undertaken in the areas of mitigation, adaptation, development of emission factors and activity data, either on a national or regional basis.

- A brief description of specific research programmes
- A brief description of the nature and level of involvement and cooperation with bilateral and multilateral institutions
- A brief description of the specific needs and priorities

Specific research programmes

Research has been undertaken in many areas. These include

- vulnerability and risk assessment
- impact of climate change

- impact on water sector
- impact on public health
- impact on coastal zone
- impact on agriculture
- impact on forestry
- impact on biophysical sector
- impact on fisheries
- societal impacts.

Among these, the vulnerability and risk, water and coastal zone issues have received the most attention. This means that the second round physical impacts have received most attention. Comparatively human system impacts such as those on agriculture have received less attention. Fisheries, for example, has received very little attention and this in a society where fish is a regular part of the diet.

Adaptation research has received the most attention in case of water, coastal zone management and agriculture. There are some sporadic studies on adaptation policy, capacity building and social issues. Disaster management issues have been examined in some cases. Similarly economic issues have also been dealt with in several studies. Note however that many studies can perhaps be categorized under more than one group.

Bangladesh is low-emitting country. It is also an LDC. It is no surprise therefore that GHG inventory and mitigation has received much less attention than other issues related to climate change.

Nature and level of involvement and cooperation with bilateral and multilateral institutions

In the recently published annotated bibliography on climate change research initiatives in Bangladesh published by the Climate Change Cell under CDMP, a total of 118 national and international research institutes have been identified who have participated in different research initiatives in Bangladesh related to climate change. The distribution of different categories of institutes is given in Table 6.8. This statistics shows a clear picture on the level of involvement and cooperation with bilateral and multilateral institutions relevant climate change research in Bangladesh. But it is also to be noted that most of the research is conducted by international research institutes/NGOs followed by donor/inter-governmental agencies. It is also to be noted that the number of national research institutes and public agencies is still very limited.

Table 6.8: Institutions involved in Climate Change Research

Category	Number of institutions
Academic Institutions	11
Donor/Inter-governmental agency	30
International research institution	1
International research institution/NGO	35
Ministries	8
National research institution/NGO	20
Public agency	11
Public trust	2
Grand Total	**118**

Specific needs and priorities for expansion and strengthening of research programmes

Several major gaps exist in the research done so far related to climate change. These are as follows:

Data, information and monitoring

i. The number of weather stations and their facilities as well as extent of data collection are highly inadequate with question marks on the quality of past data as well as their record which are not always continuous with gaps between periods. The trend in temperature, precipitation, wind speed, need to be collected over smaller grids and weather stations needs to be set up accordingly. The same applies to measuring stations for sea level rise and salinity intrusion. River discharge data, flooding and related information are probably better recorded but needs to be further strengthened and as for weather stations may need to be constantly updated and made available in the public space for research purposes.

ii. The country needs to acquire long range weather forecasting capability. This is necessary for planning in agriculture, water & sanitation, fisheries and human health interventions.

iii. A limited capability for modeling of future climate changes exist but needs to be strengthened several fold. The same applies to impact modeling (both physical and human system like agriculture and health). The macroeconomic impact modeling has hardly been done and the gap needs to be filled up soon for advising the policy makers on the over-all national impacts on growth, poverty reduction and food security.

iv. A serious limitation exists regarding, hazard mapping and tallying that with physical as well as socio-economic vulnerability mapping and their consequences in terms of adaptation including socio-demographic ones such as migration.

v. How to address risks of low probability but catastrophic events is unclear at the present stage of knowledge.

vi. Major gaps exist in terms of understanding vulnerabilities of sectors to climate change and consequent vulnerabilities of socio-economic groups involved in those sectors. There is little understanding of what would happen to say livestock or fisheries and even to crop agriculture (except rice to some extent).

vii. There is hardly any research related to loss and damage, an issue that has become important in the context of allocation of funds for financing of programmes and projects under the fast start as well as the Green Climate Fund.

viii. There had been some attempts at community-based adaptation in the country. So far there seems to be hardly any rigorous evaluation of the attempts. The potentials and limits to community-based adaptation need to be fully understood before further resources and efforts are devoted to such adaptation mechanisms. Further the relationship between national and regional level efforts and local level community-based adaptation need to be understood for the effectiveness of each. In case of community-based adaptation how this can be integrated with local government-based progarmmes should also be explored.

ix. Little work has been so far related to the emission accounting based on second tier i.e. national level parameters. Many of those as discussed in the chapter on GHG emission inventory are IPCC default values. Bangladesh needs to develop its own parameters and coefficients and a major effort needs to be given to funding of relevant scientific research.

x. Little or no definitive work related to mitigation and its implications for Bangladesh in terms of a NAMA has so far been done. Little sectoral mitigation potentials have been rigorously examined. Cases where adaptation and mitigation are intertwined (as in case of agriculture) have not been rigorously analyzed nor the trades off between them and the implication of sustainable development explored.

6.8 Information on education, training and public awareness

This part relates to the fulfillment of obligations of Parties under Article 6 of the Convention relating to climate change education, training and public awareness. As guided in the user manual provided by UNFCCC (UNFCCC, 2003) for preparing the national communication and particularly following the template for preparing this activity (UNFCCC, 2007), the content of this section could include the following information:

- Institutional framework for the implementation of Article 6 of the Convention
- Brief description of existing activities and plans, if any, to incorporate climate change into the primary, secondary and tertiary education programmes, as well as any national and foreign scholarship programmes
- Level of awareness and understanding of climate change issues
- Implemented or planned initiatives and programmes for education, training and public awareness
- Sub-regional, regional and international cooperation to promote education, training and public awareness
- Gaps, needs and priorities in climate change education, training and public awareness
- Brief description of the national adaptation programmes of action consultation process and the degree to which the information and priorities revealed are consistent with, or divergent from, national priorities and information relating to Article 6 of the Convention.

A brief description of each is provided below.

<u>Institutional framework</u>

A National Steering Committee on climate change has been established which is chaired by the Minister in charge of the Ministry of Environment and Forests (MoEF) and comprises the Secretaries of all climate-related Ministries and Divisions, and representatives of civil society and the business community to plan and coordinate all climate change related activities and programmes in Bangladesh including education, training and public awareness.

In the formal education system, under the Ministry of Education and Ministry of Primary and Mass Education, formal institutions for primary, secondary and tertiary level educational institutions and their oversight (related to syllabus, public examination, infrastructure support) bodies exist both in the general and technical stream.

Some of the public and private universities in Bangladesh have already introduced masters or diploma courses climate change related curricula including disaster management. A Climate Change Study cell has been established in the Bangladesh University of Engineering and Technology (BUET) to make it a premier knowledge centre on climate change risk and adaptation in Bangladesh. The Bangladesh Public Administration Training Centre (BPATC) has initiated training programmes on climate change for public service cadres. Some of the universities in Bangladesh have joint progammes with foreign universities to introduce climate change intensive research and training at post-graduate level.

Level of awareness and understanding

The level of awareness and understanding of CC, particularly the latter, is still limited. While the media is somewhat active, there are limited understanding of the CC process within the country. This is not surprising given that there had been only limited research carried out in the country and that there is a lack of suitable mechanism to translate science into policy false perceptions

To remedy the situation somewhat, the Climate Change Cell (CCC) in the Department of Environment earlier undertook several initiatives for increasing awareness among stakeholders, starting from the grass root level to the policy planners of Bangladesh. As a part of this, a total of 13 booklets in Bangla and English language, 17 fact sheets and two comic books were developed by the CCC for dissemination at the local and national levels to raise awareness on climate change.

Implemented or planned initiatives and programmes

Apart from formal universities and institutions of higher learning for implementation of educational programmes there had been several important training programmes from time to time by the Climate Change Cell of the DoE as well as by the Climate Change Study Cell of BUET. The Study cell arranged training on Climate Change Modeling. Met Office, UK was the collaborative partner of this project to provide and support training on regional climate modeling using PRECIS. Moreover, the Study Cell also arranged two other short courses:

- Short course on 'Climate Change Training for Water Professionals' held on 18-20 October, 2008.
- Short Course on 'Climate Change Risks and Adaptation in Water Sector' held on 10-11 February, 2008.

Among the planned initiatives, the Climate Change Unit under the Ministry of Environment and Forest has approved five projects relevant to capacity building through education and training.

Sub-regional, regional and international cooperation

The United National Development Programme (UNDP) in Bangladesh has financed a number of projects in which education, training and capacity building were integrated as core components. At present UNDP is providing funding for the following projects on climate change and disaster management most of which include education, training and awareness building. A list of the programmes/projects on which support has been provided by the UNDP is given in Table 6.9.

Table 6.9: UNDP Financed Projects on Capacity Building through Education and Training

o	Second National Communication on Climate Change (SNC)
o	National Ozone Depleting Substances Phase-out Plan
o	Institutional Strengthening for the Phase-out of Ozone Depleting Substances (Phase-V)
o	Phase-out of CFC consumption in the Manufacture of Metered Dose Inhalers (MDIs) in Bangladesh
o	Barrier Removal for Energy Standards & Labeling (BRESL)

o	Improving Kiln Efficiency in the Brick Making Industry
o	Capacity Building and Resource Mobilization for Sustainable Land Management in Bangladesh
o	Poverty, Environment and Climate Mainstreaming
o	Comprehensive Disaster Management Programme [Phase II]
o	Community based Adaptation to Climate Change through Coastal Afforestation in Bangladesh
o	Community based Adaptation to Climate Change in Bangladesh
o	Early Recovery Facility (ERF)

Apart from UNDP, ADB is supporting the Government in raising capacity for implementing the BCCSAP 2009. Others have provided help in water supply and sanitation, higher education programmes for the public administrators and technical professionals and women in natural resources management and water resources development and management. Moreover, other sub-regional, regional and international cooperation and knowledge networking initiatives like Capacity Strengthening for Least Developed Countries for Adaptation to Climate Change, Cap-Net, South Asian Network for Development and Environmental Economics (SANDEE), Climate Action Network South Asia (CANSA) and Global Water Partnership (GWP) also play a key role in education and training for the Bangladeshi professionals on climate change issues.

Gaps, needs and priorities

One of the major gaps regarding education, training and public awareness lies on the policy regime. The importance of mainstreaming climate change issues in the academic curricula is not mentioned in the National Education Policy published by the Ministry of Education. Furthermore, strengthening public education on climate change will require review of curricula, production of education/ teaching materials and orientation of teachers towards climate change issues.

Another problem is the inherent complexity of the physical process related to climate change, its impact and adaptation mechanisms. As a consequence, the core 'climate change' agenda is still in the hands of researchers and scientists at national and global levels. In order to strengthen public education and awareness on climate change, it is necessary to simplify and translate information and key documents on climate change into the main local languages and to hold sensitization workshops for key stakeholders, particularly the policy and decision makers.

Capacity to effectively undertake public awareness building on climate change will require training programmes for mass media practitioners/ reporters as well as public education programmes. It will facilitate the information dissemination process in a more systemic manner down to the grassroots level.

6.9 Capacity-building

6.9.1 Introduction

Capacity-building needs have received attention in all kinds of public documents related to planning under climate change. The progress, however, had been slow due to various reasons, one of them being the lack of proper articulation of the types of needs and the lack of finance. Moreover the attempts had been piecemeal, rather than an integrated and comprehensive one. In fact, this had been the consequence of the understanding of the all-pervading nature of the impact of climate change on the natural systems and the human society in all its facets, economy, society, legal issues and similar aspects. Here we provide the information related to capacity-building in the following manner:

- A brief outline of capacity-building projects and programmes relating to climate change which is supported by bilateral and multilateral organizations.
- A brief description of the efforts made to implement and co-ordinate projects and programmes.
- A brief description, if relevant, of the status of activities and level of participation in and promotion of South–South cooperation.
- Brief summary of capacity-building activities, if any, and building on relevant sections of national communications, specifically targeted at integrating adaptation to climate change into medium- and long-term planning.
- Brief description of specific needs and priorities identified for capacity-building (e.g. in the areas of governance, mitigation and adaptation), including a summary of the needs and priorities identified in the national capacity self-assessment, in relevant enabling activities, and in other relevant bilateral and multilateral initiatives.

6.9.2 Capacity building projects and programmes

Status of national programmes

National capacity building is an important aspect for climate change research, formulation of mitigation, adaptation and response strategies, policy formulation and planning and implementation of the mitigation and adaptation policies and options. As indicated earlier, this has been stressed in the NAPA in 2005, in the BCCSAP 2009 and finally most recently in the "Outline of the Perspective Plan: Vision 2021" prepared by the Planning Commission. NAPA (MoEF, 2005) identified two projects that directly targeted on capacity building:

- Capacity building for integrating climate change in planning, designing of infrastructure, conflict management and land water zoning for water management institutions, to be implemented by Water Resources Planning Organization; and
- Development of eco-specific adaptive knowledge (including indigenous knowledge) on adaptation to climate variability to enhance adaptive capacity for future climate change, to be implemented by the NGO consortium.

Other projects proposed by NAPA also included capacity building of human resources or institutions.

The Planning Commission has proposed strengthening its capacity for mainstreaming environment and climate change issues in the medium and long term plans for the country. Indeed, a study is on-going on how to go about the process. It has also proposed that capacity-building and mobilization of local communities be given the highest focus. Furthermore, it has suggested promoting indigenous technological capacity development initiatives through capacity enhancement, investment linkage development and market promotion both domestically and internationally. Technological up gradation in several areas has been specifically mentioned. Training has been emphasized as a major mechanism for building capacity.

BCCSAP, 2009 has "Capacity building and Institutional Strengthening" as one of the six thematic pillars and suggested several major programmes for achieving the goal. The prioritized programmes to be implemented under this theme are:

- Revision of sectoral policies for climate resilience
- Main-streaming climate change in national, sectoral and spatial development programmes
- Strengthening human resource capacity
- Strengthening gender consideration in climate change management
- Strengthening institutional capacity for climate change management
- Main-streaming climate change in the Media

However till date, none of the above mentioned programmes have been implemented in the public sector in any organized manner. On the other hand, the Climate Change Unit under the Ministry of Environment and Forest has approved eight projects related to capacity building and institutional strengthening (in line with the BCCSAP thematic area), to be implemented by different public and private sector institutions:

- Strengthening the Institutional Capacity of Climate Change Unit of the Ministry of Environment and Forests.
- Developing Capacity of BPATC & Public Sector Human Resources for Addressing Effectively the Adaptation and Mitigation Measures
- Institutional Strengthening of Climate Change Study Cell at BUET for knowledge generation and human resource development
- An Integrated Capacity Building and Institutional Strengthening Programmes for Climate Resilient Mitigation, adaptation and Sustainable Development
- Adaptation of poor people to fight against the climate change situation by creating employment opportunity and capacity building.

<u>Capacity development needs</u>

Programmes and projects which directly addresses capacity development needs are few number. But several adaptation and mitigation projects and analysis included capacity development needs analysed and discussed. For example the Asia Least Cost Greenhouse Gas Abatement Strategy, ALGAS has examined the relevant issues. So does adaptation programmes such as Forestry Resources Management Project.

<u>Description of specific needs and priorities identified for capacity building</u>

The Bangladesh Capacity Development Action Plan for Sustainable Environmental Governance (Ministry of Environment and Forests (MoEF), 2007) has identified seven synergistic areas for capacity development action plan. These are very relevant to climate change capacity building in Bangladesh. These are:

- o Institutional strengthening
- o Legal, policy and enabling frameworks
- o Public awareness and education
- o Data and information collection, dissemination and monitoring
- o Research and technology development
- o Technical and managerial capacity
- o Resource mobilization

6.10 Information and Networking

6.10.1 Issues

Non-Annex I Parties have been encouraged to provide information on their efforts to promote information sharing among and within countries and regions. The information could cover the following issues which are elaborated in the following sections:

- Efforts to facilitate information sharing among and within developing countries and regions and relevant government and non-governmental institutions.
- Efforts to engage in and facilitate regional and international networking
- Description of constraints experienced

6.10.2 Efforts to facilitate information sharing

The Ministry of Environment and Forests, DoE, and other agencies and programmes and projects usually shares its information though various means such as seminars and workshops, publications and the website. The last one is the best means of sharing information across countries. The ministry's website is usually up to date. But the contents could perhaps be richer in terms of links to research, databases, publications and to other organizations who are involved in climate change issues. This part is still somewhat limited in scope.

The MoEF usually involves the non-state actors in matters related to climate change negotiations and briefs the media regarding the issues that it wants to raise in the negotiations and holds press briefing to inform them of the results of the negotiations.

Bangladesh is part of the Climate Vulnerable Forum which has been formed in Maldives sometime back. Bangladesh has invited environment ministers from around 30 countries who are vulnerable to climate change and discuss if a common or identical views may be arrived at to be presented to the COP 17 in Durban and other meetings.

Bangladesh is working for putting up a framework for implementation of the BCCSAP 2009. And as part of that is in the process of developing and maintaining a knowledge management network. As and when this is developed and running, this will tremendously facilitate information sharing among all stakeholders at home and abroad.

While efforts are on-going at home, the Bangladesh Environment Network (BEN), a global organization of non-resident Bangladeshis have set up a network with various objectives including free flow of information

The Disaster Management Information Network (DMIN) Portal has been developed under the Ministry of Food and Disaster Management. The main objective of the DMIN web portal is to share, coordinate and disseminate disaster management information, programmes and guidelines from source down to the last mile. The portal enables the Government to collect, analyse and disseminate information for risk reduction and emergency response.

A network similar to the DMIN has been set up also by the Climate cell under CDMP. Through this network the Climate Change Cell has been collecting and collating information on climate risks and adaptation options. It disseminates the results and supports the translation and communication of information into a format useful to government line departments, local government and NGOs working with vulnerable communities.

The Climate Change Database focuses on climate related data relevant for policy makers, planners and researchers working with various aspects of climate change. The database is also a part of the Climate Change web portal, and is accessible through the Internet.

An Integrated Coastal Resources Database (ICRD) has been set up to formulate and implement the Integrated Coastal Zone Management Plan (ICZMP) of Bangladesh. The development of ICRD was divided in two phases. The first phase 'Preparatory Phase' was to provide an operational database for PDO-ICZMP. The initial tasks were performing need assessments, preparing existing data inventory, linking with NWRD, installation of hardware and software and implementing database structure and preparing the interim report. The subsequent 'Development Phase' was aimed to have a full-fledged ICRD database to support the formulation of the Coastal Development Strategy (CDS).

The Water Resources Planning Organization (WARPO) has developed a National Water Resources Database (NWRD) to meet the demand for consistent and corrected data and information related to the water sector. As a part of the mandated functions, WARPO maintains, updates and disseminates the NWRD continuously.. Data in the NWRD are organized in several main groups which are: Base data, Surface water, Groundwater, Soil and Agriculture, Fisheries, Forest, Socio-economic, Meteorological, Environment and Images. A web enabled meta-database has been created to browse within the Internet/Intranet.

6.11 Efforts to Engage in and Facilitate Regional and International Networking

Several network of regional and international nature is accessible from Bangladesh and Bangladesh is part of the network. The network of LDCs for capacity strengthening for adaptation to climate change aims to strengthen the capacity of organizations working with civil society in environment and development while integrating climate change issues in the planning and implementation of projects.

Bangladesh is part of the network called International Network for Capacity Building in Integrated Water Resources Management- Cap-Net. The membership of this network helps in collecting information, analyses and other resources related to the water sector.

The South Asian Network for Development and Environmental Economics (SANDEE) is a regional network that uses economic tools and analyses to address South Asia's environmental challenges. It is based on the premise that solutions to economic development concerns and environmental problems are integrally linked. Thus, SANDEE brings together South Asian researchers and institutes interested in the inter-connections among development, poverty and the environment. Its main goal is to build the professional skills required to enable South Asians to address local and global environmental concerns. SANDEE works in seven countries in South Asia–Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka.

The Climate Action Network (CAN) International is a global network of over 360 Non-Governmental Organizations (NGOs) in 85 countries working to promote government and individual action to limit human-induced climate change to ecologically sustainable levels. Several Bangladeshi NGOs are m of CANSA.

The Global Water Partnership (GWP) is a dynamic, not-for-profit action 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, agencies of the United Nations, bi- and multi-lateral development banks, professional associations, research institutions, non-governmental organizations, and the private sector.

GWP's action network provides knowledge and builds capacity to improve water management at all levels: global, regional, national and local. The Partnership helps countries to connect water resources planning and operations at different scales— trans boundary, regional, basin, national and local—so that actions are coherent and sustainable. GWP has several stakeholders from Bangladesh, individuals as well as NGOs.

6.12 Constraints experienced in information dissemination and networking

The main constraint in information dissemination and networking is that these are either not processed for presentation in suitable form, or are old and lost relevance or do not provide the right type of information. Further information dissemination is not always easy because these are often thought to be the last issue under any programme. In fact, that this should be a continuous activity is often lost sight of. Part of the problem is lack of requisite type of people with necessary skill and secondly the budgetary allocations for such activities are often limited.

Chapter 7

LIMITATIONS, UNCERTAINTIES, COMPLETENESS AND CONSTRAINTS:

THE LESSONS LEARNT

7.1 Preamble

The Initial National Communication 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. Hardly any modeling result could be presented at that time. The SNC is much improved in that sense, yet it suffers from some of the same or similar problems. The limitations are not all of similar nature for all the building blocks of the SNC, nor to be related solely to these constituent elements. A guideline is only a guideline to be followed but keeping the country context in view. The earlier chapters in general depict these building blocks.

The issues of concern related to data, analysis, content, consistency, relevance and others by major elements of the SNC are described below:

7.2 Issues Related to National Circumstances

The user manual has been more or less followed in preparing this chapter. There is not much of a data problem here in terms of availability, but these are scattered in various places and it takes time to put them in order. Second, the types of data needed indicate that a multi-disciplinary team should work in preparing such a chapter. And the team that prepared it was reportedly a multi-disciplinary one. Unfortunately, this did not mean that the information and analyses were relevant or consistent with each other in the initial background reports. Much of the information were descriptive which appeared to be of rather of limited use because while the User Manual says the types of information to be provided, discretion must be used in deciding what to provide or emphasize depending on the country context unless such information has to do something with the climate change either as cause or as impact (realised or potential) such information has really no value here. The information, described here should be the context for analyzing vulnerability and adaptation, as well as GHG inventory and mitigation. That such links do exist was not in many cases initially clearly explicit. This clearly argues for both an initial conceptual framework and rigorous monitoring and review process.

This lack of link is most apparent in the treatment of the socio-economic issues. Take the case of poverty. Poverty has been discussed as a general issue in the chapter. But it should rather be related to climate change and climatic variability. Only then it becomes relevant in the present context. However, a necessary condition for this to happen is that there must be prior analyses of such issues. We have little rigorous information and analysis of the links between poverty and climatic variability or between disaster and poverty in Bangladesh context. There are sporadic and anecdotal studies perhaps but not quantitatively and empirically rigorous ones which can show the links. The same is the case with growth in general and sectoral growths in particular. And this is true even for agriculture, probably the most climate-dependent human system.

The Guideline for NC calls for consideration of Article 4.8, 4.9 and 4.10 of the Convention. These relate to the special situation of developing countries (4.8) and LDCs (4.9) regarding funding and transfer of technology by developed country Parties. Bangladesh qualifies as an LDC and also as a developing country with low-lying coastal areas (4.8,b) and being prone to natural disasters (4.8, d) to receive such funding and preference in getting technology. While anecdotal evidence suggests that these considerations were probably never used in providing development aid, there is no definitive contextual analysis to suggest that this had definitively been the case. Again this probably is due to the absence of prior analysis of the issues in Bangladesh context.

In general this is true that there are only limited analyses of how various national circumstances, physical, natural, and socio-economic relate to each other and to climate. It is high time that this be the main criteria for inclusion of issues under the rubric of National Circumstances.

7.3 GHG Inventory: Energy Sectors and Non-Energy Activities

The uncertainties, quality control and quality assurance, completeness of Energy Sectors are described in Chapter3. Therefore, only the uncertainties, quality of data and completeness of Non-Energy Activities are described below.

7.4 GHG Inventory: Non-Energy Activities

7.4.1 Uncertainties

The estimation of GHGs from non-energy activities in different sectors suffers from major uncertainties. Take first the case of industries. There appears to be little definitive information on the efficiency of industrial processes in say cement and nitrogenous fertilizer. Thus default values and average proportions have to be used. For example, the average fraction of lime in clinker is taken to be 66.5%. If it becomes lower by 10% for certain supply sources, the carbon di-oxide emission would be that much lower. While for Bangladesh this does not make much of a difference for the period the estimates have been done (as there was only one cement factory, now it is several), it may make a significant difference now.

Uncertainties abound in case of agriculture. In rice cultivation, methane emission depends much on how long the fields are kept under inundated conditions. Long inundation period is no longer practised because of continuously falling area under broadcast aman. But there is little on-the ground knowledge of how much time the rice field in case of irrigated or rain fed rice are kept under water that may give rise to methane emission. More importantly, there is some controversy regarding the exact area under rice as the official statistical agency and the Extension Department of the Ministry of Agriculture do often differ in such estimates.

Uncertainties regarding the various parameters are probably quite pronounced. As estimated soil carbon release appears to account for practically the whole of LUCF emission, but the estimate is based upon a very uncertain set of data based on a few areas. In any case, there is no way at moment now to ascertain how much the uncertainty could be.

7.4.2 Quality of Data

Quality of output data for industries is good. But there are question marks over rice area data. For others, there is no way to verify quality of data.

7.4.3 Completeness

For practically all estimates, default values of parameters have to be used as there is not much by way of Bangladesh specific information. For industries, despite 4 types of industries which may be examined for emission estimation, only two have been explored for paucity of data. Apart from this, all types of activity data have been either estimated based on available, though sometimes patchy, data or there are reports on the activities. But these are by and large scattered.

7.5 Mitigation

7.5.1 Uncertainties

The projections of the baseline and the mitigation scenarios have been done using the LEAP model. As such it has all the disadvantages and advantages of the model. But most importantly, the main uncertainty arises from the assumed rate of growth of the economy. A higher rate of growth of the economy *ceteris paribus* would lead to higher consumption of energy and higher emission of carbon.

7.5.2 Completeness

The mitigation exercise suffers from several types of incompleteness. First, mitigation has been analyzed with respect to a baseline scenario only for energy-related activities and even then only for a set of chosen measures. How these have been chosen remains unclear. No baseline and mitigation scenario over time for non-energy activities have been constructed. This could perhaps be done at least for emission from future domestic rice output.

There is a third issue related to completeness. The mitigation measures give only partial effects of the measures, in relation to both energy/emission and their socio-economic impact. What may be attempted is the construction of energy and emission Input-Output tables and estimate the total emission reduction or increase due to mitigation measures throughout the economy from these tables. An economy-wide emission scenario gives better ideas of the effects of the mitigation measures by activity and indeed may suggest which measures would be more effective in aggregate (including both direct and indirect effects) than others.

7.6 Vulnerability and Adaptation

7.6.1 Uncertainties

The major uncertainty in understanding vulnerability stems from the lack of adequate modeling exercises as well as the variations in results across types of model. This is compounded by the fact that whatever is available is much coarse; the grids are too large for local level predictions of climate change, assessment of vulnerability and finally adaptation.

Other uncertainties include those related to human system impacts. Impacts on water availability including sea level rise, rice and wheat production, fisheries, livestock, and human health have been estimated using various models. All such models have their own uncertainties based on assumptions for parameters as well as assumed relationships among various variables which may or may not apply in case of Bangladesh. The margin of error in each case remains basically unknown. If these are large, the adaptation measures may not be well-targeted and there may be mal-adaptation.

The vulnerability in terms of impact on growth, poverty reduction, livelihood, employment and women is more or less uncertain. Whatever has been presented in the SNC are all conjectures and therefore very much uncertain.

7.6.2 Completeness

The main incompleteness arises from the last point in the sub-section above. A country which aspires to be a middle-income nation in 10 years' time and more or less eradicate poverty by that time must consider in all seriousness the possible impact that climate change may have on such goals.

To understand these issues, one could construct at least a macroeconomic model of climate change impact where the future macro variables could be estimated based on types of shock including those of mitigation and adaptation measures. This would have perhaps also given some idea of the deadweight loss due to climate change i.e., the loss that cannot be recouped under any measure. It may be argued that such a deadweight loss must be compensated by those who have historical responsibility for global warming and climate change.

Even where the vulnerability has been estimated or adaptation measures suggested, these remain incomplete in the sense of the needs for financing and the sources of such finance as well as the types of technology needs as well as their sources. Without such estimates of financing need and the need of the specific technology, actual adaptation may become quite difficult.

7.7 Other Relevant Information

The information to be provided here are by and large qualitative and there is not much uncertainty about such information, although again as for other core elements the requisite information are scattered over many institutions and thus costly to collect. One type of information which is lacking is the effects and impacts of various climate change related intervention and policies by type of sector or activity. It should be pointed out however that the process of mainstreaming climate change in development thinking and practice has barely begun in the country and therefore it may be too early to evaluate their impact.

7.8Assessment of the SNC Experience

Two problems have arisen and needs to be kept in purview for future such exercises which are going to be somewhat more complex as these NCs may be used for MRV as well as basis for biennial updating of GHG emission and mitigation measures. The first of these is that of 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. It is expected that the new Department of Climate Change under the MoEF will be entrusted with this responsibility.

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 up scaling of capacity at various levels and institutions including formal educational programmes at higher education level should be undertaken.

ANNEX-A

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