MAINSTREAMING ADAPTATION TO CLIMATE CHANGE IN LEAST DEVELOPED COUNTRIES (LDCS)

Working Paper 2: Bangladesh Country Case Study

Atiq Rahman and Mazharul Alam April 2003

The International Institute for Environment and Development **CLIMATE CHANGE PROGRAMME** was established in 2001. The programme's goal is to enhance understanding of the linkages between sustainable development and climate change. Priority themes for the programme include: enhancing adaptation capacity in developing countries; climate change and sustainable livelihoods linkages in developing countries; capacity strengthening in developing countries; information dissemination; equity and; enhancing opportunities for developing countries to take advantage of opportunities offered for carbon trading (including CDM).

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1 Background

Bangladesh is a signatory to United Nations Framework Convention to Climate Change (UNFCCC). In 1992, the Government of Bangladesh had signed the UNFCCC in Rio de Janeiro and ratified the Climate Convention in April 1994. It is now well recognized that Bangladesh is one of the most vulnerable countries to climate change and sea level rise. The Ministry of Environment and Forest (MOEF), which is the nodal ministry for all environment-related activities in the country, is responsible for coordinating the Climate Change Convention process and activities. A National Climate Committee was constituted in 1994 for policy guidance and to oversee the implementation of obligations under the UNFCCC process. The committee is headed by the Secretary of MOEF and is comprised of members from all relevant government and non-government organizations, including educational institutions, journalists' fora and chambers of trade and commerce.

Over the last decade a number of studies have been conducted on impact, adaptation and vulnerability assessment to climate change. The Government of Bangladesh, Academic Institutes, and Research Organizations carried out these studies and most of them were carried out collectively. At present two noteworthy studies are going on in the country i.e. National Communication to UNFCCC and Reduce Vulnerability to Climate Change. The studies are implementing by the Department of Environment and CARE Bangladesh respectively.

1.1 A List of Major Earlier Studies on Impacts, Adaptation and Vulnerability

- *Effect of Climate Change and Sea Level Rise on Bangladesh* by Dr. Fasiuddin Mahtab (1989) Sponsored by Commonwealth Institute. The objective of the study was to assess the nature of climate change in Bangladesh and to assess the physical, economic, environmental and social impacts of the predicted climate change. The study assumed a scenario of a 1 metre change in sea level by middle of next century; it combines a 90 cm (average of 30 cm and 1.5 m) rise in sea level and about 10 cm local rise due to subsidence.

- *The Greenhouse Effect and Climate Change: An Assessment of the Effects on Bangladesh* by Bangladesh Unnayan Parishad (BUP), Centre for Environmental and Resource Studies (CEARS), New Zealand, and Climate Research Unit (CRU), University of East Anglia, UK, 1993. The major emphasis of the study was to evaluate the implication of changes in climatic regimes and sea level on the natural systems of the country, its particular vulnerability to extreme weather events, the social implications and mitigation options and the overall socio-economic impacts of climate change on Bangladesh.

- *Country Study on Bangladesh under Regional Study of Global Environmental Issues* Project (Asian Development Bank, TA No. 5463) on the Impact of Climate Change in Bangladesh, the Available Options for Adaptation and Mitigation Measure and Response Strategies, 1994 By Bangladesh Institute of Development Studies (BIDS), Dhaka, Bangladesh.

- *Vulnerability of Bangladesh to Climate Change and Sea Level Rise* by Bangladesh Centre for Advanced Studies (BCAS) /Resource Analysis (RA) /Approtech Ltd., 1994 with support from The Netherlands Government. The study report has published in a set of three documents i.e. Summary Report, Technical Report (volume I & II) and Institutional Report.

- *Climate Change Country Study Bangladesh* under U. S. Climate Change Study Programme By Bangladesh Centre for Advanced Studies (BCAS) /BIDS/BUP, 1996 with support from US Government. The study had four major components i.e. a) Greenhouse Gas Emission Inventory, b) Vulnerability and Adaptation, c) Mitigation Options, and d) Dissemination. Vulnerability and Adaptation component focuses on climate change and sea level rise and its impacts on Agriculture, Water Resources, Forestry, Fisheries and Livestock. The study concluded that climate change and sea level rise would affect the whole country and not only the coastal areas. Main impact categories will be inundation, loss of crop production, etc. The study revealed that the southern part of Bangladesh would be most vulnerable in terms of inundation and salt-water intrusion. The study thus recommended that salt water intrusion should be studied based on model MIKE11-GIS integrated modelling as a function of changes in river discharges and sea levels for the entire seasons of the year.

- *Climate Change and Adaptation Study for Achieving Sustainable Development in Bangladesh*; jointly undertaken by Resource Analysis, the Netherlands; BUP and BCAS. The study was commissioned by the World Bank headquarters, Washington D.C. which dealt with first identification and preliminary analysis of a number of adaptation issues on five important sectors of the country. These are (a) agriculture, (b) coastal resources, (c) water resources, (d) bio-diversity and (e) human health. The study showed how major projects, especially the ones being undertaken by the World Bank and Asian Development responded to the needs for adaptation to climate change and how issues of adaptation could be incorporated into the long-term planning framework of sustainable development of the country. The report has highlighted key risk to climate change and possible adaptation options both in terms of physical and institutional.

- *The Vulnerability Assessment of the SAARC Coastal Region due to Sea Level Rise: Bangladesh Case* undertaken by the SAARC Meteorological Research Centre (SMRC). The Theoretical Division of SMRC has analysed the existing Tidal Data of Bangladesh coast and the findings have been presented in this report. Results of the report provide a scientific basis for the Sea Level associated scenario for Bangladesh.

1.2 A List of Major Ongoing Studies related to Climate Change

- *Initial National Communication to the United Nations Framework Convention to Climate Change* with the financial support from GEF. The draft report of the National Communication is under review process. It covers impacts, adaptation and vulnerability, and mitigation potential of the country.

- *Reduce Vulnerability to Climate Change in the six coastal districts* with the financial support from Canadian International Development Authority (CIDA). The project will work with 6000 rural households for improving resilience to climate change vulnerability context.

1.3 Climatic Situation

1.3.1 Climate

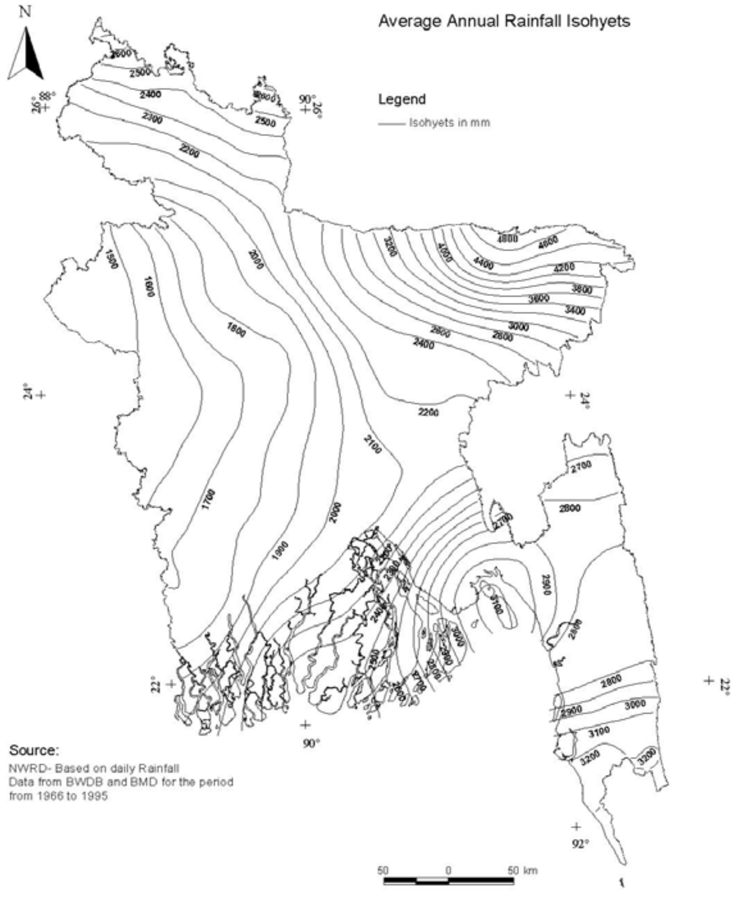


FIGURE 1 Average Annual Rainfall Isohyets

The climate of Bangladesh is characterized by high temperature, heavy rainfall, often-excessive humidity, and fairly marked seasonal variations. Though more than half the area is north of the Tropics, the effect of the Himalayan mountain chain is such as to make the climate more or less tropical throughout the year. The climate is controlled primarily by summer and winter winds, and partly by pre-monsoon and post-monsoon circulation. The Southwest Monsoon originates over the Indian Ocean, and carries warm, moist, and unstable air. The easterly Trade Winds are also warm, but relatively drier. The Northeast Monsoon comes from the Siberian Desert, retaining most of its pristine cold, and blows over the country, usually in gusts, during dry winter months.

The country has an almost uniformly humid, warm, tropical climate, throughout the country. There are three main seasons: (1) a hot *summer season*, with high temperatures (5 to 10 days with more than 40°C maximum in the west), highest rate of evaporation, and erratic but heavy rainfall from March to June; (2) a hot and humid *monsoon season* (temperatures ranging from 20°C to 36°C), with heavy rainfall from June to October (about two-thirds of the mean annual rainfall); and (3) a relatively cooler and drier *winter* from November to March (temperatures ranging from 8°C to 15°C), when minimum temperatures can fall below 5°C in the north, though frost is extremely rare.

The mean annual rainfall varies widely within the country according to geographical location, ranging from 1,200 mm in the extreme west to 5,800 mm in the east and northeast. There are three main periods of rainfall, with distinct sources of precipitation:

(1) The *western depression of winter rains*, mainly from 20th January to 25th February, when it rains from 1cm to 4cm.

(2) The *pre-monsoon thunderstorms,* known as the Nor'westers (North-westerlies), which begin about the 10th of March. The Nor'westers arise due to a variety of reasons, the main ones being the steady flow of cool dry air above 1800 meters altitude from the northwest (Anti-Trades), a warm, moist current below 1800 metres from the south, intense evapo-transpiration in the Bengal basin and Assam, and katabatic winds from the surrounding mountains.

(3) The *summer rains* known as the Monsoons. The main rainy period begins with the coming of the moisture-laden Southwest Trades, popularly known as the Monsoons, which are drawn to the Indian sub-continent by the intense heat, and consequent low pressure over Punjab (in Pakistan and India) and the Upper Ganges Valley. This gives rise to a “tropical cell”, with convection currents of massive proportions. These winds blow across the North Indian Ocean, and reach the Malabar Coast of India two weeks before they come up the Bay of Bengal to Bangladesh. One arm of these vast trades moves up the Ganges valley, and brings in rains. It is the orogenic rains caused by the striking of this east-flowing air mass against the Arakan Yomas, Meghalaya Plateau, and the Himalayas that forms the major part of the rainfall of Bangladesh.

The Monsoon rains start from the end of May and continue till mid October. The total rainfall in these months varies in different parts of the country. It is 122cm in the northwestern part, 149cm in the central part, 338cm in the coastal areas, and over 500cm in the northeastern part - across the borders from Cherapunji and Mawsyriem, two of the rainiest places in the world (Rashid, 1991). Possible connections with *El Nino* have only now begun to attract attention as a major possible influence on climatic patterns in the Sub-continent.

1.4 Climate Change Projections

1.4.1 Trend of Temperature

There are two general approaches to determine future climate change i.e. a) projection based on observed historical data, and b) using available climate model. It is found from the observed data that the temperature is generally increasing in the monsoon season (June, July and August). Average monsoon maximum and minimum temperature shows an increasing trend annually at the rate of 0.05 ^{O}C and 0.03 ^{O}C respectively. On the other hand average winter (December, January and February) maximum and minimum temperature shows decreasing and increasing trend annually at the rate of 0.001 ^{O}C and 0.016 ^{O}C respectively (Alam, M. 2002). It is also revealed that the trend has regional variation. Figure 2 shows the trend of temperature from 1971 to 1998.

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 increasing trend of mean maximum and minimum temperature in some seasons and decreasing trend in some other seasons. Overall trend of annual mean maximum temperature has shown significantly increasing trend over the period of 1961-90.

The study has also projected climatic elements up to 2050 and 2100 using 5-year running average, and actual values. Based on 5-year running average of the climatic elements, the annual mean maximum temperature is likely to rise by 0.48^{O}C and 0.88^{O}C in 2050 and 2100 respectively. It is also found that the annual mean minimum temperature is likely to decrease by 0.06^{O}C and 0.11^{O}C by 2050 and 2100 respectively. The overall annual mean temperature is likely to increase by 0.21^{O}C and 0.39^{O}C by 2050 and 2100 respectively.

The most important finding of the study is seasonal variation of future trend of temperature and rainfall. It is found that in the pre-monsoon season the mean maximum temperature is likely to decrease by 0.44^{O}C and 0.80^{O}C by 2050 and 2100 respectively. Conversely in the southwest monsoon season the mean maximum temperature is likely to increase by 0.90^{O}C and 1.65^{O}C by 2050 and 2100 respectively, and the increasing trend is statistically significant. Table 1 presents projected changes of temperature and rainfall based on 5-year running average method, and Table 2 presents projected changes of temperature and rainfall based on actual trends.

FIGURE 2 Trend of Maximum and Minimum Temperature in Winter and Monson Season from 1971 to 1998.

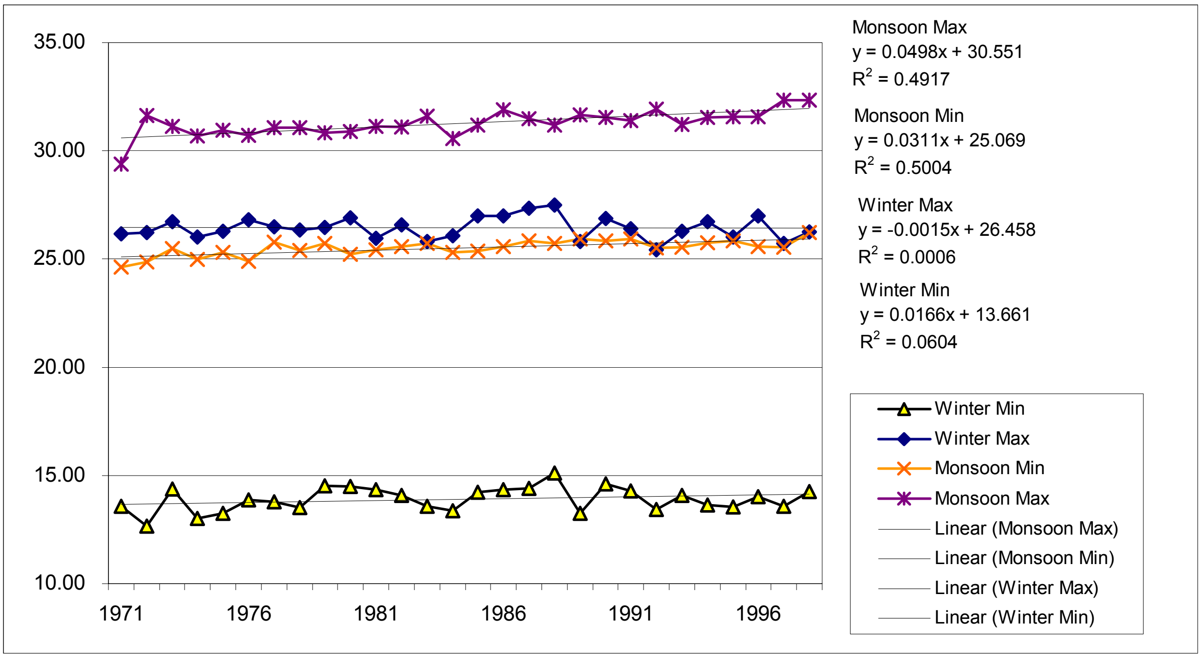


TABLE 1 Projected changes of temperature and rainfall based on 5-year running average method

Season	Max Temp (^OC)		Min Temp (^OC)		Annual Mean Temp (^OC)		Seasonal Rainfall (mm)		Annual Rainfall (mm)	
	2050	2100	2050	2100	2050	2100	2050	2100	2050	2100
Pre-monsoon	-0.438	-0.803	-0.264	-0.484	0.210	0.385	309.73	576.84	304.72	588.65
SW monsoon	0.900	1.650	0.132	0.242			46.54	85.32		
Post-monsoon	1.680	3.080	0.030	0.055			-44.17	-80.90		
Winter	-0.408	-0.748	0.762	1.397			5.47	10.02		

TABLE 2 Projected changes of temperature and rainfall based on 5-year running average method

Season	Max Temp (^OC)		Min Temp (^OC)		Annual Mean Temp (^OC)		Seasonal Rainfall (mm)		Annual Rainfall (mm)	
	2050	2100	2050	2100	2050	2100	2050	2100	2050	2100
Pre-monsoon	-0.846	-1.551	-0.402	-0.737	0.222	0.407	290.90	533.32	295.94	542.55
SW monsoon	0.840	1.540	0.108	0.198			12.74	23.36		
Post-monsoon	1.584	2.904	0.312	0.572			14.05	25.76		
Winter	-0.054	-0.099	0.984	1.804			10.49	19.23		

1.4.2 Climate Change Scenario

Climate change vulnerability studies have used different climate change scenarios to assess impacts, adaptation and vulnerability for different sectors. Climate Change Country Study, a comprehensive study on assessing impacts, adaptation and vulnerability, has used General Circulation Model to develop climate scenarios. Models were run to find correlation with the observed time-series data for 10 particular points distributed all over the country both for base and projection years. The model estimated monthly average rate of change in temperature and precipitation for those locations were superimposed on the observed time-series monthly average data to obtain data for the projection years.

The results revealed that the average increase in temperature would be 1.3^{o}C and 2.6^{o}C for the years 2030 and 2070, respectively. It was found that there would be a seasonal variation in changed temperature: 1.4^{o}C change in the winter and 0.7^{o}C in the monsoon months in 2030. For 2070 the variation would be 2.1^{o}C and 1.7^{o}C for winter and monsoon, respectively. For precipitation it was found that the winter precipitation would decrease at a negligible rate in 2030, while in 2075 there would not be any appreciable rainfall in winter. On the other hand, monsoon precipitation would increase at a rate of 12 per cent and 27 per cent for the two projection years, respectively.

TABLE 3 Extent of changes in temperature, precipitation and evaporation

Year	Average Temperature			Temperature Increase[1]			Average Precipitation			Precipitation Increase[2]			Changes in Evaporation[3]		
	W	M	Ave	W	M	Ave	W	M	Ave	W	M	Ave	W	M	Ave
	(^{O}C)			(^{O}C)			mm/month			mm/month					
Base (1990)	19.9	28.7	25.7	0.0	0.0	0.0	12	418	179	0	0	0	0.6	14.6	83.7
Output from GCM															
2030	21.4	29.4	27.0	1.3	0.7	1.3	18	465	189	+6	47	10	0.9	15.8	83.9
2075	22.0	30.4	28.3	2.1	1.7	2.6	00	530	207	-12	112	28	Inf.	135	87.9

Notes:

1) *Estimated values obtained by correlating model output data with the observed data.*
2) *Estimated based on model output data regarding rate of temperature change.*
3) *Estimated using langs Index and expressed in terms of Aridity Index*

W stands for winter, M stands for monsoon, Ave stands for average and Inf. stands for infinity

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 year 2075. It was inferred from the GCM output that moderate changes regarding climate parameters would take place for the projection year 2030, while for the projection year 2075 severe changes would occur.

The calibrated future temperature of Bangladesh shows that the average increase of temperature would be 1.3^{o}C and 2.6^{o}C for the year 2030 and 2075, respectively. The results also show the seasonal variation of the temperature i.e. 1.3^{o}C in the winter and 0.7^{o}C in the monsoon for the year 2030. Similar temperature changes for the year 2070 would be 2.1^{o}C and 1.7^{o}C for the two seasons, respectively.

The results also reveal that there is a general increasing trend regarding temperature. In 2030, the increase is much 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.

The results show that precipitation in 2030 will increase slightly in winter and moderately in monsoon. In 2075, however, the change is much pronounced in monsoon (about 112 mm/month), while there would not be any appreciable winter precipitation.

1.4.3 Sea Level Rise

The SAARC Meteorological Research Council (SMRC) carried out a study on recent relative sea level rise in the Bangladesh coast. The study has used 22 years historical tidal data of the three coastal stations. The study revealed that the rate of sea level rise during the last 22 years is many fold higher than the mean rate of global sea level rise over 100 years, which shown the important effect of the regional tectonic subsidence. Variation among the stations has also found. Table 4 represents the trend of tidal level in three costal stations.

TABLE 4 Trend of tidal in three coastal stations

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

Source: SMRC, No. 3

1.4.4 Projection of Human and Economic Development

TABLE 5 Human and Economic Development Indicators (projected)

	2010	**2020**
Population Characteristics	150	170
Population (million)	1.46	1.15
Net Replacement Ratio	1.00	1.00
Population Density (per sq. km.)	976	1118
Urban Population (%)	28.5	36.5
Human Resource Development		
Adult Literacy Rate (15 yrs.+, %)	80	95
Primary School Enrolment (gross, %)	96.8	108.3
Secondary School Enrolment (gross, %)	47.3	52.0
Employment and Labour Forces		
Unemployment Rate (%)	11.6	6.5
Civilian Labour Force (million)	86	107
Agricultural Employment (% of labour force)	44.2	38.3
Industrial Employment (% of labour force)	19.7	23.4
Output and Its Distribution		
GDP at Current Market Prices (billion Tk.)	4045	8733
GDP at Current Market Prices (billion $)	96	208
Real GDP Growth Rate	7.0	8.0
Per Capita GDP (1995$)	643	1215
Gross Domestic Investment (% of GDP)	25.0	30.0

Source: BBS; HDD, World Bank, Bangladesh Centre for Advanced Studies; and estimates of Bangladesh 2020 Study.

Most of the climate change and development studies have used different projection of human and economic development to assess future vulnerability to climate change, and needs and barriers in order to develop national development strategy. "Bangladesh 2020: A Long-run Perspective Study" carried out by The World Bank and Bangladesh Centre for Advanced Studies (BCAS) has projected human and economic development up to the year 2020. The study is very optimistic in future development of Bangladesh recognizing the enormous potentials, but warning that unless Bangladesh is fully prepared to face the challenges of a highly competitive world of the 21st century, accelerated growth and poverty alleviation could remain a dream. The project human and economic development is presented in Table 5.

1.5 Summary of actual and potential adverse effects of climate change and climate variability

Impacts of climate change has been assessed under different climate change scenario for different sectors and the following area has been identified as critical where development policy makers will have to consider necessary measures to combat with adverse impacts of climate change in a warmer Bangladesh. The sectoral analysis of impacts, adaptation and vulnerability is presented in ***section 2*** of the report.

Drainage congestion problem will remain integral to climate change. The combined effect of higher sea water levels, subsidence, siltation of estuary branches, higher riverbed levels and reduced sedimentation in flood-protected areas will gradually increase water-logging problems, and impede drainage. This effect will be particularly strong in the coastal zone, but will also be felt in riverine flood plains further upstream. The problem will be aggravated by the continuous development of infrastructure (e.g. roads) reducing further the limited natural drainage capacity in the delta, and the flood plains. On of the sky effects of drainage congestion is that it will increase the period of inundation, and will expand wetland areas. This may hamper agricultural productivity, and also threaten human health by increasing the potential for water borne disease.

Reduced freshwater availability will become a serious problem in the dry season due to low river flows and increased evapo-transpiration in the dry period. In the coastal zone, the additional effect of saline water intrusion in the estuaries and into the groundwater stimulated by low river flow and sea level rise will be significant. Pressure of the growing population and economic development will further reduce fresh water availability.

Disturbance of morphological processes will also become a significant problem under climate change. Bangladesh' riverine and 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:

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

(ii) 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 disasters (extreme events) including cyclones/storm surges, floods and droughts will become evident with climate change. Though the country is relatively well equipped in one aspect of disaster management i.e. disaster response, there remains a serious lack of current data (specially in terms of lead time) in monitoring, an preparing for these events. Additionally, increased intensity of the disasters imply major constraints to the country's social and economic development. The study shows that Bangladesh is particularly vulnerable to climate change in its coastal zone, covering about 30 percent of the country. Private sector investment in this area is likely to be affected by the risks of cyclones and increased flooding.

2 Sectoral Analysis

2.1 Poverty Alleviation Resulting from Adaption and Enhancing Capacity to Adapt

Although poverty is an income related concept it is conventionally measured in calorie intake terms[1]. For Bangladesh absolute poverty and hardcore poverty levels have been defined in terms 2122 Kcal and 1805 Kcal respectively per person per day. One may also identify (absolute) poor households in terms of access to 465 grams of food grains or less per day per person during a reference period (Rahman, 2001).

Despite the recent macro economic achievements, poverty is still pervasive and endemic in Bangladesh. According to the Household Expenditure Survey (HES) of 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 (WB, 1997). Among them, the bottom 10 percent of the population are steeped in severe deprivation so much so that they require substantial transfers to keep from starvation and to come to a level that is considered micro-credit worthy (Farashuddin, 2001). Adverse impacts of climate change will pose severe impacts on poverty, which has direct relation with income and intake of food. The following section will give a scene of present poverty and the people will be affected due to climate change.

2.1.1 The Social Scene

The status of human development as reflected through the Human Development Index (HDI) representing life expectancy, level of literacy, and standard of living (in terms of GDP per capita in purchasing power) has improved from 0.350 in 1980 to 0.470 in 1999. Bangladesh belongs to the group of low human development countries and is ranked 132 among 162 nations included in the Human Development Report of 2001 (UNDP, 2001). According to the 2001 report, the position of Bangladesh is lowest among South-Asian Countries. The HDI for Bangladesh however increased from 146 in 1994 to 144 in 1997 and 132 in 2001.

2.1.2 Trends of Poverty in Bangladesh

Poverty is a mind-boggling affair in the context of Bangladesh. The statistics concerning the extent and trend of poverty in Bangladesh give variable results depending on its definition and methodology of estimation. The calorie intake method of the BBS suggests that overall poverty has been decreasing in the 1980s and the extent of poverty is similar in the urban and rural areas. However, BIDS followed cost of basic needs/living (CBN) approach, which has recently been accepted by all quarters. The table 6 gives the trend of poverty as defined by the BBS method. It suggests that poverty reduction has been rather slow. It remained stagnant from 1983-84 to 1991-92. Indeed, poverty incidence has

[1] The total calorific value of carbohydrates, proteins and fats consumed from various food sources.

been higher in 1991-92 than in 1983-84. However, it declined to 53.1 percent in 1995-96 from 58.5 percent in 1983-84. Sound macro-economic management, higher growth and improvements in social indicators such as health, nutrition, and education may have contributed to fall in the level of poverty.

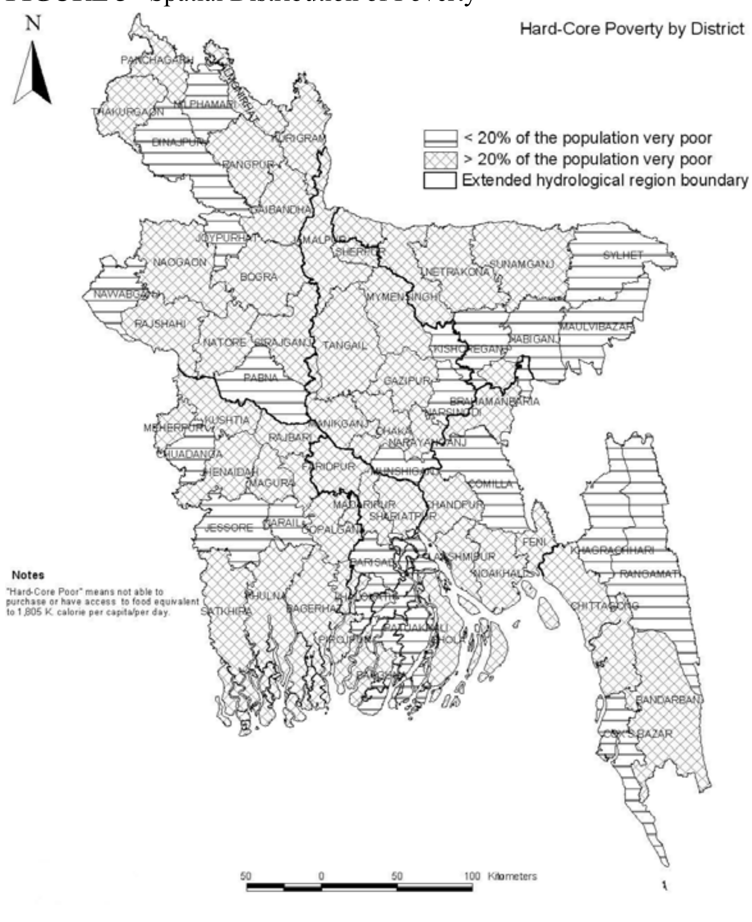
TABLE 6 Percentage of Population Below Poverty Line

Sector	Absolute Poor (Lower Poverty Line)					Poor (Upper Poverty Line)				
	83-84	85-86	88-89	91-92	95-96	83-84	85-86	88-89	91-92	95-96
Rural	42.6	36.0	44.3	46.0	39.8	59.6	53.1	59.2	61.2	56.7
Urban	28.0	19.9	22.0	23.3	14.3	50.2	42.9	43.9	44.9	35.0
National	**40.9**	**33.8**	**41.3**	**42.7**	**35.6**	**58.5**	**51.7**	**57.1**	**58.8**	**53.1**

Source: BBS, 1998.

Other findings may be derived from the above table: poverty declined more in the urban areas than in rural areas, and throughout the period rural poverty in terms of very poor was twice as high as urban poverty. In terms of the upper poverty line, the gap, is slightly reduced. In terms of actual number, however, there has been gradual deterioration in rural poverty during the 1990s. A tentative estimate suggests that between the mid-1970s and mid-1990s, the number of rural poor has increased from 44 million to 51 million (Khan, 2001). The dynamics of rural poverty has been a subject of debate. According to BIDS findings, as quoted in FiFYP there has been a decline in rural poverty from 59 percent in 1987 to 52 percent in 1994. Another source reported that the degree of chronic malnutrition among the children had declined from 70 percent in 1990 to 62 percent in 1996 (SIDA, 1998).

FIGURE 3 Spatial Distribution of Poverty



The poverty ratio available for April 1998 suggests that the hard-core poor account for a quarter of the rural population (Table 7). The country's absolute poor stand at 62 million while the hard-core poor stand at about 30 million. This number is somewhat lower than the corresponding figures in 1991 (Ahmad, 1999). But this is a huge number, and the most important aspect is that these people are extremely food vulnerable. The remaining 32 million poor also suffer from food insecurity of various degrees.

TABLE 7 Poverty Ratio based on Poverty Line Expenditure

Timeframe	Poverty ratio (%)		
	Rural	Urban	National
December 1995	46.8	43.3	46.1
April 1996	47.9	44.4	47.1
April 1997	46.8	43.4	46.1
April 1998	47.6	44.3	47.0

Source: MOF, 1999 (based on data generated by BBS).

The poverty discourse, as depicted above, is contingent on calorie intake and income/expenditure position. It is now being argued that bare subsistence or access to food is neither enough to ensure minimum condition of living, nor human dignity. As Mia (1993) pointed out, one would require shelter, clothing, health care, sanitation, and education and these needs must be taken into account in defining poverty, more precisely, human (resource) poverty. Viewed from this perspective, the proportion of population below human poverty line would be much higher, indeed more than 80 percent. They are identified in the FiFYP as capability poor[2], representing some 76.9 percent. Towards envisioning sustainable development in Bangladesh, one must address the issues of poverty. As it was correctly highlighted by the Global Forum on Environment and Poverty (GFEP), even during the UNCED, "... there can be no sustainable development without alleviation of poverty" (GFEP, 1992; BCAS, 1999).

2.1.3 Population At Risk

Future situation of poverty will be aggravated due to the fact that more people will be at risk under warmer climate resulting in low agricultural output due to drought, salinity and flooding etc., limiting livelihood options and increasing vulnerability unless proper adaptive measures are considered at the very beginning of the problem and integrating them in the national development plan.

Under the climate change scenarios high percentages of the population will be affected by inundations, the maximum being 94% for both the Business-As-Usual (BAU) and High Development Option (HDO) and the non-sharing conditions. The following observations merit mention.

- For the comparison of cases 7-6 (high development in Bangladesh) 94% population will be affected. Due to the fact that in the reference case 6 of this comparison a substantial number of people are already affected by inundations (55% of the population: table 8) additional effect of sea level rise is relatively small, compared with the BAU development options where in the reference cases (8 and 4) only 23% of the population is affected (table 8).
- In terms of population affected by inundations, the impact of climate change and sea level rise seems to be more or less proportional to the assumed sea level rises (30:100 or 1:3).

[2] Capability poor reflects the percentage of people who lack basic or minimally essential.

TABLE 8 Changes in people affected by inundations Values in % of population

	1990/100 3-1	2010BAU/ SH/100 9-8	2010BAU/ NSH/100 5-4	2010HDO/ NSH/100 7-6	1990/30 2-1	2010BAU/ NSH/30 10-4
CCS0	23	23	23	55	23	23
CCS1 or CCS2	67	85	94	94	26	35
Changes	44	62	71	39	3	12

CCS1: Moderate Climate Change Scenario; CCS2: Higher Level of Climate Change; BAU: Business-As-Usual; SH: Water Sharing; NSH: Non-water Sharing; 100: 100 cm sea level rise; 30: 30 cm sea level rise

The absolute number of people affected by droughts is shown in table 9a and 9b. Roughly, these tables show that in the Rabi / pre-Kharif season about 8.5 million people live in the severe and very severe drought prone areas in 1990. This number increases to about 25 million people under the high climate change scenario (CCS2). For the Kharif season under the low (CCS1) and high (CCS2) climate change scenarios, these numbers are 19 and 29 million people, respectively.

TABLE 9a People and areas affected by droughts: Kharif season

Population in million. Area in 1,000 km^2

VA-zone	Drought Classes	No change-------->		CCS1-------------->		CCS1-CCS0----->		CCS2-------------->		CCS2-CCS0----->	
		Area	Pop.	Area	Pop.	Area	Pop.	Area	Pop.	Area	Pop.
Whole country	1	6.676	3.855	14.700	9.100	8.023	5.245	26.126	18.499	19.448	14.644
	2	20.521	15.426	13.523	10.932	(6.998)	(4.494)	15.263	10.309	(5.258)	(5.117)
	3	28.067	21.460	27.041	20.709	(1.026)	(751)	17.101	15.925	(10.965)	(5.536)
	4	34.578	32.002	34.578	32.002	0	0	32.475	29.652	(2.102)	(2.351)
	5	0	0	0	0	0	0	0	0	0	0
	6	56.721	37.134	56.721	37.134	0	0	55.600	35.493	(1.122)	(1.641)
		146.563	109.877	146.563	109.877	(1)	0	146.565	109.877	1	(0)

Results form GIS; Class 1: very severe; Class 2: severe; Class 3: moderate; Class 4: slight; Class 5: non-existing; Class 6: slight - nil

TABLE 9b People and areas affected by droughts: Rabi and pre-Kharif season

Population in million. Area in 1,000 km^2

VA-zone	Drought Classes	No change-------->		CCS1-------------->		CCS1-CCS0----->		CCS2-------------->		CCS2-CCS0----->	
		Area	Pop.	Area	Pop.	Area	Pop.	Area	Pop.	Area	Pop.
Whole country	1	4.318	2.610	9.315	6.056	4.997	3.446	12.737	8.586	8.419	5.976
	2	8.419	5.976	12.374	8.160	3.954	2.184	19.276	16.618	10.857	10.642
	3	20.001	16.864	17.460	15.663	(2.540)	(1.201)	12.992	9.341	(7.009)	(7.522)
	4	16.325	12.158	10.938	8.534	(5.386)	(3.624)	22.200	17.156	5.874	4.998
	5	62.741	56.776	62.741	56.776	0	0	46.941	44.422	(15.801)	(12.354)
	6	34.760	15.494	33.735	14.687	(1.025)	(806)	32.418	13.754	(2.343)	(1.740)
		146.564	109.877	146.563	109.877	0	0	146.564	109.877	(3)	0

Results form GIS; Class 1: very severe; Class 2: severe; Class 3: moderate; Class 4: slight; Class 5: non-existing; Class 6: slight - nil

2.2 Human health

The generally inadequate state of human health in Bangladesh is the result of inextricable linkages between over population, poor nutritional status and inadequate potable water and sanitation provision. With a view to reducing malnutrition and improving the quality of life of the people, particularly of children and creation of healthy physical environment is of vital importance. The safe drinking water supply programme undertaken in the context of the government's commitment to universal coverage has resulted in unprecedented gains. It is found that in 1996 only 1.17% of the GDP was spent for the health sector. According to UNICEF in 1996 99% of the urban population had access to safe drinking water where as the rate is 95% for the rural population and in total 97% of the total population had access to safe drinking water the rate was only 89.49 in 1991. 97% of the population had access to drinking water from safe source (tubewell, ringwell or tap) in 1997, the ratio was 97% in rural and 99% in urban areas but only 68% in the tribal areas. The overall achievement has already exceeded the goal of 80% coverage, set for the year 2000. The success in use of rate of safe water for all domestic purposes has however lagged far behind at 56%. Surprisingly the use rate in urban slums was 98%. Though the slum dwellers spent more time like from 30 minutes to 2 hours in fetching the water. The others (5.6%) use water from ponds and marshes, rivers and springs. Use of water from unsafe sources for domestic purposes could potentially negate the benefits derived from safe drinking water particularly for malnourished child.

Improvements in sanitation or sanitary means of excreta disposal are lagging far behind the improvement in water supply. In 1996 83% of the urban population had access to sanitation services where as the rate was only 38% for the rural population and only 50% in the tribal areas, but the rate in total has increased from 11% in 1990 and covered 44% in 1996 against a goal of 80% for the year 2000. The piped water supply system is in operation and on site sanitation facilities are in operation in the four city corporations and 60 district towns. Except in Dhaka city the on-site sanitation system is also in operation. But the service coverage is very limited. In Dhaka city the population covered by sewerage facilities progressed from 25% in 1990 to only 35% in 1997. Only 25% of the population was covered by storm sewer facilities in 1995. Sanitation facilities in the fast growing urban slums and fringes are quite inadequate while in the ever expanding new slum areas they are almost non-existent, thus adding greatly to the environmental pollution and posing a threat to the health of the people. A process of installing pit latrines in pourashavas and some thana towns has started but the number remains too inadequate to meet the needs.

There are approximately 1.5 million public hand pumps or shallow tubewells in operation in rural areas, at 106 persons per pump. They include the pumps installed by DPHE and NGOs. MICS 1997 data show that these public tubewells constitute about 30% of all tubewells. It implies that there is an additional 3.5 million shallow tubewells installed privately by individual households. This extended coverage emanated directly from a policy change in 1988 which gave responsibility to NGOs and the local communities for installation, maintenance and operation of pumps, on a cost sharing basis, for which they are provided with training by DPHE. More than 600 NGOs under the banner of the NGO Forum, for Drinking Water and Sanitation are actively involved and have contributed to the promotion and provision of water supply and sanitation facilities.

The depressing fact is the declining water table. Heavy extraction of water for irrigation and decreased recharge of the groundwater is continuously causing a fall in the water table. Seasonal variations add to the problem. While only 12% of the country was within the suction zone of 7 metres in 1986, the proportion rose to 21% by 1994 and predictions have it that by the end of the year 2000 it will rise to as much as 50% of the country (Rivers of Change). In the dry season the water table goes down sharply in some areas raising the pump to people ratio to 1:500, thereby making the water shortage dangerously acute for people in such areas.

Existing literature does not provide an assessment of climate change impacts on human health in Bangladesh. Although there is a significant seasonal variation in temperature ranging from 10 to 38 degree Celsius. Due to high temperature and humidity, the elders and malnourished children will face dehydration related problem and heat stress mortality may be observed.

2.3 Iinfrastructure

2.3.1 Length of Road and Railway

The country has about 2858 kilometers of rail road, 15053 kilometers of paved road and roughly 5896 kilometers of perennial and seasonal waterways. Side by side with the development of transport efforts are under way to develop the water transport system. In fact rivers are the lifelines of the nation, which provide the cheapest means of transport, water of agricultural operation and ensure supply of fish. Steps have been taken to put more mechanized vessels into service and modernize the existing country boats.

TABLE 10 Growth of Road and Railway

	1975	1980	1985	1990	1995	1996	Source
Length of paved roads (km)	3787	4284	6215	7914	9842	11663	R.H.D.
Length of semi paved roads (km)	566	1407	4159	5913	6228	5891	R.H.D.
Length of tertiary roads (km)					3677	3472	R.H.D.
Length of railway (km)	2874	2884	2871	2746	2706	2706	B.R

Note:

R.H.D - Roads and Highways Department

B.R - Bangladesh Railway

2.3.2 Road and Railway in Flood Vulnerable Zone

TABLE 11 Summary of changes in values of expected damage due to inundations

	1990/100 3-1	2010BAU/ SH/100 9-8	2010BAU/ NSH/100 5-4	2010HDO/ NSH/100 7-6	1990/30 2-1	2010BAU/ NSH/30 10-4
in billion Taka						
CCS0 CCS1 or 2 Changes	3.5 60.8 57.3	8.0 94.0 86.0	5.3 65.9 60.6	45.4 296.8 251.4	3.5 9.9 6.4	8.0 24.2 16.2
in %						
CCS0 CCS1 or 2 Changes	1.2 21.4 20.2	1.3 16.1 14.8	1.9 23.0 21.1	7.3 48.7 41.4	1.2 3.5 2.3	1.9 5.9 4.0

Source: BCAS/RA/Approtech Ltd., 1994

Database of length of road and railway under different flood prone zone is prepared through overlapping two GIS database i.e. flood prone zone, and road and road database. Under the climate change scenario it has been found that the cost of loss of immobile infrastructure only due to inundation for a meter sea level rise for Bangladesh will be grater than 5 billion dollars, which is equivalent to 10 per cent of country's GDP. These include water works, housing and settlement, transport, utilities, and industries. Table 11 presents summary of changes in values of expected damage due to inundation.

2.4 Food Security and Crop Agriculture

The 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 analysed against the baseline climate condition.

The GFDL model predicted about 17 per cent decline in overall rice production and as high as 61 per cent decline in wheat production compared to the baseline situation. The highest impact would be on wheat followed by Aus variety. CCCM model predicted a significant, but much reduced shortfall in foodgrain production.

It was noticed that increase in 4°C temperature would have severe impact on foodgrain production, especially for wheat production. On the other hand, carbon-dioxide fertilization would facilitate foodgrain production. A rise in temperature cause significant decrease in production, some 28 and 68 per cent 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 per cent rise in rice production and 31 per cent decline in wheat production. It was found that Boro rice would enjoy good harvest under severe climate change scenario.

The apparent increase in yield of Boro and other crops might be constrained by moisture stress. A 60 per cent moisture stress on top of other effects might cause as high as 32 per cent decline in Boro yield, instead of having an overall 20 per cent 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.

2.4.1 Implication of Climate Change

In rural Bangladesh, inundation to a lesser degree has always been considered a boom to agricultural production and people welcome such physical effects. On the other hand, a prolonged flood with high degree of submergence, similar to that occurred in 1998, has been regarded as a disaster for agriculture. In two severe floods, 1974 and 1987, the shortfalls in production were about 0.8 and 1.0 Mt, respectively. Severe floods, however, do not appear every year. In general, perennial floods bring silt and nutrients associated with it, which is good for agriculture. With a receding flood, the farmers always find ways to readjust with the cropping calendar and grow alternative crops. Flash-flood occurs only in some designated areas. Recently crop loss due to flash-flood has been successfully minimized by introducing the submergible embankments in the susceptible areas. Therefore, flood related vulnerability is not acute in the country.

Both drought and salinity, recurring phenomenon, intrusion have considerably higher impacts on crop production. The effects diminish suitability of a number of seasonal crops that are usually preferred by the farmers. Under a severe climate change scenario the potential shortfall in rice production could exceed 30 per cent from the trend, while that for wheat and potato could be as high as 50 and 70 per cent, respectively (Karim, 1996). Under a moderate climate change scenario the croploss due to salinity intrusion could be about 0.2 Mt, which could be increased up to 0.56 Mt under a severe climate change scenario (Habibullah *et al.*, 1998). Considering the loss of production due to such effects, one may find these to have relatively higher intensity than the floods. However, the loss incurred in other sectors could be much higher in case of floods. The effect of low-flow on agricultural vulnerability is considered to be much less intense compared to other effects.

Higher levels of temperature and precipitation would aggravate declining condition of the soils. The organic matter content of the topsoil in majority of the areas has already declined below a critical level. The moderately affected areas would also suffer due to impact of climate change. It is likely that a significant part of the moderately affected soils would become more vulnerable due to further decline in organic matter content of the topsoils. It would certainly have adverse impact on foodgrain production.

Since climate change would cause significant changes in all these physical effects, it is obvious that the overall vulnerability of crop agriculture will be much higher compared to the modelling results. However, the higher concentrations of CO_2 in the atmosphere would also have some positive effects on the production, as revealed by the modelling exercise. Thereby, some of the adverse effects would be minimized due to CO_2 fertilization.

During the period 1961 to 1991 four population censuses were conducted. According to these census results, the population has almost doubled in less than 30 years since 1961, and is likely to be double again in another 35 years. Currently, the estimated population stands at over 125 million and by the year 2030 it is projected to be 191.1 million (World Bank, 1993). According to the projection made by BARC (1995) the requirement of foodgrain in the country at 2 per cent annual growth rate will be 25.2 Mt in the year 2000 and 42.8 Mt in the year 2030. Therefore, to become self-sufficient in foodgrain production in year 2000 and 2030, additional 6.2 and 23.8 Mt, respectively would be required. But the increased vulnerability to crop production due to changes in climate system would not allow the farmers of the country to provide food security for the millions of its countrymen. Unless appropriate anticipatory adaptation measures are considered now, foodgrain self-sufficiency would remain a distant dream for the country.

The loss of foodgrain production due to soil salinity intrusion in the coastal districts was estimated for Bangladesh under climate change scenarios. A computer model was developed that provided with a genesis of soil salinity build-up in the relatively drier months of the crop calendar. The time-series soil salinity database was compared with the field-level observations and the model was validated. It was found that the soil salinity generally increases rapidly in the winter months and reaches maximum values in April.

The time-series database was then correlated with the time specific events in the crop calendar for two crops, *Aman* and *Aus* rice, to estimate the damage in production due to adverse effects of salinity. It was found that the impacts of soil salinity would be manifold under the climate change scenarios. It was also found that the estimated crop loss under the severe climate change scenario would be the maximum. Furthermore, additional areas would become severely affected by soil salinity and thereby the affected lands would become unsuitable for a number of crops. As a result, the food security of the country would be threatened under climate change.

The modelling was extended to examine crop loss considering adaptation in conjunction with the climate change scenarios. The results show that substantial improvement might be achieved by adapting improved management and salt tolerant variety under increased soil salinity.

2.4.2 Possible Impact Of Soil Salinity On Foodgrain Production

At present there is no *Boro* cultivation in the coastal area. The soil is also unsuitable for cultivation of the other grain – wheat[3]. Such a limitation is observed due to the fact that, both *Boro* and wheat are usually cultivated in winter months and salinity reaches its maximum in those months leaving most of the lands unsuitable for rice and/or wheat production. In pre-monsoon and monsoon months, however, salinity problem is no longer a limiting factor. As a result, it appears to be possible to cultivate *Aus* and *Aman* varieties of rice in those areas between late May and September. In such cases, however, the expected yield would be reduced by certain degrees depending on the soil salinity concentration (Karim *et al.*, 1990).

TABLE 12 Soil salinity distribution under baseline condition (CCS0)

Month	Area under different soil salinity class (in thousand hectares)				
	S0	S1	S2	S3	S4
August	287.4	426.4	75.8	41.9	2.0
September	258.6	433.9	93.1	45.9	2.0
October	244.3	426.9	110.4	47.9	4.0
November	215.5	391.7	170.4	45.9	11.0
December	201.2	406.0	162.4	51.9	12.0
January	201.2	384.7	179.8	55.8	12.0
February	172.4	413.5	175.8	57.8	14.0
March	115.0	428.3	210.5	63.8	16.0
April	0.0	287.4	426.4	79.8	39.9

TABLE 13 Soil salinity distribution under the moderate climate change scenario (CCS1)

Month	Area under different soil salinity class (in thousand hectares)				
	S0	S1	S2	S3	S4
August	258.6	412.5	108.7	51.2	2.4
September	232.8	417.8	123.6	56.9	2.4
October	219.8	410.1	138.5	60.3	4.8
November	194.0	374.1	194.7	58.8	11.8
December	181.0	387.0	183.2	67.8	14.4
January	181.0	366.4	198.1	73.6	14.4
February	155.2	392.2	192.4	76.9	16.8
March	103.5	402.7	222.2	85.9	19.2
April	0.0	258.6	412.5	114.4	47.9

The available literature on impacts of salinity on different crops suggested that the soil salinity reduces productivity of rice during its germination, vegetative (early) growth and reproductive stages

[3] Wheat is only possible where thermal situation permits and early sowing is possible.

(Bhumbla *et al*., 1968; Rai, 1977a; Rai, 1977b; Ayers and Westcot, 1976; Das *et al*., 1971; BRRI, 1983; BARC, 1981-82 and BARC, 1982-83).

Looking at the annual crop calendar in the coastal areas, it is obvious that the germination or early growth stages for all the *Aman* variety would not be affected by salinity, only the effect would be significant at the reproductive stage. On the other hand, for both broadcast and high yielding varieties of *Aus* paddy the effect of soil salinity would be pronounced during both the germination and early vegetative growth stages.

TABLE 14 Soil salinity distribution under the severe climate change scenario (CCS2)

Month	Area under different soil salinity class (in thousand hectares)				
	S0	S1	S2	S3	S4
August	158.1	363.9	224.0	83.8	3.8
September	142.3	361.5	230.4	95.6	3.8
October	134.4	351.2	236.8	103.6	7.6
November	118.5	312.4	279.6	104.0	19.0
December	110.6	320.3	256.0	123.8	22.7
January	110.6	302.1	262.4	135.6	22.7
February	94.8	317.9	250.6	143.6	26.5
March	63.2	313.1	263.4	163.4	30.3
April	0.0	158.1	363.9	235.8	75.8

The modelling exercise under the present study estimated the loss in foodgrain due to soil salinity impacts under the three climate change scenarios. Tables 15 and 16 provide information on potential loss of production of two types of rice, *Aus* and *Aman*, respectively, under different climate change scenarios. Table 17 gives a summary of the results for all the three scenarios.

TABLE 15 Loss of *Aus* production under the three scenarios (without adaptation)

Scenario specification	Variety Specification	Production loss (tonnes)
Baseline (no climate change, CCS0)	B *Aus*	39710.3
	HYV *Aus*	25907.6
	Total *Aus*	65617.9
Moderate Climate Change Scenario (CCS1)	B *Aus*	46139.5
	HYV *Aus*	29631.0
	Total *Aus*	75770.5
Severe Climate Change Scenario (CCS2)	B *Aus*	55579.9
	HYV *Aus*	42042.5
	Total *Aus*	97622.4

It may be observed from Table 17 that, about 196 thousand metric tonnes of food-grain, almost 66% of which is *Aman*, is lost annually due to impacts of salinity under the baseline condition (CCS0). The loss in foodgrain production would be about 1.4 and 3.3 times higher under CCS1 and CCS2, respectively, in respect to the loss incurred under CCS0. The loss would be much less pronounced in case of *Aus* production, in comparison to that for *Aman* production, since only a small fraction of the arable land in the coastal areas are currently being used for *Aus* crop.

TABLE 16 Loss of *Aman* production under the three scenarios (without adaptation)

Scenario specification	Variety specification	Production loss (tonnes)
Baseline (no climate change, CCS0)	B *Aman*	0.0
	T *Aman*	100270.4
	HYV *Aman*	30809.8
	Total *Aman*	130780.2
Moderate Climate Change Scenario (CCS1)	B *Aman*	0.0
	T *Aman*	150405.6
	HYV *Aman*	45764.7
	Total *Aman*	196170.2
Severe Climate Change Scenario (CCS2)	B *Aman*	0.0
	T *Aman*	438682.9
	HYV *Aman*	122039.1
	Total *Aman*	560722.0

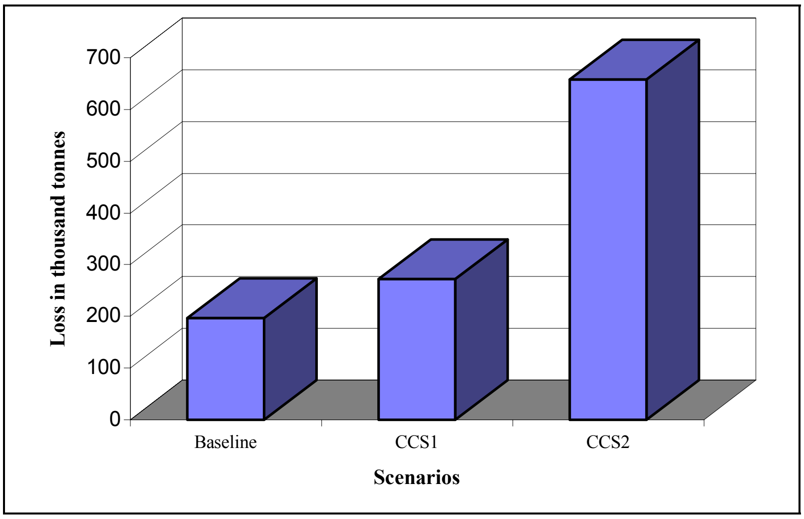
TABLE 17 Total loss in foodgrain production under the three climate change scenarios

Climate Change	Production loss due to soil salinity (in tonnes)		
Scenarios	*Aus*	*Aman*	Total grain
Baseline (CCS0)	65617.9	130780.2	196398.1
Moderate (CCS1)	75770.5	196170.2	271940.8
Severe (CCS2)	97622.4	560722.0	658344.4

The soil salinity of the coastal areas would be increased due to climate change and consequential effects. Increased salinity would significantly reduce foodgrain production, especially under the severe climate change scenario. Reduction in foodgrain production would put additional threats to the food security of the country.

The present case study is based on a huge database and the future changes in soil salinity patterns are computed based on equations, which are validated by using only 10% of the data. Moreover, the potential loss factors in the two future climate scenarios are based on expert judgements. Hence, it may not be considered as a complete study, but an indicative one to predict the loss in foodgrain production in the salinity affected areas. It has some limitations regarding the fact that it did not consider other crops that were grown in that area and also, it did not consider the areas other than the 64 Thanas where soil salinity might become a potential problem in future. If that would be the case there would be more loss incurred in foodgrain production. It would require further modelling exercises.

FIGURE 4. Total loss in foodgrain production under climate change scenarios



2.5 Water Resources

Assessment of Vulnerability of Bangladesh to Climate Change and Sea Level Rise project has carried out rigorous analysis of water resources vulnerability to climate change and sea level rise. The analysis has included changes of riverbed due to sedimentation and subsequent impacts on water level. Changes in river water levels are considered in the further analysis of inundations, low flow conditions and saltwater intrusion.

Change of river water levels include (i) sea level, (ii) upstream river discharges; and (iii) flood protecting infrastructure in Bangladesh. Moreover, the country -- being located on a geotectonically active sedimentary basin -- experiences subsidence almost all over the delta. Subsidence of land (and consequently of river beds) will not however, affect the mean sea level, it may result in changes of water levels as a relative measure over the surrounding lands and thus in changes in the depth of inundations.

Changes in river water levels may cause changes in bed levels as the sediment carrying capacity of the rivers are affected. Decreased water level gradients due to higher downstream water levels at sea result in lower flow velocities and consequently cause sedimentation of the riverbed. The morphologically highly dynamic rivers in Bangladesh are expected to adapt to such changes in water levels in a period of time, which falls within the considered time horizon of 100 years. These 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. First assessments of this effect in the study for the Jamuna Bridge showed the importance of this feed back mechanism [Rendel et al, 1990].

2.5.1 Morphologic changes in the river bed

The study has applied calculation method of the sedimentation in the channels was based on a rectangular cross-section related to bankful discharge and a schematization of the yearly river regime in 4 discharges with a duration of 1, 1, 2 and 8 months.

The applied analytical solutions have been described by de Vries (1975) and in *Principles of River Engineering*, section 3.4 [Jansen, 1979]. An alternative approach would have been morphologic computations with the Jamuna-Ganges- Padma-Meghna (JGPM) model of the SWMC, which was beyond the available time and budget resources of the study.

For the calculations the main river system of the Meghna, Padma, Ganges and Jamuna rivers were schematized to a representative rectangular cross-section for the bankful discharge in each river. The calculated bed level rises after 20, 30 and 100 years are presented in table 18 for 12 selected stations and the sea boundary of the MIKE11 General Model.

TABLE 18 Rise of bed levels in selected stations

Station No		2015	2025	2095
Name	Chainage	20 Years	30 Years	100 Years
	km	m	M	m
02 Jamuna-01	0	0.09	0.14	0.45
06 Jamuna-04	34	0.08	0.12	0.41
07 Jamuna-14	164	0.05	0.08	0.27
B Jamuna-17	210	0.05	0.07	0.23
03 Ganges-10	58	0.08	0.12	0.42
15 Ganges-18	112	0.08	0.11	0.38
13 Padma	46	0.10	0.14	0.48
12 Meghna-2-1	0	0.10	0.15	0.50
09	18	0.09	0.14	0.46
10 Meghna-18	89	0.06	0.09	0.30
11	111	0.05	0.08	0.25
17 Chandpur	100	0.11	0.16	0.53
Sea Boundary	0	0.14	0.21	0.70

An interesting result is 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. 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 Kahn 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.

2.5.2 Corrected river water levels

As a consequence of the sedimentation in the rivers, water levels as they are estimated with the fixed bed General Model will rise. Use of this model for an assessment of these bed level induced water level changes would require a reformulation of all cross sections. This is a rather cumbersome and time-consuming task, because of the level of detail of the General Model. For this reason, the corrected water levels have been estimated with a schematized model based on the WENDY software program of Delft Hydraulics.

Correction of the water levels was done for the bankful discharge in a model of the Jamuna, Ganges, Padma, Upper Meghna and Lower Meghna. In this simplified model with rectangular cross sections, first the water levels in a present equilibrium situation were determined. Then a run was made with bed levels which were raised with the expected bed level changes as presented in table 18. This resulted in river levels and river level changes with respect to the present conditions. These changes are presented in table 19.

TABLE 19 Changes in water levels at bankful discharge due to sedimentation of the river bed in selected stations

Station No.		2015	2025	2095
Name	Chainage	20 Years	30 Years	100 Years
	Km	m	M	m
02 Jamuna-01	0	0.09	0.14	0.44
06 Jamuna-04	34	0.09	0.13	0.44
07 Jamuna-14	164	0.07	0.10	0.33
16 Jamuna-17	210	0.05	0.08	0.27
03 Ganges-10	58	0.09	0.13	0.43
10 Ganges-18	112	0.08	0.12	0.41
13 Padma	46	0.09	0.13	0.41
12 Meghna-2-1	0	0.07	0.11	0.33
09	18			
10 Meghna-18	89	0.09	0.13	0.37
11	111			
17 Chandpur	100	0.06	0.09	0.26
Sea Boundary	0	0.0	0.0	0.0

2.5.3 Change of Land Type

Vulnerability of water resources considered changes in flooding conditions due to combination of increased discharge of river water during monsoon period and sea level rise for the two projection years, 2030 and 2075. MIKE11, a fixed bed hydrodynamic model, was used for the estimation of changes in river water level, which was coupled with Geographic Information System (GIS) for the estimation of extent of flooding. The climatic parameters for the base year 1990 were obtained from secondary sources and the changes of climatic parameters for the two projection years were obtained from the General Circulation Model (GCM) output. Values of these parameters were taken as input for MIKE11 model runs. Discharge values for 8 upstream boundary stations were calculated from a general relationship between changes in rainfall and runoff. The model considered other parameters under development scenario including embanking the major rivers. Model runs gave water level values for over 4,000 output stations along the rivers all over the country except Chittagong and Chittagong Hill Tracts area. These water levels were interpolated by using GIS techniques to generate water depth spatial database for the study area. Water depth spatial database for each of the projection years was compared with that of the base year to find change in water depth. These values were then superimposed on “land type database” to estimate extent of flooding in terms of water depth. A combination of development and climate change scenarios revealed that the Lower Ganges and Surma floodplains 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 embankment in the major rivers.

It found that 8 per cent and 1 per cent (i.e. 3612 sq. km and 396 sq. km) of existing F0 and F1 land would become extremely vulnerable, respectively. Analysis also showed that 54 per cent (i.e. 17672 sq. km) of F1 land would become moderately vulnerable and 36 per cent of existing F0 and 32 per cent of existing F2 land would become slightly vulnerable in 2030. Moreover, 14 per cent of F1 land, 16 per cent of F2 land and 15 per cent of F3F4 land would virtually become F0 land due to the fact that embankment would make certain area flood free. Considering all types of changes from one class to the others, the country will lose 24 per cent (10726 sq. km) of F0 land and 19 per cent (i.e. 6263 sq. km) of F1 land. On the other hand 13601 sq. km land will be added to the existing F2 land. Details of the results are presented in Table 20.

TABLE 20 Changes of land from one class to the others in 2030 *(in sq. km)*

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**

TABLE 21. Changes of land from one class to the others in 2075 (*in sq. km*)

Land Type	Study Area	Transformed in 2075			
		F0	F1	F2	F3F4
F0	43,060	**19,588**	16,203	6,730	537
F0 + F1	1,184	592	592		
F1	31,986	7,884	**4,160**	17,589	2,354
F1 + F2	260		130	130	
F2	15,572	4,735	429	**3,552**	6,857
F2 + F3 + F4	362			127	235
F3F4	14,076	3,088		46	**10,946**
Urban area	757	757			
River bank/sand bar etc.	1,539				
Forest	5,546				
Mixed land	178				
No data	647				
Total	**115,167**	**36,644**	**21,510**	**28,174**	**20,929**

Analyses of changes in inundation levels for the year 2075 suggested that substantial changes would occur both in negative and positive sense. It was found that 16 per cent (i.e. 7267 sq. km) of existing F0 and 7 per cent (i.e. 2354 sq. km) of existing F1 land would become extremely vulnerable. About

54 per cent (i.e. 17585 sq. km) of existing F1 land would become moderately vulnerable and 36 per cent (i.e. 16203 Sq. Km.) of existing F0 land would become slightly vulnerable by the year 2075. In addition, 25 per cent of existing F1, 30 per cent of existing F2 and 22 per cent of existing F3F4 land would virtually become F0 land due to the fact that embankment would make certain area flood free. Considering all types of changes from one class to the others, it was found that 16 per cent (7764 sq. km) of F0 land and 34 per cent (i.e. 1194 sq. km) of F1 land would be submerged in monsoon. On the other hand 12345 sq. km land will be added with the existing F2 land. Detailed results are presented in Table 21.

Water resources vulnerability to climate change, confinement of river course and sea level rise induced backwater effect was examined for the years 2030 and 2075, respectively, with reference to the existing depth of inundation. Extreme impact was found for F0 land followed by F1 land and moderate and slightly impact was found for F1 and F0 lands, respectively, in the year 2075 where embankment played an important role in restricting the extent of flood affected areas. On the other hand, extreme impact was found for F0 land followed by F1 land in 2030 where only the north-central region was considered to be under the protection of embankment.

A combination of development and climate change scenarios revealed that the Lower Ganges and the 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 the major rivers.

2.6 Coastal Zone

Climate change is only one aspect of the vulnerability of coastal livelihoods. Vulnerability to climate change means in fact that climate change adversely affects the capability of people to cope with such other "normal" vulnerabilities as: food and income security and safety of properties. This implies that any analysis of vulnerability to climate change should start off with a full vulnerability analysis and then assess to what degree these vulnerabilities are affected by climate change.

2.6.1 Primary physical effects of climatic changes

It is reported 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. The selection of key primary physical effects of these "agent of change" (i.e.: salt-water intrusion, drainage congestion, disasters (extreme events) and coastal morphology) is based on a full recognition of possible accumulative effects (WB, 2000).

- In the coastal zone, the effect of *saline water intrusion* in the estuaries and into the groundwater would be stimulated by low river flow, sea level rise and subsidence. Pressure of the growing population and economic development will further reduce fresh water availability in future. The adverse effects of salt-water intrusion will be significant on coastal agriculture and the availability of fresh water for public and industrial water supply.

- The combined effect of higher sea water levels, subsidence, siltation of estuary branches, higher riverbed levels and reduced sedimentation in flood-protected areas impedes drainage and will 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 Surges are expected to become more intense with climate change. Though the country is relatively well equipped in one aspect of disaster management, increased intensity of the disasters implies major constraints to the country's social and economic development. Private sector investment in this area is likely to be affected by the risks of cyclones and increased flooding.

TABLE 22 Relation between agents of change and primary physical effects in the coastal zone of Bangladesh.

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

2.6.2 Vulnerability of households

Households (hhs) function in a (local) environment of opportunities and vulnerabilities. Decisions on their activities depend basically on: (i) the locally available resources (local resource base) and the access hhs have to it (opportunities); and (ii) the risk hhs run because of the dynamics of this local resource base. Vulnerability of hhs relates to their resilience against: *shocks* (disastrous unexpected happenings, such as an earthquake or death of an income generating household member); *fluctuations* (mainly referring to seasonal variations in e.g., hydrology and food); and *trends* (long term slow developments such as soil and water quality deterioration).

As mentioned, households in the coastal zone are vulnerable to many more dynamics than climatic changes. Table 23 shows an example list of changes local people have to cope with and are considered potentially vulnerable to. These changes are referred to as the vulnerability context (VC). The table also indicates which changes are considered to be accentuated by climate change.

TABLE 23 Examples of changes coastal communities have to cope with (vulnerability context)

Vulnerability Context	Accentuated by Climate Change		
	Exposed Upazilas	Inland Upazilas	Buffer Zone
Shocks			
Cyclones and storm surges	+++	+	-
Floods	++	+++	++
Droughts	-	++	+++
Fluctuations			
Employment	+	++	+
Hydrology/water balance	+	++	+
Food availability	+	+	+
Market prices	+	+	+
Employment	+	++	+
Trends			
Increase siltation and drainage congestion	+	+++	++
Increase salinization SW and GW	+++	++	+
Increase bank erosion	+++	+++	+++
Decrease dry season river flows	+	+	++
Increase resource degradation	+	+	+
Change in land use	+++	++	+
Increase GW extraction	+	++	+++
Increase law and order problems	++	+	-
Increase unemployment: (men and women)	+	++	+
Increase water borne diseases	+	++	++
Growth food shortage	+	+	+
Growth migration patterns	++	+	
Reduction fresh water supply	++	+	

2.7 Forestry and biodiversity

Bangladesh is endowed with a number of natural forest ecosystems including inland Sal forest, dipterocarp forest, savanna, bamboo bushes in the hilly regions and freshwater swamp forests. It also has littoral mangrove ecosystems. An attempt was made to qualitatively analyse the impact of climate change on forest resources of Bangladesh.

TABLE 24 Impacts of climate change on natural ecosystems

Major natural ecosystems	Impacts of				
	Inundations	Low flows	Salt water intrusion	Drought	Storm surges
1. Mangroves					
- Sundarbans	X	XX	XX	X	X
- Chokoria sundarbans			X		X
- Coastal plantations					X
2. Wetlands					
- Haors	XX	X		X	
- Coastal chars			X		XX
- River chars		XX		X	
- Northwest (chalan beel etc.)		X			
- Baors					
3. Deciduous forest					
- Modhupur				X	
- Northeast (Sylhet)				X	
4. Rain forest					
- Chittagong Hill Tracts				X	X
5. Peat basins					
- Madaripur, Gopalganj, Khulna		X			
6. Aquatic ecosystems					
- Rivers		X	X		
- Lakes				X	
- Estuaries			X		X
- Coastal (marine) waters					X
7. Coastal plains					
- Beach					X
- Mud flats					X

XX = major negative impact
X = minor negative impact

It was found that increased rainfall during 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 evapotranspiration 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 worst victim of climate change. Due to a combination of high evapotranspiration 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. Table 24 and 25 present impacts of climate change on natural ecosystems, and its magnitude respectively.

TABLE 25 Rating of impacts on natural ecosystems

Ecosystem	Relative weight	Pair-wise comparisons of cases											
		3-1		9-8		5-4		7-6		2-1		10-4	
		Area	Rate	Area	Rate	Area	Rate	Area	Rate	Area	Rate	Area	Rate
1. Mangroves	0.4												
- Sundarbans	0.3	B	B	A	A	B	B	B	B	A	A	B	B
- Chokoria sundarbans	0.08	B	B	B	B	B	B	B	B	B	B	B	B
- Coastal plantations	0.02	B	B	B	B	B	B	A	A	A	A	A	A
2. Wetlands	0.3												
- Haors	0.2	A	A	S	S	B	B	B	B	A	A	A	A
- Coastal chars	0.01	S	S	S	S	A	A	A	A	S	S	S	S
- River chars	0.02	S	S	S	S	A	A	A	A	S	S	S	S
- Northwest (chalan beel etc.)	0.02	B	B	A	A	B	B	B	B	B	B	B	B
- Baors	0.05	N	N	N	N	S	S	N	N	N	N	N	N
3. Deciduous forest	0.01												
- Modhupur	0.08	S	S	S	S	S	S	S	S	N	N	N	N
- Northeast (Sylhet)	0.02	S	S	S	S	S	S	S	S	N	N	N	N
4. Rain forest	0.02												
- Chittagong Hill Tracts	0.02	N	N	N	N	N	N	N	N	N	N	N	N
5. Peat basins	0.01												
- Madaripur, Gopalganj, Khulna	0.01	N	N	N	N	N	N	N	N	N	N	N	N
6. Aquatic ecosystems	0.15												
- Rivers	0.05	N	N	N	N	N	N	N	N	N	N	N	N
- Lakes	0.02	N	N	N	N	N	N	N	N	N	N	N	N
- Estuaries	0.03	N	N	N	N	N	N	N	N	N	N	N	N
- Coastal (marine) waters	0.05	N	N	N	N	N	N	N	N	N	N	N	N
7. Coastal plains	0.02												
- Beach	0.01	A	A	A	A	A	A	A	A	S	S	S	S
- Mud flats	0.01	N	N	N	N	N	N	N	N	N	N	N	N

* the main Chittagong Hill Tract Ecosystem has been excluded from the 9 VA-zones

Scoring:

B = Big impact: impact of scenario (climate change and development) on ecosystem will be more than 30%;

A = Average impact: impact on ecosystem will be between 5 and 30%;

S = Small impact: impact on ecosystem will be less than 5%;

N = No impact.

2.8 *Fisheries*

Fish and Fisheries have been playing a very significant role in nutrition, culture and economy of Bangladesh from time immemorial. Currently, about 80 per cent of the animal protein intake in the daily diet of the people comes from fish. The fisheries sector, it is estimated, contributes 3.5 per cent of the GDP of Bangladesh. From habitat point of view, three principal habitat forms exist from which fish are harvested. These are pure freshwater habitats in the rivers and their floodplains. These water bodies are inhabited by 260 species of fin fish, 25 species of prawn and 25 species of turtles. In addition, 11 exotic species of fin fish have been introduced for the purpose of aquaculture. In portions of the freshwater rivers near their confluence with the sea i.e., Bay of Bengal, the water changes from fresh to saline conditions, with a wide range of salinity gradient both spatially and temporally. These tidal parts of the rivers constitute the estuaries with brackish water conditions. Many freshwater species of fish and prawn visit the estuaries and brackish water habitats at different stages of their life cycle. Similarly, post-larvae of many coastal and marine prawns come to the brackish water habitat to feed and grow into adults. In the Upper Bay of Bengal bordering Bangladesh, 475 species of fin fish are known to occur of which about 65 are of commercial importance. The marine waters also contain about 38 species of marine prawn. In Bangladesh very little or no work on the physiology and ecology of indigenous species of fin fish or prawn has been done. At this stage it is difficult to state or predict likely effects of climate change on different fish/prawn populations and the fisheries based on them.

3. Impacts on policy makers

In each of the key sectors the discussions with the sectoral stakeholders (primarily the sectoral planners and managers) was very useful and informative. Many of the sectoral stakeholders were able to assess the information given to them on the impacts of climate change on their respective sectors and help in the process of both identifying suitable adaptations as well as prioritising them according to the agreed criteria. The relative success of this exercise at the sectoral levels is given below (as a somewhat subjective judgement):

3.1 Coastal resource management

The existence of a major project on integrated costal zone management being planned (with support from the World Bank) allowed the project managers involved to readily see the utility of incorporating climate change issues into their programme planning (which they have decided to do). Thus, this was quite a successful mainstreaming into the coastal zone development community. The stakeholders involved with disaster mitigation (specially of cyclones) were also quite receptive and have decided to incorporate adaptation to climate change into their own ongoing disaster preparedness plans.

3.2 Fresh water resource management

The planners from the water sector were quickly able to see the importance of climate change impacts on their national water sector plans and have also agreed to incorporate adaptation to climate change into the 25-year water sector plan under development.

3.3 Agriculture

The stakeholders involved in agriculture research were relatively quick to see the importance incorporating climate change considerations in their research programmes (specially for drought and saline tolerant rice variety development). However those involved in agriculture extension did not see the importance of adaptation measures for their own work.

3.4 Human health

The success in this sector with the stakeholders was reasonably high with respect to getting their attention but not in any way being able to affect any decision making within the public health community (however they did express the desire to do more work on the issue).

3.5 Ecosystems and biodiversity

The impacts on the Sundarbans forest were accepted as being of major significance by the stakeholders involved in ecosystem conservation and they have agreed to incorporate the impacts assessment of climate change in a major project being undertaken for the Sundarbans. With respect to the other ecosystems the success in engaging with the relevant stakeholders was not as good.

3.6 Cross-cutting and research

As climate change and adaptation are relatively long term problems requiring research and advancement of the knowledge base it is important to enhance the research capacities in the country to deal with the issue on an ongoing basis. The stakeholders representing the research community were quite willing to be involved in further work on the issue.

3.7 High level policy makers

Perhaps the area of least success was in engaging with and getting the interest of high-level policy makers (e.g. those representing the Prime Minister's office, Finance and Planning ministries as well as legislators). This group seemed least concerned about the impacts of climate change on the overall economy of the country and need to be targeted more effectively in any future efforts to do more on adaptation to climate change in Bangladesh

4. Main lessons

The main lessons from the study and exercise carried out in Bangladesh aimed at mainstreaming adaptation to climate change may be summarized as follows:

(i) Information on climate change impacts needs to be translated from the scientific research domain into language and time scales relevant for policy makers.

(ii) Research on potential impacts of climate change needs to be supported in-country to enable information to be improved and passed on to policy makers.

(iii) All relevant stakeholders need to be involved-but their needs for information may vary and thus information must be suited to the stakeholder group being engaged with.

(iv) Sectoral level policy makers, planners and managers are relatively more likely to mainstream adaptation to climate change into their on-going and planned work (provided the information on impacts is given to them in a suitable form).

(v) High-level policy makers need to be especially targeted (with suitable material).

(vi) National and international experts and researchers need to share their knowledge with people making decisions and plans on the ground more effectively

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The Least Developed Countries (LDCs) are a group of 49 of the world's poorest countries. They have contributed least to the emission of greenhouse gases but they are most vulnerable to the effects of climate change and have the least capacity to adapt to these changes. Adaptation to climate change has become an important policy priority in the international negotiations on climate change in recent years. However, it has yet to become a major policy issue within the developing countries, especially the LDCs. The experience cited in this report of two LDC countries, namely Bangladesh in Asia and Mali in Africa, shows that although much has been achieved in terms of describing and analysing vulnerability to climate change and identifying potential adaptation options, there remains much more to be done in terms of mainstreaming adaptation to climate change within the national policy making processes in those countries.

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