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

National Adaptation Programme of Action (NAPA)

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Foreword

The Government of the People's Republic of Bangladesh has recognised climate change as an important issue and one of the key concerns to its development. Over the last decades, several studies have been conducted to analyse impacts, vulnerabilities and assessed adaptation needs and possible measures to deal with adverse impacts. The noteworthy national level adaptation strategies, programmes and plans include National Adaptation Programme of Action (NAPA) 2005, and Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2008. Key objectives of these national documents are to incorporate potential adaptation measures into overall development planning processes, make development resilient to climate change, and promote sustainable development of Bangladesh.

Adverse impacts of climate change are reality and visible in many parts of the country. A continuous efforts are being made by the Government of Bangladesh at the international forum to highlight its vulnerabilities, implications on development, and adaptation needs including additional resources to address climate change. The issue has also been recognised at the higher political level in the country. It has been emphasised that as a natural disaster prone country, Bangladesh has developed a variety of formal and informal coping mechanisms at different levels. These have greatly reduced losses of lives and properties from climate change related disasters. However, in recent years, the frequency of extreme climatic events, such as floods and cyclones has increased in Bangladesh as well as Globally. These frequent natural disasters related to climate change are putting additional stresses on national economy to recover loss and damage.

This updated version of the National Adaptation Programme of Action (NAPA) for Bangladesh has incorporated findings of studies on impacts, vulnerabilities and adaptation need assessment carried out over the last few years. It has kept the format of the National Adaptation Programme of Action (NAPA) 2005 that was prepared by the Ministry of Environment and Forest (MOEF), Government of the People's Republic of Bangladesh as response to the decision of the United Nations Framework Convention on Climate Change (UNFCCC).

The Ministry of Environment and Forests has engaged all six sectoral working groups for this effort of updating Bangladesh NAPA. The Six Sectoral Working Groups (SWG) i.e. a) Agriculture, Fisheries and Livestock coordinated by Bangladesh Agricultural Research Council (BARC), b) Forestry, Biodiversity and Land-use coordinated by IUCN, Bangladesh, c) Water, Coastal Zone, Natural Disaster and Health coordinated by Water Resources Planning organization (WARPO), d) Livelihood, Gender, Local Governance and Food Security coordinated by Bangladesh Institute for Development Studies (BIDS), e) Industry and Infrastructure coordinated by Department of Environment (DoE), and f) Policies and Institutes coordinated by Bangladesh Centre for Advanced Studies (BCAS).

In the process of updating the NAPA, it became clearer that many adverse impacts related to climate change will exacerbate many of the existing problems and natural hazards that the country faces. Though the country has developed various coping strategies and mechanisms to address natural disasters but climate change adaptation need to be incorporated within

Foreword

the development processes and implementation without delay to address urgency of the issue and adaptation need. The strategic goals and objectives of future coping mechanisms and adaptation measures should be to reduce adverse effects of climate change including variability and extreme events and to promote sustainable development.

The NAPA was the beginning of a long journey to address adverse impacts of climate stimuli including variability and extreme events keeping urgent and immediate needs. The updated NAPA has moved from the immediate and urgent needs to wider adaptation requirement to address medium and long-term climate issue. It gave emphasis on four security issues of Bangladesh i.e. a) food security, b) energy security, c) water security, and d) livelihood security (including right to health) and respect for local community on resource management and extraction.

Bangladesh government has already integrated climate change into several sectoral policies and plans. Climate change has been incorporated into the Coastal Zone Policy in 2005. Bangladesh National Water Policy has recognized climate change and knowledge gap need to be addressed. Climate change has also been adopted in the preparation of disaster preparedness plans by Food and Disaster Management Ministry. Recently, the Government has prepared the Poverty Reduction Strategy Paper (PRSP) where issue of climate change has been incorporated.

The Government of Bangladesh has recently formulated the Bangladesh Climate Change Strategy and Action Plan (BCCSAP), and allocated resources of about 100 million US Dollars from the national budget for climate change activities. Operational modalities and procedures are at the stage of finalization. It is also working on setting up a "Multi-Donor Trust Fund (MDTF)" for receiving and disbursing adaptation funds. The priority needs of the country have been outlined in the strategy and action plans considering food security, social protection and health, comprehensive disaster management, infrastructure, research and knowledge management, mitigation and low carbon development, and capacity building and institutional strengthening.

The Government of the People's Republic of Bangladesh expects that this updated version of NAPA will promote implementation of the adaptation projects. It is also expected that the involved ministries and departments will begin implementation without delay through accessing climate change fund available at national level and international levels. It also urges that global community should play their roles and comply with their commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol (KP) under the purview of Common But Differentiated Responsibility and Respective Capabilities.

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Acronyms and Abbreviations

ADB	Asian Development Bank
AIG	Alternative Income Generation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agriculture Research Institute
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Centre for Advanced Studies
BFRI	Bangladesh Fisheries Research Institute
BIDS	Bangladesh Institute of Development Studies
BRDI	Bangladesh Rice Research Institute
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CBD	Convention on Biological Diversity
CCC	Climate Change Cell
CEGIS	Center for Environment and Geographic Information Services
CIDA	Canadian International Development Agency
COP7	Seventh Session of the Conference of the Parties
DAE	Department of Agricultural Extension
DoE	Department of Environment
DOF	Department of Fisheries
DPHE	Department of Public Health and Engineering
ENSO	El Nino and the Southern Oscillation
FD	Forest Department
FEJB	Forum of Environment Journalist Bangladesh
FMP	Forest Management Plan
GBM	Ganges-Brahmaputra-Meghna
GCM	General Circulation Model
GDP	Gross Domestic Product
GFDL	Geo Fluid Dynamic Laboratory
GOB	Government of Bangladesh
GPWM	Guideline for Participatory Water Management
HDE	Human Development Index
HES	Household Expenditure Survey
HYV	High Yielding Variety
ICDDRB	International Centre for Diarrhoeal Disease Research, Bangladesh
IPCC	Intergovernmental Panel on Climate Change
IUCN	The World Conservation Union
IWRM	Integrated Water Resource Management

Acronyms and Abbreviations

LDCs	Least Developed Countries
LEG	LDC Expert Group
LGED	Local Government Engineering Department
MEAS	Marine, Earth and Atmospheric Science
MOEF	Ministry of Environment and Forests
MOFDM	Ministry of Food and Disaster Management
MOWR	Ministry of Water Resources
NAPA	National Adaptation Programme of Action
NEMAP	National Environmental Management Action Plan
NIPSOM	National Institute for Preventive Social and Occupational Medicine
NWMP	The National Water Management Plan
OECD	Organization for Economic Cooperation and Development
OFRD	On-farm Research Division
PRSP	Poverty Reduction Strategy Paper
RA	Resource Analysis
R&D	Research and Development
RVCC	Reducing Vulnerability to Climate Change
SAARC	South Asian Association for Regional Cooperation
SMRC	SAARC Meteorological Research Centre
SRDI	Soil Resources Development Institute
SRES	Special Report on Emission Scenario
SST	Sea Surface Temperature
STW	Shallow Tubewell
TBM	Tidal Basin Management
UNDP	United Nations Development Programme
UNCCD	United Nations Convention on Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
WARPO	Water Resources Planning Organization
WB	World Bank
WFP	World Food Programme

Glossary of Terms

Land Type (by depth of flooding)

F0 (highland)	0-30 cm, Intermittent flooding, land suited to HYV rice in wet season
F1 (medium highland)	30-90 cm, Seasonal flooding, land suited to local varieties of Aus and T. Aman in monsoon season
F2 (medium lowland)	90-180 cm, Seasonal flooding, land suited to B. Aman in wet season
F3 (lowland)	180-300 cm, Seasonal flooding, land on which B.Aman can be grown in wet season
F4 (very lowland)	>300 cm, Seasonal or perennial flooding does not permit growing of B. Aman in the wet season

Agriculture

B Aman	Broadcast Aman; a rice crop usually planted in March/April under dry land conditions, but in areas liable to deep flooding. Also known as deep water rice. Harvested in October to December. All varieties are highly sensitive to day length.
T Aman	Transplanted Aman; a rice crop planted usually July/August, during the monsoon in areas liable to a maximum flood depth of about 0.5 meter. Harvested in November/December. Local varieties are sensitive to day length whereas modern varieties are insensitive or only slightly sensitive.
Boro	A rice crop planted under irrigation during the dry season from December to March and harvested April to June. Local Boro varieties are more tolerant of cool temperatures and are usually planted early in areas which are subject to early flooding due to rise in river levels. Improved varieties, less tolerant of cool conditions are usually transplanted from February onwards. All varieties are insensitive to day length.
B Aus	Broadcast Aus; a rice crop planted March/April under dry land conditions. Matures on pre-monsoon showers to be harvested in June/July, and is insensitive to day length.
T Aus	Transplanted Aus; a rice crop, transplanted March/April usually under irrigated conditions and harvested June/July. The distinction between a late planted Boro (c.v) and early transplanted Aus is academic since the same varieties may be used. Varieties are insensitive to day length.
Kharif	The wet season (typically March to October) characterized by monsoon rain and high temperatures.
Kharif 1	The first part of the kharif season (March to June). Rainfall is variable and temperatures are high. The main crops grown are Aus, summer vegetables and pulses. Broadcast Aman and jute are planted.
Kharif 2	The second part of the kharif season (July to October) characterized by heavy rain and floods. T. Aman is the major crop grown during the season. Harvesting of jute takes place. Fruits and summer vegetables

	may be grown on high land.
Rabi	The dry season (typically November to February) with low or minimal rainfall, high evapotranspiration rates, low temperatures, and clear skies with bright sunshine. Crops grown are boro, wheat, potato, pulses and oilseeds.
HYV	High Yielding Variety; introduced varieties developed through formal breeding programmes HYVs have a higher yield potential than local varieties but require correspondingly high inputs of fertilizer and irrigation water to reach full yield potential.
Local	Varieties developed and used by farmers. Sometimes referred to as local varieties improved varieties (LIVs)
NCA	Net Cultivable Area; total area which is undertaken for cultivation

Executive Summary

Bangladesh is already vulnerable to many gradual change phenomena of climate change as well as climate change related extreme events. It is expected that climate change will bring changes in characteristics of gradual change phenomenon and natural hazards which will result changes in physical, social and production system. Studies and assessments on impacts, vulnerabilities and adaptation to climate change and sea level rise for Bangladesh clearly demonstrate that Bangladesh is one of the most climate vulnerable countries in the world. Rainfall is predicted to become higher and more erratic. Frequency and intensity of natural disasters are likely to increase especially in the northern and western part of the country. Several early evidences of the above phenomenon and its associated impacts in the agriculture, health, water and sanitation, biodiversity are already visible in Bangladesh.

Overall impacts of climate change on Bangladesh would be significant. It is estimated that climate change could affect more than 70 million people of Bangladesh due to its geographic location, low elevation, high population density, poor infrastructure, high levels of poverty and high dependency on natural resources. It was found that the population living in the coastal area is more vulnerable than the population in other areas (Alam and Laurel, 2005). Coastal resources upon which the most people depend are likely to be affected severely due to climate variability and change. It is predicted that for 45 cm rise of sea level may inundate 10-15% of the land by the year 2050 resulting over 35 million climate refugees from the coastal districts. Ultimately adverse impacts have the potential to undermine poverty reduction efforts and could compromise the Millennium Development goals (MDGs), such as the eradication of poverty and hunger by 2015. The OECD and World Bank also estimated that 40% of the Overseas Development Assistance (ODA) to Bangladesh may be climate sensitive or at risk.

It is also revealed from the studies and assessments that the context of vulnerabilities and associated impacts vary by spatial, temporal scale and socio-economic condition of communities, resulting need for different adaptation measures and actions. Coastal area of the country is prone to salinity intrusion and tropical cyclone; floodplains in the central areas are prone to flood; north western region of the country is prone to drought; north eastern part of the country is prone to flash flood; and hilly region of the country is prone to erosion and landslide. Water resources and agriculture are reported to be most impacted sectors due to climate change.

Recognition of adverse impacts of climate change on economic development, life and livelihoods of the poor and ultimately impeding Millennium Development Goals has pushed urgent need for adaptation to deal with unavoidable impacts of climate stimuli including variability and extreme events in Bangladesh. The Ministry of Environment and Forests, Government of Bangladesh has prepared Bangladesh Climate Change Strategy and Action Plan 2008 as a living document while Ministry of Finance has allocated about US$ 100 million to begin implementation of the strategy and action plans. The development partners in Bangladesh and the Government of Bangladesh has also agreed to setup a “Multi-Donor Trust Fund (MDTF)E to deal with climate change adaptation and mitigation.

Executive Summary

1 Background

The Government of the People's Republic of Bangladesh is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol (KP). Ministry of Environment and Forests, Government of Bangladesh has formulated the National Adaptation Programme of Action (NAPA) in 2005 to address immediate and urgent adaptation needs as a response to the decision of the UNFCCC. It is to be noted that international communities have received Bangladesh NAPA very well. The first priority project of NAPA has received financial support from Least Developed Countries Fund (LDCF) and being implemented by the Ministry of Environment and Forests.

Meanwhile, several other developments and progresses have been happened at international and national levels. These include release of Forth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) in 2007; landmark decision of the Thirteenth Session of the Conference of the Parties (CoP13) known as Bali Action Plan (BAP) to address emission of greenhouse gases, enhanced actions on adaptation, technology transfer for mitigation and adaptation, and financial flow and investment for both mitigation and adaptation. Moreover, Ministry of Environment and Forests has prepared Bangladesh Climate Change Strategy and Action Plan (BCCSAP) to carry forward and coordinate activities giving emphasis on adaptation, mitigation, capacity building, technology transfer and fund raising (MoEF, 2008).

The report on Impacts, Adaptation and Vulnerability of the Forth Assessment Report by IPCC makes it clear that climate change in now and here, some degree of impacts are unavoidable (IPCC, 2007). Many challenges that Bangladesh faces now will be aggravated due to climate change and these challenges will emerge as one the greatest long-term threats to the development trajectory. It is likely that development efforts in all aspects of Bangladesh including economy, livelihood, food security, environment and social development will be affected severely. Therefore, both immediate and urgent, and long term adaptation measures are necessary to design and implement at national, sub-nation and local levels.

Bangladesh Climate Change Strategy and Action Plan (BCCSAP) has comprises 37 Programmes under 6 Thematic Areas to deal with adverse impacts of climate change as well as supporting low carbon economic growth. The BCCSAP has incorporated immediate and urgent adaptation projects identified in NAPA, which was prepared using methodology developed by Least Developed Countries Expert Group (LEG) and endorsed by the Conference of the Parties (COP). Engagement of different stakeholders through sub-national (divisional) level consultations was integral part of the formulation process of NAPA. It is to be noted that formulation of BCCSAP was initiated to response a need, the UK-Bangladesh high level meeting held in London, UK. It has been clearly stated in the BCCSAP that it is a living document and changes will be made as appropriate by the respective sectoral agency.

This updated version of the National Adaptation Programme of Action (NAPA) for Bangladesh has incorporated findings of impacts, vulnerabilities and adaptation studies carried out over the last few years. It has also extended its scope of identification of adaptation measures from immediate and urgent to medium and long-term adaptation measures. It has done through incorporating additional projects

and brought synergies with BCCASP and adaptation activities identified by the respective sectoral working group of NAPA. However, this document has kept the format of the National Adaptation Programme of Action (NAPA) prepared in 2005.

In process of updating the NAPA, it became clearer that many adverse impacts related to climate change are visible and will exacerbate many of the existing problems and natural hazards. It is also reported that there are various coping mechanisms, formal and informal, already are in place. The urgency and scale of the matter are new and therefore need to be integrated into the development process and begin implementation without any future delay. The strategic goals and objectives of future coping and adaptation mechanisms should be to reduce adverse effects of climate change including variability and extreme events and promote sustainable development. Enhanced action on adaptation through strengthening means of implementation particularly institutional capacity building has been given priority in the revised NAPA.

The NAPA was the beginning of a long journey to address adverse impacts of climate stimuli including variability and extreme events by identification and implementation of immediate and urgent needs. But the updated NAPA has moved from immediate and urgent need and to cover wider adaptation need. It gave emphasis on four security issues of Bangladesh i.e. a) food security, b) energy security, c) water security, and d) livelihood security (including right to health) and respect for local community on resource management and extraction.

2 Country Context

Bangladesh, except for the hilly regions in the northeast and southeast and terrace land in northwest and central zones, is one of the largest deltas in the world, formed by the dense network of the distributaries of the mighty rivers namely the Ganges, the Brahmaputra and the Meghna. The country is located between 20°34' to 26°38' north latitude and 88°01' to 92°42' east longitude. The total land area is 147,570 sq. km. and consists mostly of low and flat land. A network of more than 230 major rivers with their tributaries and distributaries crisscross the country.

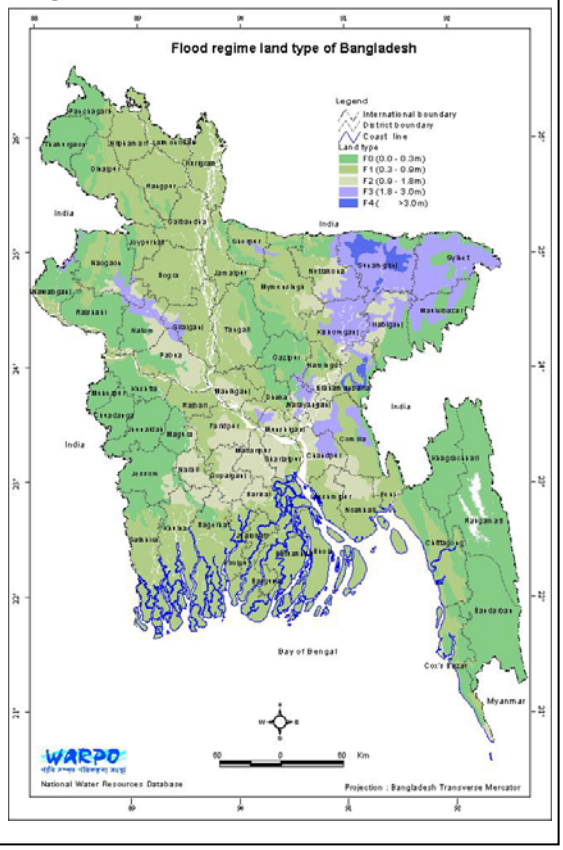
2.1 Physical, Social and Economic Circumstances

This section provides a brief description of the biophysical, social, economic, technological and political context of the country. These characteristics depict exposure, sensitivity, adaptive capacity and vulnerability of these systems to climate variability and change.

2.1.1 Physiographic Condition

The land area of the country may be divided broadly into three categories i.e. floodplain (80 %), Pleistocene terrace (8 %), and tertiary hills (12 %) based on its geological formation. The floodplain comprises of a succession of ridges (abandoned levees) and depressions (back swamps or old channels). Differences in the elevation between adjoining ridge tops and depressions range from less than 1 meter on tidal floodplains, 1 meter to 3 meters on the main rivers and estuarine floodplains, and up to 5 to 6 meters in the Sylhet Basin in the north-east. Only in the extreme northwest do land elevations exceed 30 meters above mean sea level. The tertiary hill soil occupy the Chittagong hills in the south-east, and the low hills and hillocks of Sylhet in the north-east. The two major uplifted blocks (Pleistocene terrace) are known as Madhupur (in the central Bangladesh) and Barind tracts in the north-west.

Figure 1. Flood Regime and Land Type of Bangladesh



The land type of the country has been classified according to depth of inundation with seasonality. All land types except highlands are exposed to monsoon flooding for part or whole of the year. Spatial distribution of land types depending on average flood depth are shown in Figure 1 while Table 1 show land area with different flood depths as well as seasonality.

Floodplains located in the north-western, central, south-central and north-eastern regions are subject to regular flooding at different frequency and intensity while the coastal plain is subject to cyclones and storm surges, salinity intrusion and inundation. Pleistocene terrace land is prone to moisture stress while flash flood is common in the hilly areas and the piedmont plains in the northeast and north-western parts of the country.

2.1.2 Demographic Situation

Bangladesh had a population of about 124.35 million in 2001 which increased to 143.91 million in 2007 (BBS, 2008) with a per capita Gross Domestic Product (GDP) of US$ 554 per annum (Planning Commission, 2008). The population of the country has increased over time with significant variation between urban and rural population growth. In the last decade (1991-2001), the overall increase was about 16 percent while urban and rural growth was about 37 percent and 11 percent, respectively (BBS, 2003). It is estimated that the population of the country will be 170 million by the year 2020 (WB and BCAS, 1998) and will increase further to about 218.25 million by 2030 (BBS, 2008).

Though most of the people live in the rural areas but growth rate of urban population is

Table 1. Land Areas of Different Flood Phases

Land type	Maximum depth of flooding	Seasonally flooded	Permanently flooded
Medium Highland 1 (F0)	0.3m	16%	0%
Medium Highland 2 (F1)	0.9m	44%	1%
Medium Lowland (F2)	1.8m	23%	1%
Lowland (F3)	3.0m	11%	3%
Very lowland (F4)	>3.0m	1%	1%
Total		95%	6%

Source: NWMP, 2001

higher. Between 1961 and 1974, the rate of growth in urban population was 6.7 % per annum. Between 1974 and 1981, it shot up further to 10.7 % per annum. Since then the rate has fallen, but between 1991 and 2001 it was 3.15 %, which was just double the rate of overall population growth.

Spatial distribution of population is important in the context of climate change. It is estimated that about 79% (70% inland plain and 9% inland hills) people live somewhat away from the sea and rest 21% (15% coastal plain and 6% coastal hills) accounts for population in the coastal districts.

2.1.3 Socio-economic Condition

Bangladesh has performed fairly well in terms of macroeconomic stability in general and economic growth in particular over the last decade. Market oriented economic reforms and deregulations in early 1990s led to a more stable macroeconomic environment compared with that in 1970s and 1980s. The Gross Domestic Product (GDP) growth rate improved steadily during the 1990s. The average annual GDP growth was 4.65 % from 1991 to 1995 and rose further to 5.5 % from 1996 to 2000. According to the Bangladesh Bureau of Statistics the economic growth rate of Bangladesh was 6.43% for 2006-07.

According to the Human Development Report 2007, Bangladesh ranks at 140 in the Human Development Index (HDI). The life expectancy at birth is 63.1 years and adult literacy rate was 47.5% in 2005 (UNDP 2007). However, Bangladesh has made significant progress in addressing the Millennium Development Goals (MDG) with regard to sanitation, water supply and nourishment. For instance, improved sanitation coverage has increased from 20% in 1990 to 39% in 2004 while 74% of the population was using improved water source in 2004 (UNDP 2007). Percentage of the GDP that is spent on health and education is 0.9 and 2.5, respectively. In terms of energy consumption and electricity supply, Bangladesh is still lagging behind. About 96 million population of Bangladesh still live without electricity.

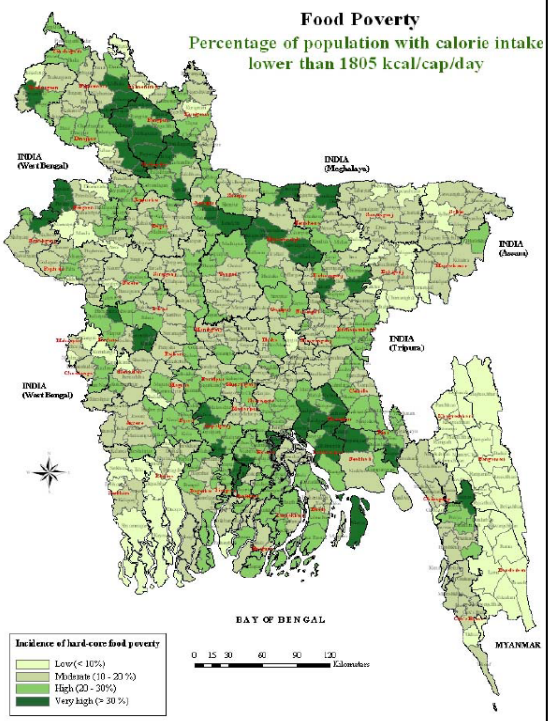
According to the Household Income and Expenditure Survey (HIES) of Bangladesh Bureau of Statistics (BBS), using the most commonplace definition, about half of the population could be considered poor in the mid-1990s, while a quarter of the population could be considered extreme poor (BBS, 2007). The situation remained basically unaltered by the turn of the century.

Levels of poverty vary substantially across the country and are strongly correlated with spatial distribution of food insecurity. The United Nations World Food Programme (WFP) has reported that the poorest upazilas can be found in the north-west, the coastal belt, Mymensingh, Netrakona, Bandarban and Rangamati. In terms of absolute numbers, districts with more than one million people living in extreme poverty include Sirajganj, Naogaon, Bogra, Mymensingh and Chittagong (GOB and FAO, 2004). Figure 2 shows the spatial distribution of poverty in the country.

Given the size of population, and poverty incidence by administrative divisions, it shows that the largest number of poor lives in Rajshahi (northwest part) followed by Dhaka (central region), Chittagong (southeast region), Khulna (southwest region), Barisal (south central region) and Sylhet (northeast region). Table 2 provides information about density of poor by administrative division.

Recent analysis by General Economic Division revealed that the proportion of poor is higher compared to its proportion of

Figure 2. Spatial Distribution of Poverty



Source: GOB and FAO, 2004

population in the lagging divisions. On the other hand, proportion of poor is lower compare to its proportion of population in the forward divisions. In 2005, the proportion of population in Khulna division was 11.68% and the proportion of poor was 13.3 %. The proportion of population in Barisal division was 6.42% where the proportion of poor was 8.3%. The proportion of population was 24.08% in Rajshahi and the proportion of poor was 30.8%. In Dhaka Division the proportion of population was 32.23% and the proportion of poor was 25.8%. The proportion of population in Chittagong Division was 19.25% while the proportion of poor was 5.4%. This distribution hold true for all districts as well (GED, 2008).

2.1.4 Key Economic Sectors

Agriculture, manufacturing industries, and various services such as transport and trade are the major economic sectors of the country. While there are some debate regarding the direct contribution of agriculture to the national income, two facts remain undisputed. Firstly, there is a decreasing trend in its share in GDP. Secondly, despite this, it is still of paramount importance, because it still supports a large number of people and most other sectors or activities depend on it, either for processing its products, or servicing the sector. Further, the government strives for self sufficiency in food grain and attaches great importance to maintaining a sustainable growth rate in agricultural sector. Table 3 provides real GDP of major sectors of Bangladesh in Million Taka.

Table 2. Number and Density of Poor People by Administrative District

Region	Area		Population		Poverty Incidence %	Poor		Population density/Sq. km	
	Square Km	%	Crore	%		Crore	%	Poor	All
Barisal	13297	9.01	0.89	6.42	52.0	0.46	8.3	346	669
Chittagong	33771	22.88	2.67	19.25	34.0	0.91	16.4	270	790
Dhaka	31120	21.09	4.47	32.23	32.0	1.43	25.8	460	1436
Khulna	22273	15.09	1.62	11.68	45.7	0.74	13.3	332	727
Rajshahi	34514	23.39	3.34	24.08	51.2	1.71	30.8	495	967
Sylhet	12596	8.54	0.88	6.34	33.8	0.30	5.4	238	699
Bangladesh	417571	100	13.87	100	40.0	5.55	100	376	940

Source: General Economic Division, 2008

Table 3. Real GDP of Bangladesh (Major Sectors) in Million Taka

Sectors	2003-04	2004-05	2005-06	2006-07	2007-08 (p)
Agriculture (including fisheries)	558,050	570,367	598,532	625,796	648,400
Manufacturing	390,688	422,690	468,197	513,722	551,833
Wholesale and Retail Trade	337,698	361,552	385,961	416,996	447,018
Transport, Storage & Communication	236,764	255,522	275,922	298,093	323,994
GDP (real)	2,519,680	2,669,740	2,846,726	3,029,709	3,217,855
Growth Rate (real)	6.27	5.96	6.63	6.43	6.21
GDP (per capita in Taka)	18,637	19,489	20,512	21,550	22,597
GDP (per capita in USD)	418	441	447	487	554

Source: BBS Data
Note: (p) denotes provisional

2.1.5 Industries and Infrastructure

Bangladesh is predominantly an agrarian country. However, along with urbanization industrialization is progressing primarily through private sector investment. The Government of Bangladesh is continuously supporting private sector investment through different financial incentives such as tax holiday. Manufacturing and processing are key industries where both indigenous and imported raw materials are being used by large scale industries. Jute, cotton, textile, paper and newsprint, sugar, cement, chemicals, fertilizers and tanneries are most important among them. Readymade Garments is one of key foreign currency earning industries.

Industries owned by the Government of Bangladesh are being operated by the different corporations under Ministry of Industries. Bangladesh Chemical Industries Corporation (BCIC) is operating 13 major industries most of which are located on the bank of major rivers and are therefore prone to several climate change related extreme events including lack of freshwater availability.

There is a very high density of Small and Medium Enterprises (SMEs) in the industrial economy of Bangladesh. It comprises over 99 percent of private sector industrial establishment and providing 70 to 80 percent job opportunities of the non-agriculture labour forces (GED, 2008). One of the noteworthy feature in the SMEs is engagement of women engagement. Small and Medium Enterprises located in the central and coastal region are prone to flood and cyclonic storm and surges.

Over the last decades, significant development happened in infrastructure particularly transport system for increasing connectivity of rural growth centres with cities and large markets. The transport system of Bangladesh operates through four modes. Road, rail, inland waterways and airways. Land transport infrastructure particularly road network is fragmented by numerous ferry crossings and land transport has to move over circuitous routes because of extensive river systems. Costs for construction and maintenance of transport infrastructure particularly road network are very high because of difficult terrain strewn with numerous water courses, periodic flooding requiring

elevated infrastructure embankments, and poor soil conditions coupled with general scarcity of construction materials and lack of adequate construction industry.

Currently, the total length of roads under Road and Highways Department (RHD) is about 21,57a km of which 16,500 km are paved and 5,071 km are brick-pavement. Of the total network, 3570 km are national highways, 4323 km are regional highways, and 13678 km are zila roads. In addition, RHD also maintains 3790 bridges and 10981 culverts of different size and length.

Local Government Engineering Department (LGED) is another government institute continuously developing connectivity of the rural growth centres, union parishad headquarters, upazial parishad headquarters, social service institutions such as schools and hospitals. The also construct bridges and culverts in the rural areas.

These bridges and culverts are important infrastructures for water flow and keep system congestion free. However, present design is not always capable to handle erratic behaviour of rainfall and many areas often face drainage congestion. It is expected that climate change will increase erratic behaviour of rainfall and present drainage congestion will increase in future.

2.1.6 Policy, Planning, Institutions and Governance

The Government of Bangladesh has recognised that an integrated approach is required to deal with climate change and need involvement of different relevant ministries and agencies, civil society and the business sector.

The Ministry of Environment and Forest (MOEF), the climate change focal point of the government, has set up a National Climate Committee in 1994 for policy guidance and to oversee the implementation of obligations under the UNFCCC. In addition to the Ministry of Environment and Forests, and Department of Environment, other key ministries of the Government of Bangladesh are involved in climate change. Key ministries and agencies involved are the Ministry of Food and Disaster Management (MoFDM) including the Disaster Management Bureau (DMB) and the Comprehensive Disaster Management Programme (CDMP); Ministry of Water Resources including the Bangladesh Water Development Board, Water Resources Planning Organization and forecasting organisations; Local Government, Rural Development and Cooperatives, which includes the Local Government Engineering Department (LGED) and the Department of Public Health Engineering (DPHE); Ministry of Agriculture including the National Agricultural Research System that develops new crops and demonstrates practices suited to different climatic conditions in the country; Livestock and Fisheries including Department of Fisheries and it research wing; and Ministry of Health and Social Welfare.

Several national level strategy and programme has recognized necessity of strengthen capacity of government including key development agencies and departments to plan, design and implement their development programmes in the context of climate change. The recently developed Bangladesh Climate Change Strategy and Action Plan (BCCSAP) has suggested several capacity building aspects to meet the challenges of climate change. Capacity building related to adaptation are a) mainstream climate change in national, sectoral and spatial development planning and ensure that impacts on vulnerable groups and women are prioritised in plans; and b) build the capacity of key government ministries and agencies to take forward climate change adaptation

including Ministry of Food and Disaster Management, Local Government Engineering Department; National Agricultural Research System.

The Planning Commission is the key agency formulates short-term and long-term plans as well as guides and supervises the national development programme. The BCCSAP suggested two changes in the process to mainstream climate change. These are a) introduce a set of design and planning parameters for projects, for selected target years (e.g. 2030, 2050 and 2100), which take into account likely climate change impacts; b) the project formulation document designed in a way to ensure that all elements for taking decisions for climate resilience or climate sensitivity are included and correctly reflected. These need revision of existing modalities of project formulation and make aware project designers about climate change issues so that concerns can be appropriately included in the planning process.

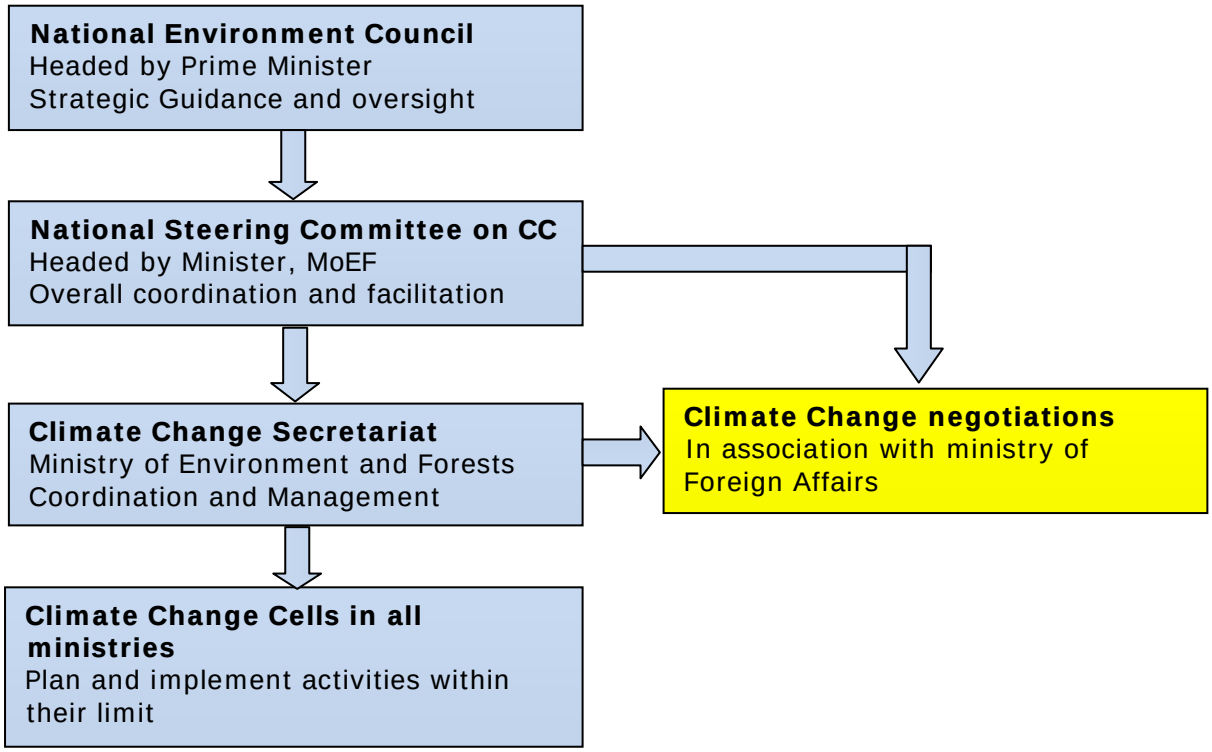
The General Economic Division of the Planning Commission has undertaken a policy research and analysis to understand linkage between climate change impacts and overall economic growth and poverty. One of the key objectives of the study is to integrated climate change issues in planning and designing process to support economic growth and poverty reduction. The early findings of the study indicate that it needs more research to understand link between climate change and economic growth and poverty to initiate or bring modification of the exiting actions to address ground realities.

Ministry of Environment and Forests, Government of Bangladesh has already established Climate Change Cell at the Department of Environment under the Comprehensive Disaster Management Programme (CDMP) with the objective of "Establishing an Integrated Approach to Climate Change Risk Management at National and Local Levels." The Climate Change Cell's work focuses on building the capacity to mainstream climate change issues in development activities in particular adaptation to climate change.

In order to coordinate climate change related activities, the Government of Bangladesh (GOB) has established an inter-ministerial committee on climate change headed by the Minister for Environment and Forests (MOEF) and with representation from relevant government ministries and departments as well as key Non-governmental organizations (NGOs) and research institutions. There is also a National Environment Committee to determine environmental policies chaired by the Prime Minister and with representation from Members of parliament (MPs) as well as government and civil society. It may be pointed out, however, that the institutional capacity including human resource quality in most such organizations are weak and poor and needs substantial improvement if the challenges of climate change are to be faced squarely.

The Inter-ministerial committee It reports to the National Environment Committee, chaired by the Prime Minister. The National Environment Committee and the National Steering Committee on Climate Change also provide guidance on international climate change negotiations, including bilateral, multilateral and regional programmes for collaboration, research, exchange of information and development. A Climate Change Secretariat has been set up in the Ministry of Environment and Forests, to support the National Steering Committee on Climate Change. It works with climate change cells in all ministries. Schematic presentation of the institutional structure is given in Figure 3.

Figure 3. Schematic Presentation of the Institutional Structure



2.2 Key Climate Change Related Development Concern

There are several environmental issues and concerns to development that are already hindering development process of Bangladesh. Climate change will become an additional issue and concern as it will aggravate several of those problems in future. A brief description of key environmental concerns related to development and climate change are given below.

2.2.1 Land and Soil

Agricultural land is decreasing rapidly as it is being diverted to other uses, mainly for urbanization and building of human settlements. The annual loss of arable land stands at about 100 thousand ha per year.

In addition to structural change of land use, riverbank erosion is rampant in areas along the active river channels of the Ganges, the Jamuna and the Tista rivers and in the coastal and offshore areas of Bangladesh. About 1.7 million hectares of floodplain areas are prone to riverbank erosion (Karim and Iqbal, 2000). It has been observed that between 1973 and 1996, a total of 73,552 ha of land was eroded while only 10,628 ha of land have been formed by accretion (WARPO, 2000). Physical, chemical and biological properties of soil are deteriorating including organic maters, loss of micro nutrient, increase soil salinity and lack of proper replenishment of plant nutrient etc. Forty five percent net cultivable area has even less than 1% organic matter. Out of 2.85 million hectares of the coastal and offshore areas, about 1.2 million hectares of arable land are affected by varying degrees of soil salinity. Tidal flooding during wet season, direct inundation by saline or brackish water and upward or lateral movement of saline to groundwater during dry season and inundation with brackish water for shrimp farming are key causes for salinization of coastal land. The severity of salinity problem has increased over time with the desiccation of the soil.

2.2.2 Water

Bangladesh is richly endowed with water resources. The water ecosystem comprises the tributaries and distributaries of the three major rivers system, the Ganges-Padma, the Brahmaputra, and the Meghna (GBM), and numerous perennial and seasonal wetlands known locally as *haors, baors, pukurs, dighies, khals and beels*. Owing to the fact that 92% or more of Bangladesh's annual runoff enters into the country from outside its borders. There is a high degree of uncertainty about the quantum of the water that will be available from trans-boundary rivers in future due to climate change. River flows have very large seasonal variations. In the monsoon, the combined flow of the Ganges and the Brahmaputra reaches a peak between 80,000 to 140,000 m3/s in the July-August or early September period (NWMP, 2001). Dependable flow (80%) in the Ganges (according to Ganges Water Treaty) can be less then 1,000 m3/s from February to April. In the river Brahmaputra, flow (dependable) is less then 4,000 m3/s during March and April (NWMP, 2001).

Mainly two types of problems do exist in the coastal water bodies, namely, salinity in the estuarine areas, and water pollution in the marine zone. The magnitude of these problems depends on seasonal freshwater flow from the rivers, and operation of seaports, Chittagong and Khulna.

Generally, water scarcity is a dry season phenomenon when the availability of freshwater becomes less than the demand, or the quality of the water restricts its use. Dry season water resources are comprised of the runoff and trans-boundary river inflow, together with water contained in surface water bodies and groundwater. Scarcity is also dependent on the amount of soil moisture available at the beginning of the season. Trans-boundary inflow in the dry season has decreased due to upstream development, and withdrawal of water for irrigation and other purposes. Groundwater is the major source of irrigation and domestic water supply in Bangladesh. There has been a tremendous increase in the suction mode technology in irrigation & water supply using groundwater sources since 80's. Contamination of shallow aquifer has recently been identified as a major problem with about 25% of the population exposed to arsenic level exceeding Bangladesh standards (0.05mg/l) (NWMP, 2001). Other problems in different parts of the country include, water logging (particularly in the coastal and urban centres) as well as poor water management and drainage systems in many places.

2.2.3 Biodiversity

The terrestrial and aquatic areas of the country support a large number of diverse biological populations, both plant and animal. Notwithstanding insufficient baseline information on biological resources, it is believed that development practices have caused a significant depletion of terrestrial and aquatic species diversity. Over-exploitation of some very common species in an unwise manner has led to their existence to a vulnerable status.

Sundarban's mangrove forest in the south-west forms a unique environment of floral-faunal assemblages. Leaf litter undergoing decomposition provides particulate and dissolved organic matter to the estuarine ecosystem, and this complex detritus-based food web supports a number of marine and brackish water organisms. The Sundarban supports a very rich and diverse fish fauna of 400 species, 270 species of birds, and over 300 species of plants. It is an important staging and wintering ground for migratory shore birds, gulls, and terns. The mangrove is the largest remaining tract of

habitat for the Royal Bengal Tiger (*Panthera tigris*). St. Martin's Island is an important nesting area for marine turtles, and a wintering ground for migratory shore birds.

In addition to the Sundarbans (which has been declared by UNESCO as "World Heritage Site", there are also other significant wetlands (both coastal and inland-fresh water) with important plant (e.g. swamp forest), animal, aquatic species and over-wintering grounds for many migratory bird species.

2.2.4 Natural Disasters

The geographical setting of Bangladesh makes the country vulnerable to natural disasters. Every year one or more natural calamities upset people's lives in some part of the country. The major natural hazards include flood, cyclone and storm surge, flash flood, drought, tornado, earthquakes, riverbank erosion, and landslide.

Flood in Bangladesh is a normal phenomenon. Floods affect about 80% of land in Bangladesh. In a normal year, 20-25% of the country is inundated by river spills and drainage congestions. Approximately 37%, 43%, 52% and 60% of the country is inundated with floods of return periods of 10, 20, 50 and 100 respectively (MPO, 1986). Four types of flooding occur in Bangladesh. Table 4 provides nature of floods, time of occurrence and usual impacted areas.

Devastating floods of 1987, 1988 and 1998 inundated more than 60% of the country. The 1998 flood alone caused 1,100 deaths, inundated nearly 100,000 sq-km, rendered 30 million people homeless, damaged 500,000 homes and caused heavy losses to infrastructure. In 2004, flood inundated 38% of the country while 2007 flood inundated about 42%. Figure 4 shows flood prone area of Bangladesh and Table 5 indicates broad adverse impacts of major floods during the last 50 years.

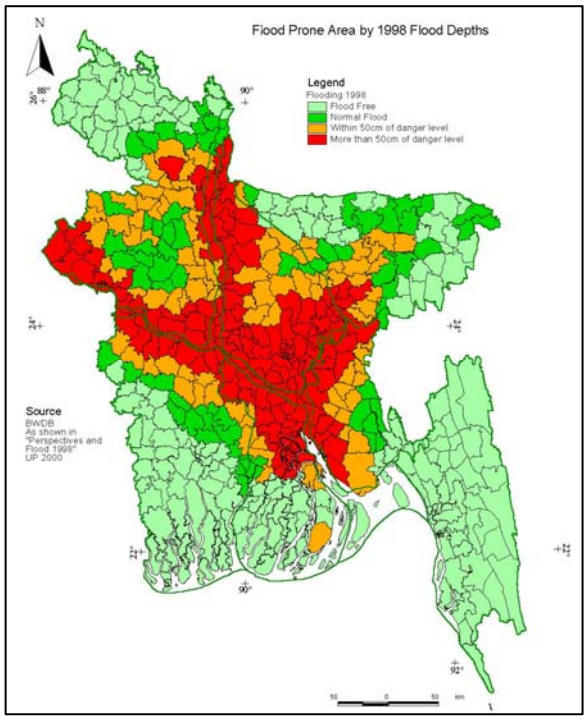
Disaster records of last three decades revealed that frequency of flood has increased over time. Table 6 shows that frequency of flood has increased in last two decades. For example, a flood event that inundates 37% of land suppose to occur once in every 10 years. But it is found that

Table 4. Different Types of Flood, Causes and Time of Occurrence in Bangladesh

Types of Flood	**Causes of occurrence**	**Time/duration**	**Tentative affected area**
Flash Flood	Run-off during exceptionally heavy rainfall occurring in neighboring upland areas	Pre monsoon months of April and May	The foot of the Northern and eastern hills of Bangladesh
Rainwater flood/ Monsoon Flood	Heavy rainfall occurring over flood plane and terrace areas within Bangladesh.	April-May June-August	In the south-western part of the country
River Flood	Snow melt in high Himalayans, Heavy monsoon rainfalls over the Himalayans, the Asam Hills, the Tripura Hills and the Uppar Brahmaputra and Ganges flood plains	April-May and June-September	Catchment areas of three major rivers.
Coastal Flood	In case of important cyclones the entire coastal belt is flooded. Coastal areas are also subjected to *tidal flooding*	Tidal flood occurs from June to September	South western coastal areas.

Source: Ahmed, 2006

Figure 4. Flood Prone Area by 1998 Flood Depth



Source: WARPO

number of floods inundated 37% of land occurred 5 times in last 30 years and 3 times in last 10 years. Similarly, flood that inundates 60% area suppose to occur once in every 50 years but in last 30 years such flood has occurred twice.

Cyclonic storm surge is another natural disaster that causes most direct and indirect damage. The Bay of Bengal is a known breeding ground of tropical cyclone which hits the coastal area of Bangladesh during pre-monsoon (April and May) and post-monsoon (October and November). One of the reasons why it hits Bangladesh coast often is the conical shape of the Bay of Bengal. Over the last 50 years, 15 severe cyclones with wind speed ranging from 140 to 225 km/hr have hit in the coastal area of Bangladesh of which 7 hit in pre-monsoon and rest in the post-monsoon season.

Table 5. Impacts of Major Floods in Last 50 Years

Event	Impact
1954 floods	Affected 55% of country
1974 flood	Moderately severe, over 2,000 deaths, affected 58% of country, followed by famine with over 30,000 deaths
1984 flood	Inundated 52,520 sq-km, cost estimated at US$378 million
1987 flood	inundated over 50,000 sq-km, estimated damage US$ 1.0 billion, 2055 deaths
1988 flood	Inundated 61% of country, estimated damage US$ 1.2 billion, more than 45 million homeless, between 2,000-6,500 deaths
1998 flood	1,100 deaths, inundated nearly 100,000 sq-km, rendered 30 million people homeless, damaged 500,000 homes, heavy loss to infrastructure, estimated damage US$ 2.8 billion
2004 flood	Inundation 38%, damage US$ 6.6 billion, deaths 700, affected people nearly 3.8 million
2007 flood	Inundated 32,000 sq. km, over 85,000 houses destroyed and almost 1 million damaged, approximately 1.2 million acres of crops destroyed or partially damaged, estimated damage over $1 billion, 649 deaths
2008 flood	Inundated 3,394 sq. km, fully damaged houses is 11,448, approximately 0.35 million acres of crops destroyed or partially damaged

Source: NAPA 2005, MOEF 2008, DMB, 2008 and Relief Web, 2008

Table 6. Inundated Area of Different Floods and Number of Occurrence in Last 30 Years

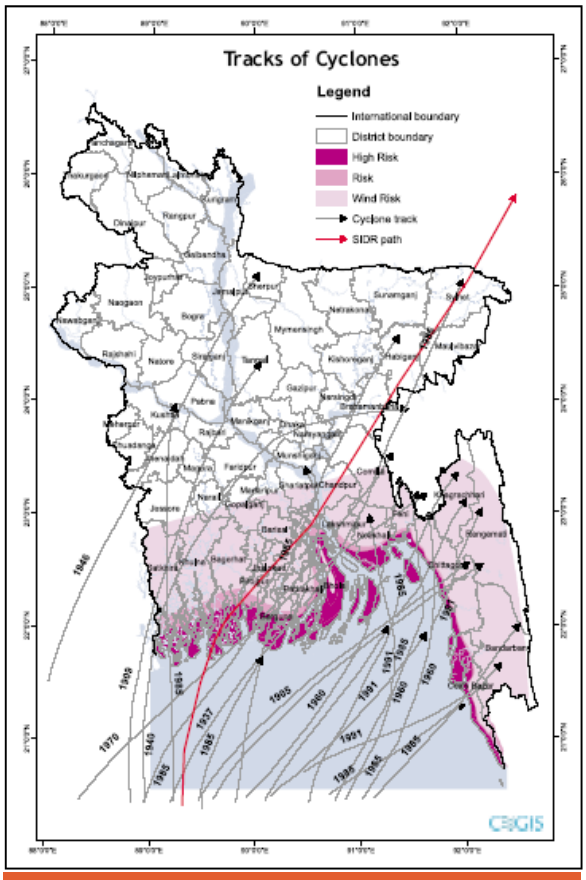
Flooded Area	Return period (Years)						
	2	5	10	20	25	50	100
Area affected %	20	30	37	43	52	60	70
Last 30 years			5	3	2	2	
Last 10 years			3	2	1	1	

Source: General Economic Division

Cyclones which struck in 1919, 1970, 1991 and 2007 considered as catastrophic. The tropical cyclones in 1970 and 1991 are estimated to have killed 500,000 and 140,000 people, respectively. Figure 5 shows historical path of cyclone struck Bangladesh.

From the scientific point of view, it is difficult to attribute a single tropical cyclonic event to climate change directly. However, the nature and intensity of Sidr cyclone in 2007 that crashed the Bangladesh coast is consistent with the projection and prediction of IPCC. Different models used by IPCC revealed that future tropical cyclones are likely (typhoons and hurricanes) will become more intense, with larger peak wind speeds and heavy precipitation associated with ongoing increases of tropical sea surface temperatures. Intensity with large peak wind speed of Sidr reported 226 kilometres per hour which can be linked with observational evidence as stated in the IPCC. It also suggested that intense tropical cyclonic activity has relation with increases of tropical sea surface temperatures. Over the last decade, the number of natural disaster has doubled globally and is again consistent with IPCC findings.

Figure 5. Historical Track of Cyclone



Bangladesh experiences major droughts once in 5 years. Droughts at local scale are much more frequent and affect part of the crop life cycle. The western part of the country is vulnerable to drought during pre-monsoon period.

In the last 50 years, Bangladesh suffered from 20 droughts. The drought condition in north-western Bangladesh led to a shortfall of rice production of 3.5 million tons in the 1990s. If other losses, such as, to other crops (all rabi crops, sugarcane, tobacco, wheat as well as to perennial agricultural resources, such as, bamboo, betel nut, fruits like litchi, mango, jackfruit, banana etc. are considered, the loss will be substantially much higher. Current Severe drought can affect yield in 30% of the country, reducing national production by 10%. Table 7 provides the exiting drought affected areas

Table 7. Area under Different Types of Drought Classes

Drought Class	Rabi	Pre-Kharif	Kharif
Very Severe	0.446	0.403	0.344
Severe	1.71	1.15	0.74
Moderate	2.95	4.76	3.17
Slight	4.21	4.09	2.90
No Drought	3.17	2.09	0.68
Non-T. Aman			4.71

Source: BARC

under different drought classes. Figure 6 and 7 depict spatial distribution of area under different drought classes in Rabi and Pre-kharif, and Khrif season respectively.

When a major disaster has stuck, the whole economy suffered. Agriculture suffered probably more than non-agricultural sectors. Yet, as Islam (1997) has found, even in such a situation floods cause much of the damage indirectly though the sectoral linkage effects.

Figure 6. Drought Prone Area in Rabi and Pre-Kharif Season

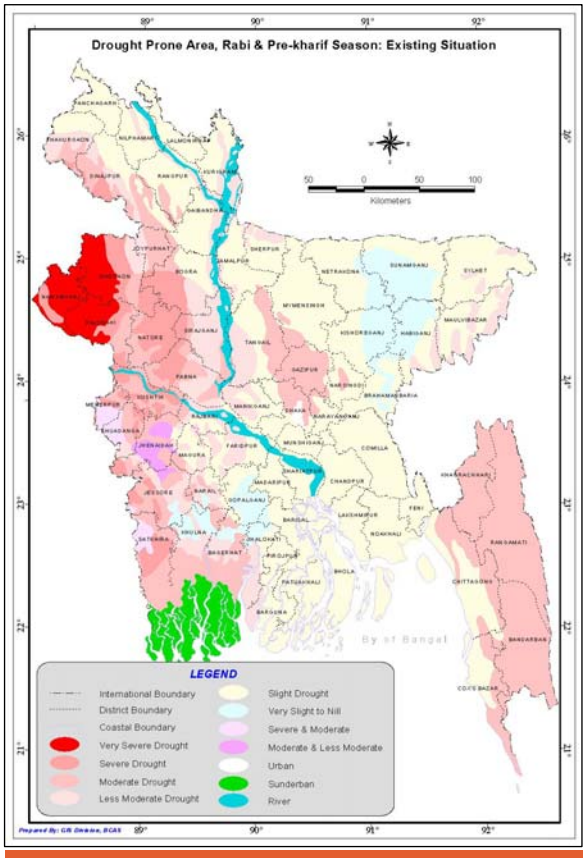
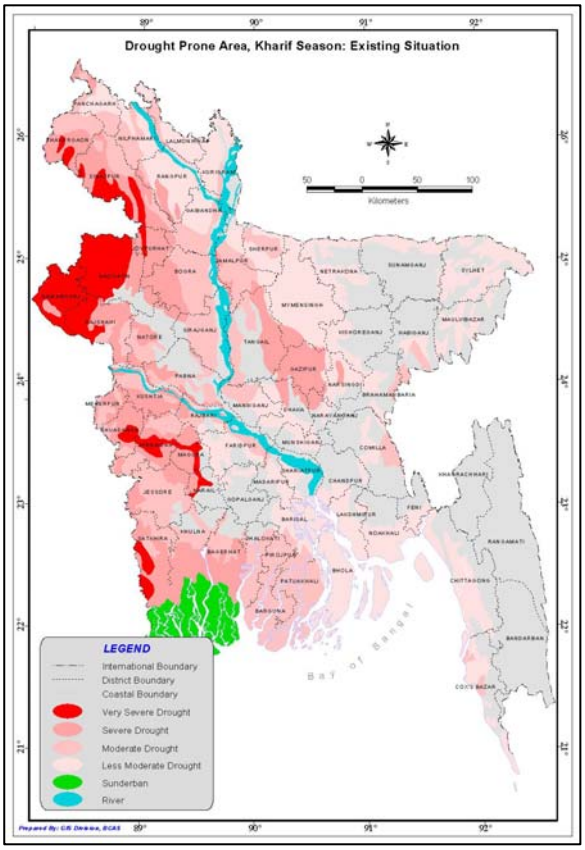


Figure 7. Drought Prone Area in Kharif Season



2.3 Adverse Effects of Climate Change and Variability on Biophysical and Key Sectors

Over the last decade several studies have been conducted on climate change impacts, vulnerability and adaptation assessments for Bangladesh using different climate change scenarios. Most of the studies focus on water, agriculture, biodiversity, human health, and infrastructure (BCAS et al., 1994; Huq et al., 1999; World Bank, 2000;

ADB, 1994; 2000, IUCN, 2004). Recently several studies have been conducted at sub-national/geographical sub-region scale as well as on different sectors giving special focus on coastal zone and agriculture sector (IWM and CEGIS, 2007; BCAS, 2007; CEGIS, 2006; CNRS, 2007). It is also to be noted that the second National Communication is in the process of preparation.

Most of the studies have assessed impacts of, and vulnerability and adaptation to climate change and sea level rise by sectors and geographic areas. The sectors include water, agriculture, infrastructure, forestry and health and geographical areas include coastal zone, Barind Tract, and floodplain and hilly region. It has been observed that the vulnerability of the country to climate change is the result of a complex interrelationship among biophysical, social, economic and technological characteristics. It is revealed that many anticipated adverse impacts of climate change including sea level rise, higher temperatures, enhanced monsoon precipitation and run-off, potentially reduced dry season precipitation, and an increase in cyclone intensity would in fact aggravate many of the existing stresses that already pose a serious impediment to the process of economic development of Bangladesh. The climate change policy, particularly adaptation thus becomes a part and parcel of the development policies of the country.

The adverse effects of climate change including variability and the extreme events on the overall development of Bangladesh are significant. Most of the adverse impacts are related to possible changes to be experienced in the water sector. It is also noted that most damaging effects of floods, cyclones, salinity intrusion, and droughts which affect crop productivity almost every year. Climate change induced challenges are: (a) scarcity of fresh water due to less rain and higher evapo-transpiration in the dry season (b) drainage congestion due to higher water levels in the confluence with the rise of sea level, (c) river bank erosion, (d) frequent floods and prolonged and widespread drought, (e) wider salinity in the surface, ground and soil in the coastal zone (WB, 2000). Table 8 provides strength of relationship of climate change and variability with physical vulnerability context.

Low level of economic development and corresponding low investment capacity, inadequate infrastructure, low level of social development, lack of institutional capacity, and a high dependency on the natural resource base make the country highly vulnerable to climate change (including both variability as well as extreme events). It was found that the population living in the coastal area are more vulnerable than the population in other areas (Alam and Laurel, 2005). The agricultural sector will face significant yield reduction. Thus food-grain self sufficiency will be at risk in future (BCAS/ RA/Approtec, 1994, and Alam, 2004).

The ultimate key impacts of climate change and variability will be on livelihoods of the peoples depending on natural resource base and services of other sectors including infrastructure and industries. For example, the changes in agriculture may lead to a fall in domestic production of food, fodder and fibber. What all of these mean is falling output, employment and incomes of the people may fall lowering their consumption that will lead to a rise in malnutrition and income poverty.

Table 8. Relationship of Climate Change and Variability with Physical Vulnerability Context

Climate Change					Climate Variability			
Increase average temperature	Increase average rainfall	Decrease average rainfall	Sea level rise	Erratic temperature (extreme heat or cold)	Erratic rainfall (excessive rainfall and lack of timely rainfall, untimely rainfall)	Erratic tidal Wave	Cyclone and storm surges	
								Physical Vulnerability Context
+	++		++		+	+	+	Inundation
+		++			+			Low Flow
			++			++	++	Salt Water Intrusion
	++				++			Flash Flood
++		+++		++	+			Drought
	+		++			++		River Morphology

Note: +++ refers to high, ++ refers to moderate, and + refers to low level of relationship

3 Climate Change Impacts, Adaptation and Vulnerability

3.1 An overview of Climate Variability and Change

The pattern and behaviour of climate and weather play a significant role in freshwater availability, agriculture, economic growth and performance, and livelihoods. Recent studies and the regional stakeholder consultation workshops have revealed that the erratic nature of rainfall and temperature has indeed increased (NAPA Regional Workshop reports 2005). Adverse effects of erratic nature of rainfall and temperature on agricultural productivity and availability of freshwater is already quite evident in many areas of Bangladesh.

3.1.1 Observed Changes

Observed data indicates that the temperature is generally increasing in the monsoon season (June, July and August). Average monsoon time maximum and minimum temperatures show an increasing trend annually at the rate of 0.05^{O}C and 0.03^{O}C, respectively. On the other hand average winter time (December, January and February) maximum and minimum temperatures show respectively a decreasing and an increasing trend annually at the rate of 0.001^{O}C and 0.016^{O}C (Rahman and Alam: 2003). It is also revealed that 1998 was the warmest year in the last 30 years.

SAARC Meteorological Research Centre (SMRC) has studied surface climatological data on monthly and annual mean maximum and minimum temperature, and monthly and annual rainfall for the period of 1961-90. The study showed an increasing trend of mean maximum and minimum temperature in some seasons and decreasing trend in some others. Overall the trend of the annual mean maximum temperature has shown a significant increase over the period of 1961-90.

Regional variations have been observed around the average trend (SMRC, 2003).

Observed data of the Rangpur Station from 1978 to 2002 indicates that overall annual maximum and minimum temperature is generally increasing annually at the rate of 0.035°C and 0.027°C, respectively. However, rate of change of maximum temperature in the monsoon season is slightly lower than annual rate of change. In monsoon season (June, July and August), average maximum temperature shows an increasing trend annually at the rate of 0.02°C while changes in minimum temperature in the monsoon season is insignificant. On the other hand average maximum temperature in winter season (December, January and February) shows an increasing trend annually at the rate of 0.041°C while minimum temperature shows an increasing trend annually at the rate of 0.026°C which reflects winter is also becoming warmer (Atiq *et al.*, 2007). Figure 8 and 9 depicts trend of annual average of maximum and minimum temperature of Rangpur station.

Observed rainfall data revealed that there is no significant change in annual rainfall. However, analysis shows that days without rainfall is showing increasing trend, for example, Bogra and Rangpur station. Figure 10 shows trend of annual rainfall and number of days without rainfall of Rangpur station.

There is a clear evidence of increased salt water intrusion in the coastal zone. For example, in the coastal city of Khulna the main power station needs to collect freshwater to cool its boilers by sending a barge upstream to get freshwater. Over the last one, decade the barge has to go further and further upstream to get suitably freshwater for the purpose. While there are other factors behind the salinity intrusion (such as the withdrawal of water at Farakka

Figure 8. Trend of Annual Average of Maximum Temperature of Rangpur Station

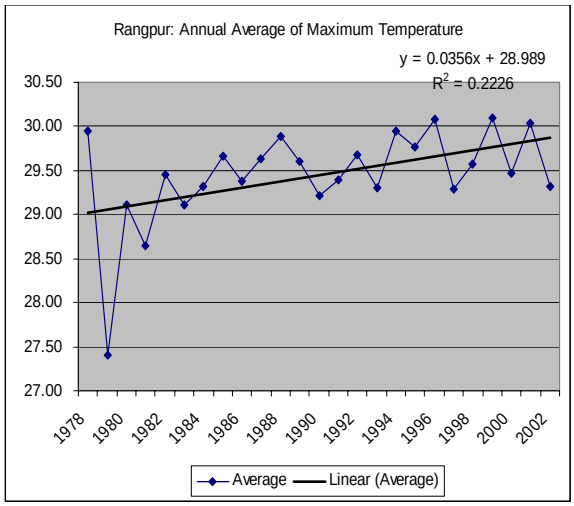


Figure 9. Trend of Annual Average of Minimum Temperature of Rangpur Station

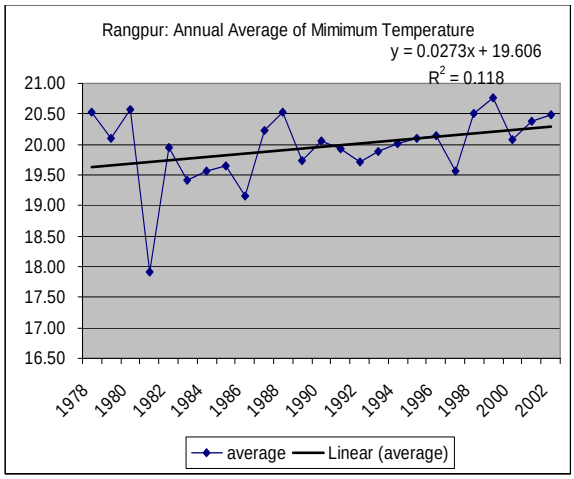
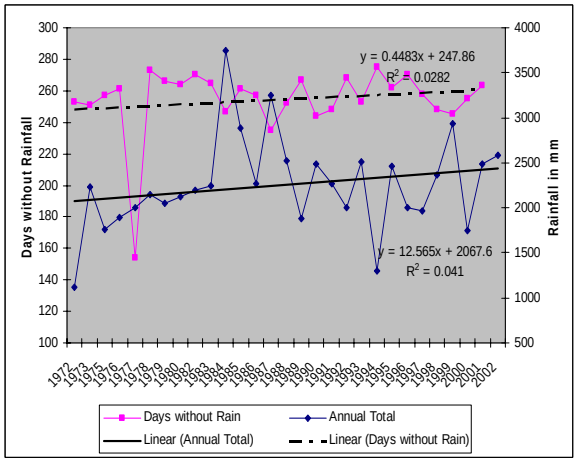


Figure 10. Trend of Annual Rainfall and Number of Days without Rainfall of Rangpur Station



by India to divert water flows to Calcutta), the trend towards salinization in the coastal zone is very clear.

Causes of changes in coastal morphology are complex. Sea level rise is an additional issues and therefore impacts of sea level rise on coastal morphological formation need to be incorporated as one of the dynamic functions. The coastal area of Bangladesh is very dynamic, and landmass is still growing by gradual deposition of sediment. The average sediment accumulation rate for the last few hundred years in the coastal areas is 5-6 mm a year. Against a sea level rises of 4-7 mm/year, it may appears that the changes in coastal area matched by an equivalent accretion-albeit at different points along the coast. But significant implication of the sea level rise is losing the productive land which has formed over time and newly accredited land needs additional time to become productive.

It is revealed in a study carried out by SAARC Meteorological Research Council (SMRC) that there has been a significant increasing trend in the cyclone frequency over the Bay of Bengal during November and May which are main months for cyclone in the Bay of Bengal (SMRC, 2003).

The SAARC Meteorological Research Council (SMRC) carried out a study on recent relative sea level rise in the Bangladesh coast (SMRC 2003). The study has used 22 years historical tidal data at three coastal stations. The study shows that the rate of sea level rise during the last 22 years is many (4.0 mm/year at Hiron Point, 6.0 mm/year at Char Changa and 7.0 mm/year at Cox's Bazar) times higher than the mean rate of global sea level rise over the last 100 years. It must be pointed out, however, that the rise in sea level includes regional tectonic subsidence. Variation among the stations was also found. Table 9 represents the trend of tidal level in three coastal stations

3.1.2 Future Scenarios

Future changes of temperature and rainfall are estimated for Bangladesh using two general approaches i.e. (a) projection based on observed data, and (b) using available climate model. It is to be noted that projection based on observed data had no scope to incorporate future concentration of CO_2 in the atmosphere under different emission scenarios. Therefore, model based results are being used for assessing vulnerability of different sectors.

Earlier vulnerability and adaptation assessment studies carried in Bangladesh have used both older and newer versions of General Circulation Models. However, there are new climate change scenarios available from PRECIS and impacts assessment based on IPCC new projection especially impacts of sea level rise in the coastal area. Details on model outputs are given in Box 1. Table 10 shows summary of future climate change scenario of Bangladesh.

Table 9. Trend of Tide in Three Coastal Stations

Tidal Station	Region	Latitude (N)	Longitude (E)	Datum (m)	Trend (mm/year)
Hiron Point	Western	21°48'	89°28'	3.784	4.0
Char Changa	Central	22°08'	91°06'	4.996	6.0
Cox's Bazar	Eastern	21°26'	91°59'	4.836	7.8

Source: SMRC, No. 3

Box 1. Knowledge Base on Climate Change Scenario Building in Bangladesh

General Circulation Model (GCM) used by the US Climate Change Study team for Bangladesh reported that the average increase in temperature would be 1.3°C and 2.6°C for the years 2030 and 2070, respectively. It was found that there would be a seasonal variation in changed temperature: 1.4° C change in the winter and 0.7°C in the monsoon months in 2030. For 2070 the variation would be 2.1°C and 1.7°C for winter and monsoon, respectively. For precipitation it was found that the winter precipitation would decrease to a negligible rate in 2030, while in 2075 there would not be any appreciable rainfall in winter at all. On the other hand, monsoon precipitation would increase at a rate of 12 % and 27 % for the two projection years, respectively (Ahmed et, al., 1999).

It was found that there would be excessive rainfall in the monsoon causing flooding and very little to no rainfall in the winter forcing drought. It was also found that there would be drastic changes in evaporation in both winter and monsoon seasons in the projection for year 2075. It was inferred from the GCM output that moderate changes regarding climate parameters would take place by 2030, while severe changes would occur by 2075.

The results also reveal a trend of a general increasing temperature. In 2030, the increase is much more pronounced in winter months, although the maximum change is observed for post-winter months, i.e., April, May and June. However, in 2075, the increase in temperature during April and May is much higher; about 4.0^{O}C (Ahmed et, al., 1999).

OECD has recently carried out 17 General Circulation Models for Bangladesh in order to assess changes in average temperature and precipitation using a new version of MAGICC/SCENGEN. It has selected 11 out of the 17 models which best simulate current climate over Bangladesh. The models were run with the Intergovernmental Panel on Climate Change (IPCC) B2 scenario of Special Report on Emission Scenario (SRES) (Agarwala et, al., 2003).

The climate models all estimate a steady increase in temperatures for Bangladesh, with little inter-model variance. Somewhat more warming is estimated for winter than for summer. With regard to precipitation - whether there is an increase or decrease under climate change is a critical factor in estimating how climate change will affect Bangladesh, given the country's extreme vulnerability to water related disasters. The key is what happens during the monsoon? Most of the climate models estimate that precipitation will increase during the summer monsoon because air over land will warm more than air over oceans in the summer. This will deepen the low pressure system over land that happens anyway in the summer and will enhance the monsoon. It is notable that the estimated increase in summer precipitation appears to be significant; it is larger than the standard deviation across models. This does not mean that increased monsoon is certain, but increases confidence that it is likely to happen. The climate models also tend to show small decreases in the winter months of December through February. The increase is not statistically significant, and winter precipitation is just over 1% of annual precipitation. However, with higher temperatures increasing evapo-transpiration combined with a small decrease in precipitation, dry winter conditions, even drought, are likely to be made worse (Agarwala et, al., 2003).

The PREICS model result shows that temperature (maximum and minimum) and rainfall vary over space and time. Value of some months is much higher than the season or annual average. Annual average of maximum temperature show an increasing trend but shows that increase over time will decline while minimum temperature shows gradual increase over time. Projection shows that rainfall in monsoon and post-monsoon seasons will increase while rainfall in the dry season will remain closer to historical amount. Rainfall in pre-monsoon shows erratic nature. It predicts that rainfall will increase about 4, 2.3 and 6.7 percent in 2030, 2050 and 2070, respectively in reference to the observed baseline period 1961-1990 (BUET, 2008).

Table 10. Future Climate Scenarios used for Preparation of NAPA for Bangladesh

Model	Year	Temperature change (°C) Mean (standard deviation)			Precipitation change (%) Mean (standard deviation)			Sea Level Rise (cm)
		Annual	DJF	JJA	Annual	DJF	JJA	
GCM	2030	1.0	1.1	0.8	5	- 2	6	14
PRECIS	2030 (Max)	0.3	-0.02	1.3*	4	-8.7	3.8	
	2030 (Min)	1.18	0.65	1.78*				
GCM	2050	1.4	1.6	1.1	6	- 5	8	32
PRECIS	2050 (Max)	0.2	0.07	0.89*	2.3	-4.7	3.0	
	2050 (Min)	1.24	0.59	1.65*				

Source: MoEF, 2005, BUET, 2008, Note: * JJAS

This updated National Adaptation Programme of Action for Bangladesh has complied future impacts, vulnerability and adaptation based on existing model outputs and several assessments.

3.2 Actual and Potential Adverse Effects of Climate Change

3.2.1 Present Impact of Climate Variability and Extreme

Most damaging effects of erratic behaviour of present climate and extreme events are flood, drought, cyclone and storm surges that are found to drastically adversely affect crop productivity in almost every year. About 1.32 m ha of cropland is highly flood-prone and about 5.05 m ha moderately flood-prone. Besides crops, perennial trees and livestock are damaged by flood every year. In two severe flood years of 1974 and 1987, the shortfalls in production from trend were about 0.8 and 1.0 Mmt of rice, respectively. During 1984, flood affected both Aus and Aman rice crop and the shortfall was about 0.4 Mmt.

Drought of different intensities in Kharif, Rabi and pre-Kharif seasons cause damage to 2.32 m ha of T. Aman and 1.20 m ha of Rabi crops annually. Yield reductions due to drought vary from 45-60% in T. Aman and 50-70% in Rabi crops in very severe drought situation. In the severe drought year of 1979, the shortfall was about 0.7 million tons. During 1981 and 1982, droughts affected the production of monsoon crop (Aman) and the shortfalls from the trend were 0.5 and 0.3 Mmt, respectively.

3.2.2 Potential Future Vulnerability

Over the last decades, a number of studies have been carried out on impacts, vulnerability and adaptation assessment for Bangladesh to climate change and sea level rise. Regional stakeholder consultation workshops have identified vulnerability of different sectors in the context of climate variability and change.

Most of the future vulnerability due to climate change will not necessarily add any new climate related hazards to the already well known ones such as floods, droughts and cyclones. But it will enhance both the frequency as well as intensity of such climatic events in future. Particularly, the areas prone to the floods, cyclones and salinity intrusion will face aggravated impacts in future. The climate related hazards will in turn be compounded by other factors including land use patterns, water management and control of river flows upstream. Some of the specific impacts and vulnerabilities on sectors and areas due to climate change are described below.

3.2.2.1 Water Resources

Water related impacts due to climate change and sea level rise are likely to be the most critical issues for Bangladesh, especially in relation to coastal and riverine flooding, and winter (dry season) drought in certain areas. The effects of increased flooding resulting from climate change will be the greatest problem faced by Bangladesh as both coastal (from sea and river water), and inland flooding (river/rain water) are expected to increase. In addition, changes of the riverbed level due to sedimentation and changes in morphological processes due to seasonal variation of water level and flow are also critical for Bangladesh.

Sedimentation and River Bed Rise

The process of sedimentation may rise as water level gradients due to higher downstream water levels at sea resulting in lower flow velocities. The morphologically highly dynamic rivers in Bangladesh are expected to adapt to such changes in water levels over a period of time of several decades. The changes in bed levels in turn will cause additional changes in river levels, which effect will propagate the impact of sea level rise in upstream direction. The first assessments of this effect in the study for the Jamuna Bridge showed the importance of this feed back mechanism (Rendel et al., 1990).

Forecasts show that at the bifurcations of the Jamuna river with its distributaries Dhaleswari river and Old Brahmaputra river, the bed level will rise 0.08, 0.12 and 0.41 m at the mouth of the Dhaleswari river and 0.05, 0.08 and 0.27 m at the mouth of the Old Brahmaputra river for the years 2015, 2025 and 2095 respectively (BCAS/ RA/Approtech, 1994). This will probably result in a considerable increase in the discharges in the distributaries and a small decrease of the discharges in the Jamuna and Padma rivers. The discharge distribution at the tributaries of the Ganges and the Padma rivers (Gorai and Arial Khan rivers) will change also due to the considered sedimentation. These changes might be of important consequences for the course of the main river channels in Bangladesh.

Change of Land Type

Bangladesh Climate Change Country Study in 1997 (Huq *et al.*, 1999) assessed vulnerability of water resources considering changes in flooding conditions due to a combination of increased discharge of river water during monsoon period and sea level rise for the two projection years, 2030 and 2075.

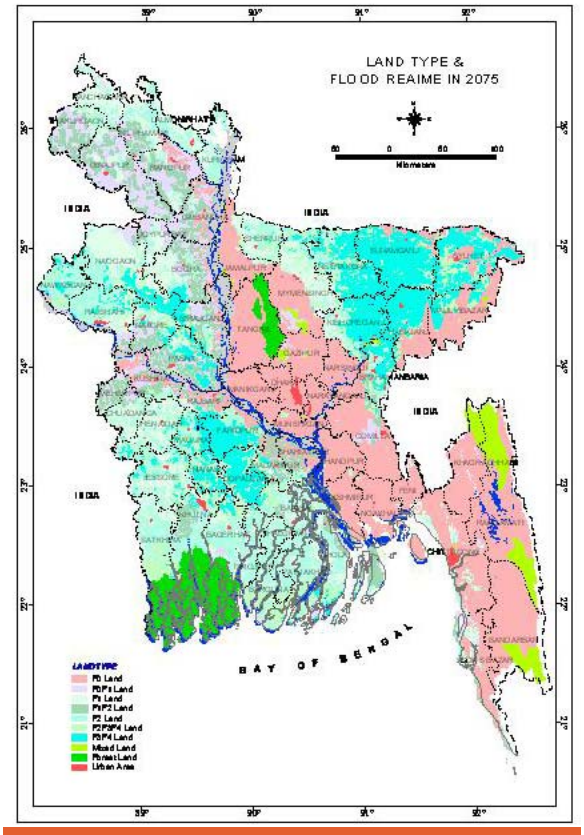
From the analysis it is found that much of the impact would be for F_0 land followed by F_1 land in the year 2075 where embankment played an important role in restricting the extent of flood affected areas. Again, it is the F_0 land followed by F_1 land in 2030 which would experience much of the changes in he north-central region in 2030. A combination of development and climate change scenarios revealed that the Lower Ganges and the

Table 11. Changes in Land Type Flooding Regime

Land Type	Study Area	Transformed in 2030			
		F0	F1	F2	F3F4
F0	43,060	**23,415**	16,033	3,442	170
F0 + F1[1]	1,184	592	592		
F1	31,986	4,399	**9,519**	17,672	396
F1 + F2[2]	260		130	130	
F2	15,572	2,440	162	**7,903**	5,067
F2 + F3 + F4[3]	362			127	235
F3F4	14,076	2,080	9	155	**11,836**
Urban area[4]	757	757			
River bank/sand bar etc.	1,539				
Forest	5,546				
Mixed land	178				
No data	647				
Total	**115,167**	**33,683**	**26,445**	**29,429**	**17,700**

Surma floodplain would become more vulnerable compared to the rest of the study area. On the other hand, the north-central region would become flood free due to embanking of the major rivers (Alam, et al., 1999). Table 11 shows changes in land type and flood regime in 2030 and Figure 11 shows spatial distribution of land type and flood regime in 2075.

Figure 11. Flood Regime and Land Type in 2075



3.2.2.2 Coastal Zone

Several studies indicate that the coastal zone vulnerability would be acute due to the combined effects of climate change, sea level rise, subsidence, and changes of upstream river discharge, cyclone and coastal embankments (BCAS/RA/ Approtech, 1994, WB, 2000). Four key types of primary physical effects i.e. saline water intrusion; drainage congestion; extreme events; and changes in coastal morphology have been identified as key vulnerabilities in the coastal area of Bangladesh (WB, 2000). A relationship between agents of change and primary physical effects in the coastal zone of Bangladesh is given in Table 12.

- The effect of saline water intrusion in the estuaries and into the groundwater would be enhanced by low river flow, sea level rise and subsidence. Pressure of the growing population and rising demand due to economic development will further reduce relative availability of fresh water supply in future. The adverse effects of saline water

Table 12. Relation between agents of change and primary physical effects in the coastal zone of Bangladesh.

Primary Physical Effects / Agents of Change		Salt-water Intrusion	Drainage Congestion	Coastal Morphology	Cyclone and Storm Surges
Climate change (temperature, precipitation, evapo-transpiration)		+	+	-	+++
Changes of upstream river discharge	Peak	-	++	+++	-
	Low	+++	-	-	-
Sea level rise		+++	+++	++	++
Subsidence		++	++	++	++

Source: Rahman and Alam, 2003

intrusion will be significant on coastal agriculture and the availability of fresh water for public and industrial water supply will fall.

- The combined effect of higher sea water levels, subsidence, siltation of estuary branches, higher riverbed levels and reduced sedimentation in flood-protected areas will impede drainage and gradually increase water logging problems. This effect will be particularly strong in the coastal zone. The problem will be aggravated by the continuous development of infrastructure (e.g. roads) reducing further the limited natural drainage capacity in the delta. Increased periods of inundation may hamper agricultural productivity, and will also threaten human health by increasing the potential for water borne disease.

- Disturbance of coastal morphological processes would become a significant problem under warmer climate change regime. Bangladesh' coastal morphological processes are extremely dynamic, partly because of the tidal and seasonal variations in river flows and run off. Climate change is expected to increase these variations, with two main (related) processes involved:

  - Increased bank erosion and bed level changes of coastal rivers and estuaries. There will be a substantial increase of morphological activity with increased river flow, implying that riverbank erosion might substantially increase in the future.

  - Disturbance of the balance between river sediment transport and deposition in rivers, flood plains and coastal areas. Disturbance of the sedimentation balance will result in higher bed levels of rivers and coastal areas, which in turn will lead to higher water levels.

- Increased intensity of extreme events. The coastal area of Bangladesh and the Bay of Bengal are located at the tip of northern Indian Ocean, which has the shape of an inverted funnel. The area is frequently hit by severe cyclonic storms, generating long wave tidal surges which are aggravated because the Bay itself is quite shallow. Cyclones and storm urges are expected to become more intense with climate change. Though the country is relatively well equipped particularly in managing the aftermath of cyclones, the increased intensity of such disasters implies major constraints to the country's social and economic development. Unless proper adaptive measures are undertaken, private sector

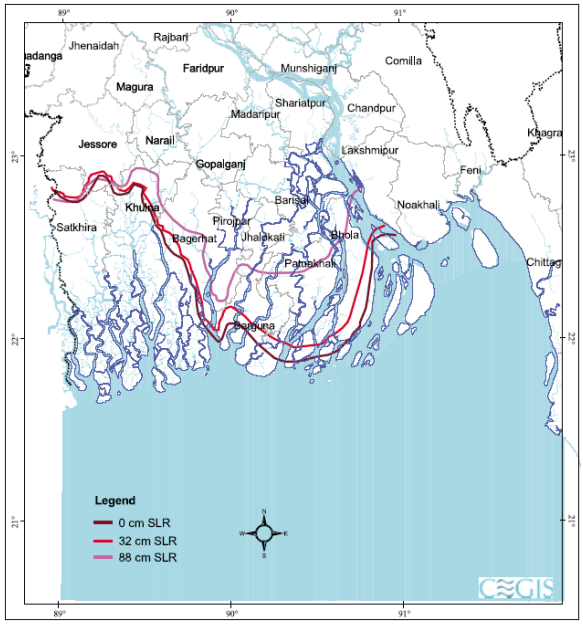
investment in the coastal zone is likely to be discouraged by the increased risks of cyclones and flooding.

Salinity intrusion in surface water is highly seasonal in Bangladesh. Salinity and its seasonal variation are dominant factors for coastal eco-system, fisheries and agriculture. Therefore, any changes in present spatial and temporal variation of salinity will affect the biophysical system of coastal area.

Distribution of salinity level and landward intrusion in the rivers and surface water for the year 2005 found that in monsoon (June to September), the saline water is fully flushed out of the Meghna Estuary, but in the western part of the lower delta it is still saline due to scarcity of freshwater flow from upstream. It is found that 5 ppt isohaline (line of equal salinity level) intrude more than 70 km landward in the western part of Sundarbans, through the lean flowing Jamuna-Malancha-Raimangal river system, whereas comparatively higher freshwater flow through Pussur-Sibsa river system pushes the 5 ppt saline front more downward and keeps it at the estuary mouth. Similarly, the Baleswar-Bishkhali river systems with higher monsoonal freshwater flow from the Padma-Lower Meghna, keeps this south central region almost saline free during monsoon. During dry season (December to March) deep landward intrusion occurs through various inlets in the western part of coastal zone and through Meghna Estuary.

From the analysis it is found that the area under salinity level of 5 ppt under the Business as Usual scenario is increasing. The 5 ppt line move from lower tip of Sundarbans to the point of lower Meghna river at Chandpur by he year 2100 under an assumed SLR of 88 cm. The salinity front will move about 60 km to the north in about 100 years. The SLR will increase the

Figure 12. Impact on Salinity, Intrusion of 5 ppt Salinity Line for Different Sea Level Rise



Source: CEGIS

salinity level in the Tentulia River which at present the only freshwater pocket in the estuary. Figure 12 shows the changes of salinity front under different levels of sea level rise.

A recent analysis showed that salinity will intrude more landward specially during dry season due to sea level rise. Consequently brackish water area would increase. It is seen that sea level rise of 27 cm causes 6% increase of brackish water area compared to base condition. About an additional area of 327,700 ha would become high saline water zone (>5 ppt) during dry season due to 60 cm sea level rise. In the monsoon, about 6% of sweet water area (276,700 ha) will be lost. Impact of 15cm sea level rise on salinity intrusion under low emission scenario B1 in the year 2080 is insignificant. Table 13 provides changes in fresh and brackish water area in the dry and monsoon seasons.

Due to backwater effect, the water levels around the polders are also likely to be affected. A hydrodynamic model shows that high water levels at the surrounding rivers of polders may increases in the range

Table 13. Changes in Fresh and Brackish Water Area [Ha] in Dry and Monsoon

Scenario	Dry Season			Monsoon Season		
	Fresh water area (<1 ppt)	Brackish water area (>1 ppt)	Change	Fresh water area (<1 ppt)	Brackish water area (>1 ppt)	Change
Base (2005)	2,562,500	2,152,000		3,779,600	9,403	
A2, 27cm [2050]	2,273,300	2441200		3,665,400	10,508	114200
A2, 62cm [2080]	2,135,700	2,578,800	426800	3,502,800	12,111	276,700

of 30 to 80 cm for sea level rise in the range of 32 to 88 cm. This rise will eventually hamper the proper functioning of a number of polders.

3.2.2.3 Crop Agriculture and Food Security

Agricultural crop of Bangladesh is influenced by seasonal characteristics and different variables of climate such as temperature, rainfall, humidity, day-length etc. It is also often constrained by different disasters such as floods, droughts, soil and water salinity, cyclone and storm surges. Several studies indicate that climate is changing and becoming more unpredictable every year in Bangladesh. There is a strong possibility that moisture content of the topsoil in the north-western region would decrease substantially resulting from decrease in winter precipitation and higher evapo-transpiration.

Degradation of productive land including quality and physical loss are key concerns for coastal agriculture due to salinity intrusion and sea level rise. Drainage congestion and water logging is very likely in the coastal region as a result of combined effect of higher sea water levels, subsidence, sedimentation of estuary branches, higher riverbed levels and reduced sedimentation in flood-protected areas.

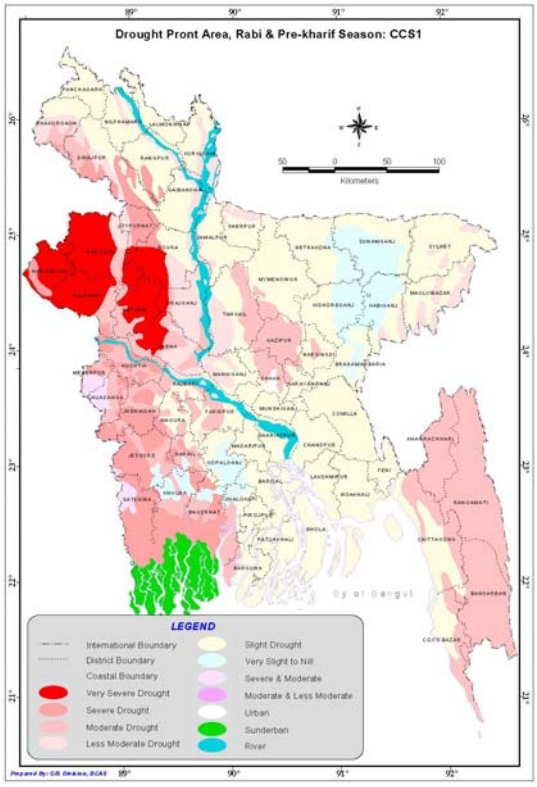
The higher temperatures and changing rainfall patterns coupled with increased flooding, rising salinity in the coastal belt, droughts in the northwest and southwest, and drainage congestions are likely to reduce crop yields and crop production. Decision Support System for Agro-Technology Transfer (DSSAT) model result shows that yield reduction will vary by types of crops and their growing season. IPCC estimates that, by 2050, rice production in Bangladesh could decline by 8 percent and wheat by 32 percent.

Studies indicate that a rise of 1 to 2^0 C in combination with lower solar radiation causes sterility in rice spikelets. High temperature was found to reduce yields of HYVs of *aus*, *aman* and *boro* rice in all study locations and in all seasons. The effect was particularly evident at a rise of temperature by 4^0C. Climate changes, especially in temperature, humidity and radiation, have great effects on the incidence of insect pests, diseases and microorganisms. A change of 1^0C temperature would changes the virulence of some races of rust infecting wheat.

The production of crop in Bangladesh is constrained by too much water during the wet season and too little during the dry season. Presently total irrigated area is 4.4 million ha which is more than 50 % of the potentially irrigable area of 7.12 million ha cultivated area. This area is being irrigated through surface and ground water resource.

Irrigation coverage through Shallow tubewells (STWs) during the dry period has grown very fast following a policy of privatization and deregulation. As a result, the groundwater table in Bangladesh is declining at a rapid rate causing STWs non-operating in many parts of the country during dry period. Lack of surface water during the dry season limits the function of Low Lift Pumps. A simulation study conducted under the climate change country study assessed the vulnerability of foodgrain production due to climate change in Bangladesh. Two general circulation models were used for development of climate scenarios. The experiments considered impact on three high yielding rice varieties and a high yielding wheat variety. Sensitivity to changes in temperature, moisture regime and carbon dioxide fertilization was analyzed against the baseline climate condition.

Figure 13. Drought Impacted Area in 2030



The GFDL model predicted about 17 % decline in overall rice production and as high as 61 per cent decline in wheat production compared to the baseline situation by 2100. The highest impact would be on wheat followed by rice (*aus* variety). This translates to a reduction of 4.5 million tons of rice at the present level (2002) of production. Of the three varieties of rice grown in Bangladesh, the *aus* rice (grown during the summer, monsoon period under rain-fed conditions) seems to be the most vulnerable. The other model, Canadian Climate Change Model (CCCM) predicted a significant fall in food-grain production. It should be noted, however, that this scenario was based on projecting existing cropping patterns into the future-which is not necessarily what will happen, as there are signs of significant changes in cropping patterns already occurring.

It was noticed that temperature increase of 4^{o}C would have severe impact on food-grain production, especially for wheat production. On the other hand, carbon-dioxide fertilization would facilitate food-grain production. A rise in temperature would cause significant decrease in production, some 28 % and 68 % for rice and wheat, respectively. Moreover, doubling of atmospheric concentration of CO_2 in combination with a similar rise in temperature would result into an overall 20 % rise in rice production and 31 % decline in wheat production. It was found that *boro* rice would enjoy good harvest under severe climate change scenario with doubling of atmospheric concentration of CO_2 (Karim et al., 1999).

The apparent increase in yield of boro (dry season rice crop generally grown under irrigated conditions and includes high yielding varieties) and other crops might be constrained by moisture stress. A 60 % moisture stress on top of other effects might cause as high as 32 % decline in boro yield, instead of having an overall 20 % net increase. It is feared that moisture

stress would be more intense during the dry season, which might force the Bangladeshi farmers to reduce the area for boro cultivation. Shortfall in foodgrain production would severely threaten food security of the poverty-ridden country.

Under a severe (4^{o}C temperature rise) climate change scenario, the potential shortfall in rice production could exceed 30 % from the trend, while that for wheat and potato could be as high as 50 % and 70 %, respectively (Karim, 1996). Under a moderate climate change scenario the crop loss due to salinity intrusion could be about 0.2 Mt (Habibullah et al., 1998). The loss of production due to such effects may be relatively higher compared to that under floods. However, the loss incurred in other sectors could be much higher in case of floods than the direct climatic changes.. The effect of low-flow on agricultural vulnerability is considered to be much less intense compared to other effects. The ultimate impacts of loss of food grain production would increase import of food which will require spending hard currency).

3.2.2.4 Fisheries and Livestock

There is limited quantitative assessment of impacts of climate change on fisheries but it is anticipated that aquaculture will be affected adversely due to increased flooding and lack of availability of water in the dry season. While production may increase in open water fisheries as a result of monsoon flood. Therefore, total production of freshwater fishes may remain same. It is also expected that composition of coastal fisheries may change overtime as a result of coastal inundation and salinity intrusion. It appears that the impacts on fisheries would not be remarkable in national level rather it would affect investment at individual level.

Fisheries sector will face the similar types of present problem related to climate change including variability and extreme. Key difference will be frequency, intensity and scale of the problem. Similar to the present situation, flood will have both positive and negative impacts in future. Flood will affect aquaculture infrastructure, pond siltation, habitat of fish breeding at larger scale while increased area under inundation and long duration is likely to increase open water fisheries. Drought will affect fish growth, breeding & production, increase disease vulnerability, reduce fishing season and reduce broods of natural small indigenous species of fish. Probable impacts of cyclone are almost similar to existing impacts but severity will be increased which will affect poverty at wider scale. Salinity intrusion and erratic rainfall will also affect fish production.

It is also anticipated that livestock will face fodder crisis in the coastal and heat related stress in the north-west region of the country. Death and production of livestock will decrease considerably with increasing intensity and frequency of shocks such as cyclone and storm surges. These will lead to decrease health status affecting meat and milk production.

3.2.2.5 Forestry and Biodiversity

Bangladesh is endowed with a number of natural forest ecosystems including inland Sal forest (*Shorea Robusta*), dipterocarp forest, savanna, bamboo bushes in the hilly regions and freshwater swamp forests. It also has littoral mangrove ecosystems and swamp forests. In addition to the forests, the country also has a very rich aquatic biodiversity (with over 400 species) and bird and plant life. The biodiversity (including both in the forested areas as well as elsewhere) is undergoing threats due to human interventions and fragmenting of habitats, etc. Climate change impacts will add an extra dimension to these ongoing stresses.

Bangladesh Climate Change Country Study has made an attempt to qualitatively analyze the impact of climate change on forest resources of Bangladesh. It was found that increased rainfall during the monsoon would cause increased runoff in forest floor instead of infiltration into the soil. As a result there would be enhanced soil erosion from the forest floor. The erosion problem would be more pronounced in poorly dense hill forest areas. Prolonged floods would severely affect growth of many timber species, while it would cause high incidence of mortality for Artocarpus species. In contrast, enhanced evapo-transpiration in winter would cause increased moisture stress, especially in the Barind and Madhupur Tract areas, affecting the Sal forest ecosystem. The tea plantations in the north-east would also suffer due to moisture stress. It was found that the Sundarbans mangrove forest would be the most severely affected by climate change. Due to a combination of high evapo-transpiration and low-flow in winter, the salinity of the soil would increase. As a result the growth of freshwater loving species would be severely affected. Eventually the species offering dense canopy cover would be replaced by non-woody shrubs and bushes, while the overall forest productivity would decline significantly. The degradation of forest quality might cause a gradual depletion of rich diversity of the forest flora and fauna of the Sundarbans ecosystem (Ahmad et al., 1999).

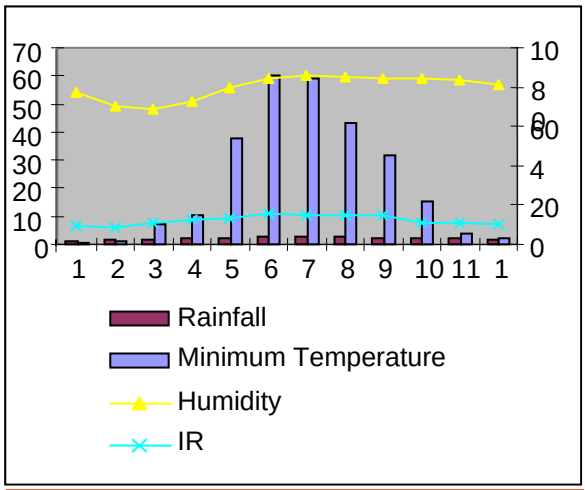
3.2.2.6 Human Health

According to IPCC (2001), the global warming would increase the vector borne and water borne diseases in the tropics. Best-estimate climate change scenario indicates that the incidences of dengue may increase. The increasing trend and variation of dengue occurrences are consistent with the corresponding trend and variation of temperature, which infers that the anticipated future warming in Bangladesh might increase the dengue occurrence.

A case study in Chittagong Hill Tracts found positive correlations between monthly incidence of malaria and monthly mean maximum and minimum temperatures and monthly total rainfall. The correlation coefficient for the association between monthly mean minimum temperature and monthly incidence of malaria is greater than that for the association between monthly mean maximum temperature and the incidence. This indicates that minimum temperature seems to play a more important role in the transmission of the disease than maximum temperature does. The results of a similar study conducted in Shuchen Country, China suggests that monthly minimum and maximum temperature and rainfall are the main significant climatic factor.

High summer temperatures could result in enhanced deaths due to heat stress, but the extent of such impacts have not been quantitatively assessed yet. However, the combination of higher temperatures and potential increases in summer precipitation could create favourable conditions for greater intensity or spread of many

Figure 14. Relationship with Climatic variables and Malaria Incidence Rate



infectious diseases. Still, the perceived risk to human health is low relative to those in other sectors (such as water resources) mainly because of the higher uncertainty about many of the possible health outcomes. Increased risk to human health from increased flooding and cyclones seem most likely. Changes in infectious disease are less certain as the causes of outbreaks of infectious disease are quite complex and often do not have a simple relationship with increasing temperature or change in precipitation.

ICDDR,B has done a number of studies on Climate Change and its impact on health mainly on Waterborne diseases in particular cholera. It has been clearly demonstrated in that climatic factors influence the cholera epidemics in Bangladesh. It has been found that the temperature and sunshine are the main contributing factors for maintaining the seasonality of cholera in Bangladesh (Islam MS, et al, 2009).

In another study based on cholera case data (1989-2006) collected from Matlab hospital, Chandpur revealed tendency to shift maximum cholera incidence from the month of October to November during fall outbreak. Significant 2- month lagged autocorrelation coefficient indicted that cholera gave short-term immunity to the population.

Cholera prediction model was developed based on eighteen years monthly record of cholera occurrence and local climatic variables of Matlab. The model explained 68% variability of the monthly cholera record. Temporal and conjugate effects of temperature, rainfall, sunshine hour and humidity were identified from the model. Study revealed a positive association of temperature, sunshine hour, humidity and tidal height with the incidence of cholera occurrence in the cholera epidemic region. Rainfall and tidal height contributed positively to the increased incidence of cholera after two and three month respectively. Cholera pattern itself explained 58% of its transmission dynamics.

Implications of climate change to future urban and rural water supply could be manifold. First, in summer, increased urban temperatures may increase the demand for water for drinking and bathing. Second, increased temperature may increase the demand for industrial cooling water. These increased demands may aggravate the current conflict between domestic and industrial water supplies in the urban areas.

Climate change induced low flow and high evaporation will reduce availability of surface water in the water bodies including rivers, artesian wells and ponds -- and thereby accentuate the prevailing crisis of drinking water in the dry season. Ponds that are used in rural areas for bathing (by people and for livestock) may dry up even more quickly. The ponds connected to Pond Sand Filter (PSF) for drinking water may also dry up. Shortage of water in the standing water bodies will also generate pressure on hand tubewells (HTWs) and other drinking water sources. More than 90% of the drinking water source in Bangladesh is groundwater. The higher abstraction of groundwater will deplete further the groundwater table as they may not be fully replenished.

If droughts escalate, domestic water supply in rural areas will suffer, and current conflict with irrigation water supply will worsen. For agricultural purpose people will abstract groundwater even more – further lowering the groundwater in many areas. One such critical area would be the Barind Tracts in the North-West region. Again if the farmers depend on increased number of agricultural shallow tubewells,

the rate of groundwater abstraction from the shallow water tables will be much higher and might lead to increased arsenic contamination of ground water.

Sea level rise contribute salinity intrusion to the land area cause saline water contamination to the sweet surface water as well as to the groundwater. Presently the surface and shallow groundwater in the coastal zone is saline. In some areas fresh water is available in deeper aquifer were expensive deep tubewell is used. In some areas the deeper aquifer is also saline and people are facing serious problem. They sometimes have to travel several kilometres to fetch drinking water. In these areas alternative technologies such as rain water harvesting are used but with limited success. Due to climate change the saline water boundary will be pushed inland and vast areas will face severe water crisis.

Coastal area is frequently hit by severe cyclonic storms, generating long wave tidal surges. These surges are amplified when they traverse shallow waters, and have a disastrous effect on the coastal areas of Bangladesh. Recently a Bangladesh coastline was hit by the devastating "Sidr". Strong cyclones damage the WSS infrastructure – tubewell heads and sanitation units are partially or fully damaged.

Because of the climate change and global warming the intensity of the tropical cyclone will increased. As the sea level rises, the cyclone water height will also increase. During cyclone the coastal dam can no longer protect the storm surges. Huge volume of saline water will come to the land area and contaminate with the stagnant sweet water pond. These will severely damaging the existing drinking water sources. For instance ponds for the Pond Sand Filters (PSF) and dug wells may be flooded with saline water. It may also contaminating the hand tube well and other sources. The sanitation system would collapse as they are either washed away or submerged under water.

It is not clear if the magnitude of the change in health risks resulting from climate change will be significant compared to current risks. It is also not clear if increased health risk will be apparent in the next few decades. However, in general climate change is expected to present increased risks to human health in Bangladesh, especially in light of the poor state of the country's public health infrastructure.

3.2.2.7 Industry and Infrastructure

Interaction between climate change and industry and infrastructure is complex and multifarious. Therefore, assessment of impacts of climate change on industry and infrastructure is intricate and understanding of interactions yet to be understood comprehensively.

One of the ways to assess impacts of climate change on industry and infrastructure is through assessing damage due to climate change related extreme events. The devastating flood of 1998 damaged 29,154 km of rural roads. Of the 29,154 km, 6500 km of paved road was damaged. About 21,308 meters of bridges/ culverts, 155 growth centre/markets, and 42 ghats/jetties were also damaged in the 1998 flood. The rehabilitation cost of these 29,154 km of rural roads was Tk 6,255 million, while the cost of rehabilitation of 21,308 km culverts/bridges was Tk. 1,752 million. The flood of 2004 damaged 19,882 km of rural roads, 26,025 meters of culverts/bridges, and 231 growth centres and market. An estimated cost of rehabilitation of these damages is Tk 9,296 million. Table 14 provides damage and cost of maintenance of three major floods in Bangladesh.

Table 14. Impacts of Major Flood of Recent Years (1988,1998 and 2004)

Component	Unit	1988			1998			2004		
		Affected: 89970 km2 (61%) Max. Duration : 23 days			Affected: 100250 km2 (68%) Maxm. Duration : 68 days			Affected: 53280 km2 (37%) Max. Duration : 40days		
		Roads & infrastructures in affected area			Roads & infrastructures in affected area			Roads & infrastructures in affected area		
		Total	Damaged	Rehab cost (MTK)	Total	Dam-aged	Rehab cost (MTK)	Total	Damaged	Rehab cost (MTK)
Rural road	Km	145868	3015	1782	174177	29154	6255	219760	19882	5580
Bridge / culvert	M	403800	16240	1530	526610	21308	1752	763180	26025	3430
GC / Mar-kets	Nos				16188	155	216	17106	231	286
Ghat / Jetty	Nos					42	27	204		
Total				3312			8251			9296

It is reported that in 1998 floods more than 22,000 educational institutional were affected in terms of damage to building, furniture, equipment and books. The cost of repair and reconstruction was estimated to taka 271 crores as shown in Table 15. About 762 health care establishments were affected. Hospitals at district HQ level and health complexes at Upazilla levels were, also, considerably damaged. The number of affected rural health centre was 550 which suffered major damages. A study estimated that about 2.6 million houses in the residential sector were damaged by the flood '98. About 73% of the damaged house were affected severely. The study found that the residential sector was one of the major victims with estimated loss of Taka 2090 crores. According to the study the structural damage constituted 75%.

Based on quantitative and qualitative assessment based on GIS database and expert judgement, it is estimated that a total of 2.5 million industrial employment will be affected due to adverse impacts of climate change by year 2030 which will be increased to 70 million by 2100.

Table 15. Number of Affected Educational Institutional and House : Flood '98

Flood intensity	No. of Upazilla	No. of affected Institutions				Damage (in '000 Tk) to		
		Primary School	High School/ Madrasa	College	Total	Estimate	Equipment/ Furniture	Total loss (000Tk)
Normal	65	3,035	1,883	21	4,939	36,712	415,932	452,644
Modulate	125	3,730	2,225	24	5,974	57,866	631,014	688,880
Severe	124	7,177	4,452	49	11,678	136,207	1,453,708	1,589,915
Total	314	13,942	8,560	94	22,591	230,785	2,500,654	2,731,439

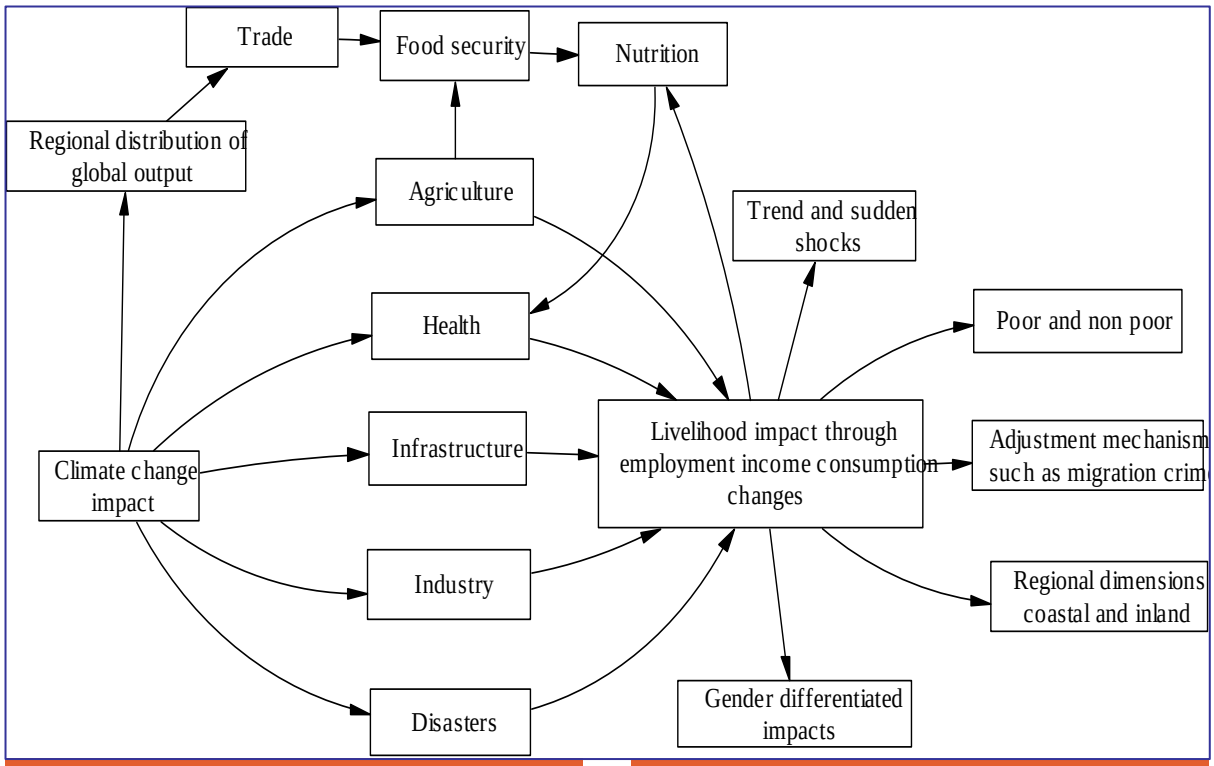
3.2.3 People's Perception of Impacts of Climate variability and Change

Four regional stakeholder consultative workshops in each of the major administrative divisions of the country had been held to solicit people's perception of impacts and vulnerability to climate variability and change. Stakeholders from various walks of life including farmers, fishermen, businessmen, social activists, representatives of civil society and women joined these workshops. These stakeholder consultation workshops pointed to erratic behavior of weather some times first time in their memory such as fogs in places where these were never heard of during summer time, drought, salinity intrusion far from the sea, floods including flash flood, and cyclone and storm surges as major problems they are facing in different parts of the country . Problems related to floods include water logging and drainage congestion, early and untimely floods, localized inundation and flash floods. Salinity intrusion due to reduction of freshwater flow from upstream, salinization of groundwater and fluctuation of soil salinity are major concern. Continuous and prolonged droughts, extreme temperature and delayed rainfall are major problems that agriculture sector is facing. Storms, cyclones and tidal surges appear to have increased in the coastal areas. While the local people did not necessarily relate any of these observed changes to future climate change they did notice trends and changes in patterns that had already occurred or were still occurring. There was a clear sense from all the workshops around the country that local people felt that the climate had indeed changed, mostly for the worse, over the years.

3.2.4 Impacts on Livelihood

Whatever happens to climate and subsequently to various other sectors, all these are important for the main reason that these affect the lives and livelihood of the people. The NAPA exercise tried to figure out these likely changes as a second round impacts of climate change. Figure 15

Figure 15. Intensity of Impacts on Different Sectors due to Climate Change



illustrates the generic links of immediate climate change impacts with issues of livelihood concerns. Climate change is expected to have major physical impacts on agriculture, industry, infrastructure, disaster, health and energy and consequently on people's livelihood in terms of employment, income and consumption (including food security). Various groups in society will experience the impacts in various degrees dependent upon their initial economic conditions (poor or non-poor), location (coastal or non-coastal, rural or urban) and gender. Furthermore, some of the impacts and consequent adaptation may be observed at the macroeconomic level such as trade to close the future food gap.

The impacts on livelihood due to climate change depend on the nature and severity of the physical impacts relating to agriculture, water availability and quality, disaster-proneness, hospitability of the physical environment due to rising temperature and changing water regimes to pathogenic activity and coastal inundation. Given these physical changes including sea level rise, the livelihood impacts may be felt in several ways, not necessarily in any given sequence although the final outcome is always a diminution in employment or employability, income and consumption, although the impacts may be felt in different degrees by different socio-economic groups. These mean a poorer Bangladesh compared to a situation without climate change and lower level of development. Climate change impacts on livelihood thus become a challenge of development under most adversarial changes in dynamics of nature.

On a more specific plan, in absence of climate change, the projected requirements for food grains by 2030 will be 42.5 m mt. The best that Bangladesh can produce by 2030 is 37.8 m mt requiring an annual import of 4.7 m mt about that time. Of the total import, 0.8 m mt or nearly 16% is expected to be the result of additional shortfall due to climate change.

Part of the vulnerability will be due to water shortages for agriculture. But there are other areas where water-related vulnerability may increase. Some of these would be related to health and disaster. On the other hand, extensive water-logging that is being experienced now may exacerbate creating major problems of livelihood for a poor person all of whose land may be submerged permanently.

Both flooding and drought may increase in frequency. Particularly floods may be more devastating creating major problems of livelihood and macroeconomic dislocations, slowing growth and pushing people down the poverty line. Also if cyclones and storm surges increase in frequency and intensity, the potential losses to life and livelihood would be most severe.

The health problem will arise due to climatic factors such as temperature rise, increased SST and ENSO and degrading water quality as well as shortage giving rise to increased likelihood of cholera, diarrhoea, dysentery, malaria and typhoid and also involuntary fetus abortion in the coastal areas due to rising salinity leading to hypertension. Increased food insecurity will exacerbate the problems further by causing more widespread malnutrition. Unfortunately these are little calibrated or not enough to be superimposed on to socio-economic trends to refine the livelihood impacts. Yet, one can safely assume that the poor will suffer much more disproportionately than the non-poor and more so in the coastal and rural areas than elsewhere.

Taking a livelihoods analysis approach to potential impacts of climate change it is clear that the most vulnerable groups

within each community are the poorest amongst them and even within the poor groups the most vulnerable are the women, children, elderly and the sick. It is therefore quite likely that the adverse impacts from climate change will fall disproportionately on these most vulnerable groups within the country as a whole as well as within each vulnerable region of the country.

Therefore, any attempt to adapt or to cope with the adverse impacts of climate change will need to have special emphasis on protecting and helping these most vulnerable groups.

3.2.5 *Summary of Important Climate Change Aspects for Bangladesh*

Impacts of climate variability (and quite possible also of climate change) on the biophysical system and consequences on different sectors are already evident in different parts of the country. It is also found that coastal zone, northwestern zone, central region and piedmont plain are most susceptible to present climate variability and anticipated future climate change. A summary of types of physical impacts, vulnerable areas and impacted sectors along with the strength of these impacts are given Tables 14 and 15.

3.3 Adaptation Measures and Relationship with Development Goals

Bangladesh has been preparing its medium term national development plan known as the Five-Year Plan since 1973. Along

Table 16. Causes of Impacts, vulnerable areas and impacted sectors

Climate and Related Elements	Critical Vulnerable Areas	Most Impacted Sectors
Temperature rise and drought	• North-west	• Agriculture (crop, livestock, fisheries) • Water • Energy • Health
Sea Level Rise and Salinity Intrusion	• Coastal Area • Island	• Agriculture (crop, fisheries, livestock) • Water (water logging, drinking water, urban) • Human settlement • Energy • Health
Floods	• Central Region • North East Region • Char land	• Agriculture (crop, fisheries, livestock) • Water (urban, industry) • Infrastructure • Human settlement • Health • Disaster • Energy
Cyclone and Storm Surge[1]	• Coastal and Marine Zone	• Marine Fishing • Infrastructure • Human settlement • Life and property
Drainage congestion	• Coastal Area • Urban • South West	• Water (Navigation) • Agriculture (crop)

Source: NAPA Team

[1] *Frequency of formation cyclone in the Bay resulted frequent return of fisherman from the deep sea*

Table 17. Intensity of impacts on different sectors due to Climate Change

Physical Vulnerability Context								
Extreme Temperature	Sea Level Rise		Drought	Flood		Cyclone and Storm Surges	Erosion and Accretion	**Sectoral Vulnerability Context**
	Coastal Inundation	Salinity Intrusion		River Flood	Flash Flood			
+++	++	+++	+++	+	++	+++	-	Crop Agriculture
++	+	+	++	++	+	+	-	Fisheries
++	++	+++	-	-	+	+++	-	Livestock
+	++		-	++	+	+	+++	Infrastructure
++	+++	++	-	++	+	+	-	Industries
++	+++	+++	-	++	-	+	-	Biodiversity
+++	+	+++	-	++	-	++	-	Health
-	-	-	-	-	-	+++	+++	Human Settlement
++	+	-	-	+	-	+	-	Energy

Source: NAPA Team

with the other sectoral development strategies and priorities, the Fourth Five Year Plan for the first time and subsequently the Fifth Five-Year Plan (1997-2002) more urgently tried to address the need of protection and conservation of the environment towards sustainable development of the economy.. The major environmental issues identified and addressed in the Fifth Five-Year Plan are natural disasters, industrial pollution, health and sanitation, deforestation, desertification, changes in climatic condition, salinity and deteriorating habitat of flora and fauna. Since the Fifth Five Year Plan, there had been no other. But the government has prepared and just approved a Poverty Reduction Strategy Paper (PRSP) which has more or less reiterated the same concerns in various forms within the document apart from a separate chapter on environment wherein these are reiterated from the point of view of resource management, environmental health, biodiversity and multilateral environmental agreements including those related to climate change.

3.3.1 Urgency and Immediacy of Adaptation Measures

The urgency and immediacy of adaptation needs are assessed based on the level or degree of adverse effects of climate change on the nation keeping the overall development activities and critical sectors in mind within the framework of poverty reduction strategy and sustainable development. It has also considered degree of impacts on natural eco-systems (coastal zone, freshwater, etc.), production system (agriculture, fisheries, livestock, industries, biodiversity, etc.), and the human system (poverty, livelihood, food security, etc.).

It has also considered changes in frequency and intensity of natural disasters (cyclone, floods, drought etc.) and subsequent

impacts on above systems. One of the key assumptions considered is that the delay to start adaptation measures could increase vulnerability, or lead to increase cost of adaptation at a later stage.

3.3.2 Complementary with National Goals and other MEAs

This updated National Adaptation Programme of Action (NAPA) has been identified the adaptation measures as a set of actions complementary to national goals and objectives of other multilateral environmental agreements to which Bangladesh is one of the signatories. For example "Strategic Block II: Critical Sectors for Pro-poor Economic Growth" section of PRSP has identified climate change as one of the important concerns for water resource management. Other concerns like floods, drainage congestion, droughts, river erosion and accretion, cyclones, water quality and rights, and surface water salinity, as discussed earlier will be aggravated under a warmer climate. Climate change, particularly sea level rise is identified as a matter of grave concern for Bangladesh. The Policy matrix under the "Comprehensive Disaster Management towards Poverty Reduction and Growth" has recognized NAPA as an ongoing activity to address some of the pertinent climate change issues. Policy Matrix 18: Environment and Sustainable Development identified that integration of climate change adaptation in all policies, programmes and projects as one of the key targets. Awareness raising has been identified as a future need in this regard. The NAPA is also clearly closely related to other environment related policies and programmes in particular the National Action Plan on Biodiversity as well as the earlier implemented National Environmental Management Action Plan (NEMAP). There will be a need to ensure compatibility with these others plans, policies and programmes in implementing the actions recommended in the NAPA. A key feature of any adaptation action to climate change proposed to be undertaken (either through the NAPA or other programmes) is that they need to be well integrated with other ongoing activities so that they can build upon the synergy among them to be cost effective rather than stand-alone activities at higher cost.

3.3.3 Potential Barriers to Implementation

There are a number of barriers to implementation of adaptation programme and projects. Over the last decades, awareness has been increased but failed to trigger large scale implementation. One reason may be that the potential gravity and the extent of the problem as well as possible actions are not clear yet.

Another barrier (also related to lack of awareness amongst the key groups and institutions) is the lack of incorporation of climate change impacts in developing policies, plans and programmes in some of the most climate sensitive sectors (e.g. water management, agriculture, disaster management, etc). However, the need for such integration is being slowly realized and Bangladesh Climate Change Strategy and Action Plan is a step forward the actual integration in planning, designing and implementation of climate change in the development activities.

A final barrier to actually implementing adaptation actions (where awareness has been raised already) is the lack of adequate tools, knowledge and methodologies to provide guidance and advice to the people making their decisions. This is equally applicable at the technical level in different sectors, e.g. water management but also at the grassroots levels for the vulnerable communities themselves. Thus generating good knowledge, data, methodologies and

tools (and then disseminating them) will need to be an important activity in the short term.

4 Identification of Key Adaptation Needs

4.1 Existing Knowledge on Coping Strategies

Coping with extreme climatic events like floods, drought, and cyclone and storm surges is not new to the people of Bangladesh. Over the period of time both government and non-government organizations have initiated number of activities to minimize the adverse effects of extreme natural events.

The country has set a pioneer example in disaster management particularly addressing cyclones and floods. The role of the government and non-government organizations during the pre and post-disaster periods helped lower the number of deaths and damage. The initiatives were appreciated and recognized worldwide. As a part of adaptation measures, the GoB has constructed over time nearly two thousand cyclone shelters in the coastal areas, and about 200 flood shelters for evacuation of people threatened by cyclone or flood. In addition, about 3,931 km long coastal embankments have been constructed over the years to protect coastal land from inundation by tidal waves and storm surges. Similarly, drainage channels with a total length of 4,774 km have been dug.

The Government of Bangladesh has undertaken a Green Belt Project in the coastal areas with community participatory approach. This reforestation program aimed at reducing the adverse impacts of natural disasters, particularly cyclones and storm surges in the coastal regions as well as improving livelihood of the community.

Increasing salinity has exacerbated the problem of drinking water availability in the coastal zone. Rain water harvesting is an adaptation measure in such circumstances. Both government and non-government organizations are playing significant role in disseminating rainwater harvesting technologies.

Floating agriculture during flooding (monsoon) season is not new in some part of coastal area but both government and non-government organizations are promoting this technology through training and cross visit. The development of salinity tolerant species by BARI and BRRI is a recent technological development to address salinity for crop agriculture. Establishment of shallow tube-well for irrigation to reduce impact of salinity, supplementary irrigation and drainage control in the drought prone area depending on seasons are common technologies to grow crops.

It is reported in the consultation workshops that farmers adopt short duration crop variety based on situation i.e. depth and duration of flood, timing of flood, recession of flood water etc. Artificial management of temperature through different techniques and technologies for poultry and livestock such as the use of wet jute bags over shade, use of exhaust fans (during hot weather), electric bulbs for heating room (in winter season) is common.

4.2 Future Coping Strategies and Mechanisms

The strategic goals and objectives of future coping mechanisms are to reduce adverse effects of climate change including variability and extreme events and promote sustainable development. Future coping strategies and mechanisms have been suggested based on existing process and practices, particularly in other geographic areas which may face problems similar to those elsewhere at present. Development of

techniques for transferring knowledge and experiences from one area/ecosystem to another is thus necessary.

Some initial activities have already been pioneered in Bangladesh as adaptation to climate change at the community level. For example a project called "Reducing Vulnerability to Climate Change (RVCC)" under implementation in a number of flood-prone villages in coastal Bangladesh by CARE, an international NGO, with local partners has generated much useful knowledge about communicating climate change (and adaptation) messages at the community level. This knowledge was also shared at an international workshop on Community Level Adaptation to Climate Change held in Dhaka in January 2005.

Addressing future problems related to sea level rise appear to be a complex issue for Bangladesh as it involves various interactive production systems as well as human systems together with physical ecosystems all within the overall parameters of coastal zone dynamics. An integrated systems approach acceptable to the communities at large may be suggested.

It will also be important to monitor the actual impacts of climate change in different parts of the country to more accurately predict. This will help in more clearly targeting the problems for resolution.

It is evident from the science of climate change and impacts studies that severity of impacts and frequency will increase in future and therefore limitation of existing coping strategies need to be assessed. New and improved adaptation measures may be increasingly called for. This necessitates creating a research system or sub-systems within the existing ones for studying the problems due to climate change for future coping strategies and actions.

No adaptation measure can entirely eradicate the adverse impacts of climate change and climatic variability. A part of the cost, however small, has to be borne by the society. To strengthen the capacity to withstand such losses, insurance mechanisms need to be strengthened and sensitized to the future needs. Areas for such insurance schemes may include crop failures, losses due to cyclones and storm surges and other natural hazards.

4.3 Possible Adaptation Measures

A. Research and Knowledge Management

1. *Model climate change scenarios for Bangladesh by applying global climate change models and methodologies at regional and national levels*

2. *Model the likely hydrological impacts of climate change on the Ganges-Brahmaputra-Meghna system to assess likely future system discharges and river levels in order to derive design criteria for flood protection embankments*

3. *Monitor and research the impacts of climate change on ecosystems and biodiversity*

4. *Research the likely impacts of climate change on the macro-economy of Bangladesh (a Bangladesh 'Stern Report') and key sectors (e.g., livelihoods and food security) and contribute to developing a climate-proof national development plan*

5. *Research the linkages between (a) climate change and poverty; and (b) climate change, poverty and health (disease incidence, nutrition, water, sanitation) in order to identify possible interventions to increase the resilience of poor and vulnerable households to climate change*

6. *Filling the Climate Change Knowledge Gap for Water Resources Planning, designing and implementation of project*

7. *Establish a Centre for Research and Knowledge Management on Climate Change (or a network of centres) to ensure Bangladesh has access to the latest ideas and technologies from around the world, and ensure that data is widely and freely available to researchers*

B. Agriculture, Fisheries and Livestock

1. *Develop climate change resilient cropping systems (e.g., agricultural research to develop crop varieties, which are tolerant of flooding, drought and salinity, and based on indigenous and other varieties suited to the needs of resource poor farmers), fisheries and livestock systems to ensure local and national food security*

2. *Introduce and scale up existing innovative technologies to deal with flood, drought and salinity such as maize production under wet bed no-tillage method, no–tillage potato cultivation under water hyacinth mulch in wet sown condition, vegetable cultivation on floating bed, sorjan systems of cropping in tidally flooded agro-ecosystem etc.*

3. *Development and protection of dry season fish refuges for sustainable management of fisheries through community husbandry in the north-western part of Bangladesh*

4. *Adaptation of fish culture techniques to increased flood levels and diversification of aquaculture techniques in the flood- prone north-central region of Bangladesh*

5. *Adaptation to flood on freshwater wetlands (beel) fisheries with special emphasis to recruitment of small indigenous fish species*

6. *Adaptive measures for the fisheries resources with the impacts of climatic changes in the coastal ecosystem of Bangladesh*

7. *Adaptive measures to reduce stresses in ruminants and poultry due to temperature extremes through housing and management systems*

8. *Improvement in the supply of feeds and forages through community based production and conservation for feeding livestock and poultry in case of flood, drought, salinity and tidal surges*

C. Health

1. *Implement surveillance systems for existing and new disease risks and ensure health systems are geared up to meet future demands*

2. *Development of Strategy for Alternative Sources of Safe Drinking Water and Sanitation Programme in areas at risk from climate change (e.g., coastal areas, flood-and drought-prone areas)*

3. *Awareness and Behavioural Change and Communication for Climate Change related Health Problems*

D. Building Climate Resilient Infrastructure

1. *Repair and rehabilitate existing infrastructure (e.g., coastal embankments, river embankments and drainage systems, urban drainage systems) and ensure effective operation and maintenance systems*

2. *Plan, design and construct urgently needed new infrastructure (e.g., cyclone shelters, coastal and river embankments and water management*

systems; urban drainage systems, river erosion control works, flood shelters) to meet the changing conditions expected with climate change

3. *Undertake strategic planning of future infrastructure needs, taking into account the likely (a) future patterns of urbanisation and socio-economic development; and (b) the changing hydrology of the country, because of climate change*

4. *Particular Specification in National Building Code for building industry and infrastructure in potentially vulnerable areas*

E. Disaster Management

1. *Strengthen the government's capacity and that of civil society partners and communities to manage natural disasters, and ensure that appropriate policies, laws and regulations are in place*

2. *Strengthen community-based adaptation programmes and establish them in each of the disaster prone parts of the country*

3. *Strengthen our cyclone, storm surge and flood early warning systems to enable more accurate short, medium and long-term forecasts*

4. *Incorporation of Climate Change Considerations in Standing Order for Disaster (SOD) Preparedness in Bangladesh*

5. *Coastal afforestation Programme in the Coastal Region to protect natural and human system from cyclone and storm surges*

F. Livelihood

1. *Increase the resilience of vulnerable groups, including women and children, through development of community-level adaptation, livelihood diversification, better access to basic services and social protection (e.g., safety nets, insurance) and scaling up*

G. Biodiversity

1. *Undertake Community Participated Afforestation Programme in all the regions of the country to improve natural environment and to enhance livelihood of common people.*

2. *The Sundarbans (the World Heritage Site) receive special attention to preserve and to enhance it biodiversity on sustainable basis*

H. Policy and Institutional Capacity Building

1. *Review and revise, where appropriate, all government policies (sector by sector) to ensure that they take full account of climate change and its impacts*

2. *Mainstream climate change in national, sectoral and spatial development planning (in government ministries and agencies, local government, the private sector, civil society and communities) and ensure that impacts on vulnerable groups and women are prioritised in plans*

3. *Build the capacity of key government ministries and agencies to take forward climate change adaptation (e.g., Ministry of Food and Disaster Management, Bangladesh Water Development Board, Local Government Engineering Department; National Agricultural Research System, the health system, the Ministry of Women's and Children's Affairs)*

4. *Build the capacity of the government to undertake international and regional*

negotiations on climate change. Regional and international cooperation is essential in order to build necessary capacity and resilience

5. *Capacity Development for Water Sector Managers for Designing Structural Adaptation*
6. *Development of Negotiating Instruments for Sustainable Drainage Systems*
7. *Formulation of Land and Water Zonation for Climate Change Adaptation in Bangladesh*

5 Criteria for Selecting Priority Activities

5.1 Selection Criteria

Criteria used for prioritization of projects in Bangladesh NAPA 2005 were according to NAPA guideline prepared by Least Developed Countries Expert Group (LEG). The 10 Guiding Elements (sec 7 a-j of NAPA guideline) contain criteria, such as complementary to existing national and sectoral plans and programmes including national action plans under the UNCCD & CBD, sustainable development, gender equality, and cost effectiveness. Section 15 of the guideline listed 4 general criteria, such as level or degree of adverse effects of climate change, poverty reduction, synergy with other MEAs and cost effectiveness.

Again Section 16 of the guideline stated several criteria those will be applied to, inter alia: a) loss of life and livelihood; b) human health; c) food security and agriculture; d) water availability, quality and accessibility; e) essential infrastructure; f) cultural heritage; g) biological diversity; h) land-use management and forestry; I) other environmental amenities; and j) coastal zones, and associated loss of lands. For example, poverty reduction is related to health, food security and water availability. In a similar manner, the degree of an adverse effect can be measured in terms of loss of life and livelihood, loss of health, loss of land, loss of biodiversity etc. Considering the set of criteria in this way helps in determining where criteria overlap or are correlated.

It is further stated that the selected set of criteria should be locally-driven and *inter alia* is added to criteria of both sections 15 & 16. The LEG interpretation is that the list can be seen as a checklist of possible relevant criteria, depending on the country, area, sector etc. The Guidelines provide enough flexibility in finalizing the country-specific appropriate set of criteria for prioritization of adaptation activities.

In the context of Bangladesh, the following considerations are of vital importance for selecting the set of criteria and their ranking:

1. Almost two-third of the 40 million strong labor force is engaged in agriculture and related activities, which are largely nature and water-dependent. But these are the sectors likely to be hit hardest by climate change, particularly in the southern coastal and northern drought-prone areas of Bangladesh.
2. Impacts and vulnerabilities can be looked at from several overlapping angles, sectoral or regional perspectives or in terms of loss of life, livelihood or income. In the context of Bangladesh, it is more rational and just to gauge vulnerabilities and multiple stresses on the lives and livelihoods of the poor.
3. As poverty reduction is a complex and composite phenomenon, selection of NAPA projects looked into the potential of socio-economic empowerment and development of skills and capabilities of the poor as well.

4. The fact that poverty reduction initiatives to enhance adaptive capacity of the poor may not always pass the economic efficiency criteria has also been taken into consideration.

5.2 Prioritization Criteria and Indicators

In conformity with the guiding elements of country-drivenness, simplicity and flexibility in procedures, set in the NAPA Guidelines, poverty reduction and security of livelihoods with a gender perspective has been used as the most important set of criteria for prioritization of adaptation needs and activities.

a. Impact of climate change on the lives and livelihoods of the communities

b. Poverty reduction and sustainable income generation of communities

c. Enhancement of adaptive capacity in terms of skills and capabilities at community & national levels

d. Gender equality (as a cross-cutting criteria)

e. Enhancement of environmental sustainability

f. Complementary and synergy with national and sectoral plans and programs & other MEAs

g. Cost effectiveness.

6 List of Priority Projects for Development and Implementation

Short-term Projects

- Financial Needs Assessment to Combats Climate Change by Department of Environment, Ministry of Environment and Forests
- Mainstreaming adaptation to climate change into policies and programmes in different sectors by Department of Environment, Ministry of Environment and Forests
- Enhancing resilience of urban infrastructure and industries to impacts of climate change including floods and cyclone by Department of Environment, Ministry of Environment and Forests
- Exploring options for insurance and other emergency preparedness measures to cope with enhanced climatic disasters by Department of Environment, Ministry of Environment and Forests
- Revision of sectoral policies for climate resilience by Ministry of Planning and Ministry of Environment and Forests
- Mainstreaming climate change in national, sectoral and spatial development programmes by Ministry of Planning and Ministry of Environment and Forests
- Strengthening Human Resource Capacity by Ministry of Planning and other respective Ministries

Medium Term

- Formulation of Land Zonation for Climate Change Adaptation in Bangladesh by Ministry of Land and Ministry of Local Government

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