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PROTOCOL FOR MONITORING OF IMPACTS OF CLIMATE CHANGE AND CLIMATE VARIABILITY IN BANGLADESH

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PROTOCOL FOR MONITORING OF IMPACTS OF CLIMATE CHANGE AND CLIMATE VARIABILITY IN BANGLADESH

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FOREWORD

It is now unequivocally established that climate change is a reality, and the adversities of climatic transformations pose one of the greatest challenges facing humanity today. Even a cursory observer of recent world events may very well notice the examples of extreme climatic conditions such as the record breaking rainfalls in India, Pakistan or even in Australia leading to flooding of vast expanses, and unprecedented snowfall in Europe or in North America. In Bangladesh, scientists have noticed a degree of systematic rise in temperature and an increase in the frequency of cyclones and associated disasters. It is now often noted that signs and distinctiveness of the country's 'six seasons' are getting increasingly blurred.

Information on resultant impacts of disasters - e.g, loss of life, damage to crops and infrastructures are reasonably found - although far from comprehensive. There are other more pressing questions, however, which warrant our attention; these include: how do you register or quantify the impacts of the already observed gradual changes (or vis-à-vis the predicted changes)? What are the likely impacts of climate change? Can a pattern be recognised in these impacts? Where the impacts are most likely to occur and how to register them? How do we fathom and develop a more holistic view of these consequences and implications over time?

This publication on “Protocol for Monitoring of Impacts of Climate Change and Climate Variability in Bangladesh” is a modest yet pioneering attempt to proffer a systemic methodology to quantify and record the impacts of climate change across selected key sectors. The sectors that are considered for monitoring include hydro-meteorology, agriculture, livestock, both fresh and marine fisheries, forest flora and fauna, human health and livelihood and poverty.

This is an important step towards strengthening our efforts for increasing the adaptive capacity. If the proposed monitoring mechanism and protocol is properly implemented with the support and cooperation of all key stakeholders, the framework may provide an opportunity to reckon and estimate the impacts of climate change in more concrete terms, and pave the way for a more effective role of the country in the international negotiation forums.

Professor Niaz Ahmed Khan, Ph.D
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PREFACE

Climate change is no longer something to happen in future but rather an ongoing phenomenon. According to the study carried out by German watch (2009) Bangladesh is one of the top most nations vulnerable to climate change. The Intergovernmental Panel on Climate Change (IPCC) also recognizes Bangladesh as one of the most vulnerable countries in the world to the negative impacts of climate change. The United National Development Programme (UNDP) has further identified Bangladesh to be the most vulnerable country in the world to tropical cyclones and the sixth most vulnerable country to floods.

Climate change is a major and long-term constraint permeating all sectors of the economy adversely affecting the well-being of men and women, young and old, people in the coast as well as inland, in the hills and in the plains. It is essential that Bangladesh prepares now to adapt to the adverse impacts of climate change and safeguard the future well-being of its citizens.

IUCN Bangladesh has been implementing the project entitled "Enhancement of Bangladesh's Capacity to Participate in Road to Copenhagen and Post Copenhagen Regime". One of the major objectives of this project is to set-up monitoring mechanism of evidences of climate change and climate variability for Bangladesh. This has also been highlighted in Bangladesh Climate change Strategy and Action Plan 2009.

The main objective of monitoring protocol is to track changes that are taking place in climatic parameters and as well as climate induced impacts on different sectors with the ultimate goal of protecting and managing the vulnerable sectors, i.e., for improving our adaptive capacity.

Covering the 12 bio-ecozone of Bangladesh and considering the severity of impact of climate change, monitoring protocols have been identified for eight thematic sectors such as (1) hydro-meteorology, (2) crop, (3) livestock, (4) forest flora and fauna, (5) fresh water fisheries, (6) marine water fisheries, (7) health and (8) livelihoods. These eight sectors can be broadly classified to (a) Hydro-meteorology / climate parameters – as it is necessary to know changes and variations in climate parameters, (b) the primary sectors of the economy (e.g., crop, forest, fisheries) – as these directly relate to the climatic variables and (c) human dimensions (health and livelihood).

Selection of indicators for these sectors has been a long but steady process. There has been series of consultations of which two national workshops took place on 24th July and 23rd September, 2010 respectively. A high-level core group with prominent researchers in their respective fields was formed, who subsequently led the each sector along with other experts, researchers, and managers.

To guide the sectoral teams, a simple framework was presented - (1) why this indicator is selected (responsive or linkage to climate change), (2) what is the parameter, (3) where to measure it and (4) when to measure it. Accordingly after research and consultation the sectoral teams prepared reports on the respective sector. This publication is the compilation of all eight sectoral reports.

A lot of people put forward their support along the way and it is difficult to acknowledge all given the space limitation. However, it is worth mention some distinguished name here.

We are grateful to Dr. Mihir Kanti Mazumder, Secretary, Ministry of Environment and Forest, Dr. Munjurul Hannan Khan, Deputy Secretary, MoEF for giving valuable guidance to take forwards this initiative. We would like to thank all expert members who have taken part in this process.

We are also thankful to the thematic team leaders namely Dr. Rezaur Rahman, Dr. Shahidul Islam, Md. Abdur Razzaque Mia, Dr. Abdur Rob Mollah, Mr. Md. Shamsuddoha, Mr. Junaid Kabir Chowdhury, Dr. Md. Sayedur Rahman, Ms. Sharmind Neelormi for their effort in preaparing and finalizing this nationally important document.

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I would like to thank my colleagues of IUCN Bangladesh Country Office for the logistic support provided to the specialist's teams days and nights, and organizing two major consultation workshops. Special thanks to Dominica Rozario, Office Manager, Tulshi Das Roy, Senior Finance Manager and Aktar Hossain, Finance Officer. As always, Sheikh Asaduzzaman, Library & Publication Officer, made this publication a reality.

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And finally, Dr. Ainun Nishat who led the entire process of identifying monitoring protocol and the project, Dr. Zakir Hussain, Head, Constituency Unit, IUCN Asia Regional Office and Dr. Niaz Ahmed Khan, Country Representative, IUCN Bangladesh Country Office for their relentless oversight.

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ABBREVIATIONS AND ACRONYMS

AOGCMs	Atmospheric and Ocean Global Circulation Model
AR4	Fourth Assessment Report
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Center for Advanced Studies
BCCSAP	Bangladesh Climatic Change Strategy and Action Plan
BFRI	Botany or Forestry Research Institute
BIWTA	Bangladesh Inland Water Transport Authority
BLRI	Bangladesh Livestock Research Institute
BMD	Bangladesh Meteorological Department
BUET	Bangladesh University of Science and Technology
BWDB	Bangladesh Water Development Board
CBOs	Community Based Organisations
CC/CV	Climate Change/Climate Variability
CCD	Colony Collapse Disorder
CDMP	Comprehensive Disaster Management Programme
CLT	Core Lead Team
COPD	Chronic Obstructive Pulmonary Disease
CPD	Center for Policy Dialogue
CS	Cyclonic Storm
DAE	Department of Agriculture Extension
DANIDA	Danish International Development Agency
DBH	Delta Brac Housing
DFID	Department for International Development
DJF	December, January, February
DLS	Department of Livestock
DMB	Disaster Management Bureau
DoE	Department of Environment
DRR	Directorate of Relief and Rehabilitation
EH	Eastern Hill
ENSO	El Niño Southern Oscillation
ETEC	Enterotoxigenic Escherichia coli
FAO	Food and Agriculture Organization
FD	Forest Department
FFWC	Flood Forecasting and Warning Center
FPIRS	Forest Policy Implementation Review and Strategy
GBM	Ganges- Brahmaputra-Meghna
GCM	Global Circulation Model
GDP	Gross Domestic Product

GED	General Economic Division
GHG	Green House Gas
GPS	Geographical Positioning System
HYV	High-Yielding Varieties
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
JJA	June, July, August
MAM	March, April, May
MDG	Millennium Development Goals
MIS	Management Information System
MJO	Madden-Julian Oscillation (weather pattern)
MoEF	Ministry of Environment and Forest
MoFDM	Ministry of Food and Disaster Management
MoHFW	Ministry of Health and Family Welfare
NCSA	Bangladesh National Capacity Self-Assessment
NE	North East
NGOs	Non-Government Organisations
NIPSOM	National Institute of Preventive and Social Medicine
OMS	Open Market Sale
PPR	Peste des Petits Ruminants
PRECIS	Providing Regional Climate Scenarios: a regional climate model used for downscaling GCM scenarios, developed by the Met Office, UK
RCC	Reinforced Cement Concrete
SON	September, October, November
SRDI	Soil Resource Development Institute
SRES	Special Report on Emissions Scenarios
SST	Sea Surface Temperature
THI	Temperature Humidity Index
UMIS	Unified Management Information System (UMIS)
UNDP	United National Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USF	Unclassed State Forest
UV	Ultraviolet
VF	Village Forest
VGF	Vulnerable Group Feeding
WGs	Working Groups
WHO	World Health Organization
WWF	World Wildlife Fund

GLOSSARY

Aman	Rice crop planted in the monsoon and harvested in November/December
Aus	Rice crop planted in pre-mosoon and harvested in June-July
Boro	Rice crop planted in January-February and harvested in May
Char	Low-lying river island
Monga	Unemployment leading to seasonal hunger

CHAPTER – 1

CLIMATE CHANGE IN GLOBAL AND LOCAL PERSPECTIVE

Nasim Aziz, Nandan Mukherjee

1.1 CHANGES IN GLOBAL SCALE

The Inter-Governmental Panel on Climate Change (IPCC) defines (IPCC, 2007) Climate change as "a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer". This change in the state of the climate can be due to natural variability or as a result of human activity. But it differs from the definition given by the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (IPCC, 2001).

The Fourth Assessment Report of IPCC (2007) has observed the following changes in the earth's climate. The 100-year linear trend (1906-2005) of global average surface temperature is 0.74 [0.56 to 0.92]^{0}C and is larger than the corresponding trend of 0.6 [0.4 to 0.8]^{0}C (1901-2000). This observed warming is consistent with shrinking of Arctic sea ice and satellite data since 1978, it is already evident that annual average Arctic sea ice extent has shrunk by 2.7 [2.1 to 3.3]% per decade. Global average sea level has risen since 1961 at an average rate of 1.8 [1.3 to 2.3] mm/yr and since 1993 at 3.1 [2.4 to 3.8] mm/yr due to thermal expansion, melting glaciers and ice caps, and the polar ice sheets. The report also states that from 1900 to 2005, precipitation has found to either increase or decrease in different parts of the world and that globally, the area affected by drought might have increased since the 1970s (IPCC, 2007).

The changes in atmospheric concentrations of greenhouse gasses (GHGs), and aerosols, land cover and solar radiation alter the energy balance of the climate system resulting in the above-mentioned observed changes. Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004. Carbon dioxide (CO_2) is the most important anthropogenic GHG and its annual emissions has grown by about 80% between

1970 and 2004 and exceed the natural range compared over the last 650,000 years based on evidence from ice core samples (IPCC, 2007). Global increases in CO_2 concentrations are primarily due to fossil fuel use, with land-use change providing another significant but smaller contribution.

The IPCC Special Report on Emissions Scenarios (projections made in the IPCC fourth assessment reports, 2007 follows the socio-economic scenarios developed in SRES, 2000) projects an increase of global GHG emissions by 25 to 90% (CO_2-eq) between 2000 and 2030 with fossil fuels being the dominant among the global energy sources. For the next two decades a warming of about 0.2^{0}C per decade is projected for a range of SRES emissions scenarios (IPCC, 2007). Even if the concentrations of all GHGs and aerosols are kept constant at year 2000 levels, a further warming of about 0.1^{0}C per decade would be expected. Lower ends of different model based projections of global average sea level rise at 2090-2099 relative to 1980-1999 are expected to be in the range of 0.18-0.26m (IPCC, 2007).

1.2 OBSERVED CHANGES IN LOCAL SCALE

The impact of global climate change on Bangladesh is becoming more visible day by day and is being analyzed and documented. A summary of such studies on already observed changes are given below:

Increasing temperature: The observed climatic data from 1971 to 2002 indicate that the temperature is increasing in the monsoon season (June, July and August). The average monsoon maximum and minimum temperatures show an increasing trend annually at 0.05^{0}C and 0.03^{0}C, respectively (GED, 2009). Average winter season (December, January and February) maximum and minimum temperature show respectively a decreasing and an increasing trend annually at 0.001^{0}C and 0.016^{0}C (Rahman & Alam, 2003). It is also revealed that 1998 was the warmest year in the last 30 years.

Frequency and intensity of rainfall: There are studies that identified changes in rainfall characteristics, however, these changes are not statistically significant and does not show any specific trend like that of temperature. For example Quadir and Iqbal (2008) studied rainfall data from 1951 to 2007 of 9 coastal BMD stations and found that only 5 stations showed increasing trend, while 4 stations showed negative trend for monsoon period rainfall. For winter and pre-monsoon period, there is an increasing trend of rainfall for all stations expect Bhola, which is an unusual phenomenon according to the authors (Quadir and Iqbal, 2008). The authors also reported higher pre-monsoon rainfall trend for other parts of the country. On the other hand GED (2009) reported that the “number of days without rainfall” in Bogra station (1972 to 2002) shows an increasing trend while the total annual rainfall is showing decreasing trend (not statistically significant). In another station in Rangpur (GED, 2009), both number of days without rainfall and annual total rainfall in Rangpur is increasing, which means more rain is occurring in short duration. All these may suggest an erratic behaviour of rainfall.

Increasing trends of sea surface temperature (SST): Quadir and Iqbal (2008) found that the annual mean SST is rising at the rate of 0.094 ^{0}C per decade leading to an increase of 0.47 ^{0}C during last 50 years. The increase of SST is supposed to enhance the tropical cyclogenesis in the Bay of Bengal, especially in the months of October and November.

Increasing trends of severe cyclonic storm of hurricane intensity (SCS-H): Quadir and Iqbal (2008) in their assessment of the tropical cyclones of the Bay of Bengal for the period of 131 years (1877-2007), found that while the frequency of Depression (D: wind speed 40-50 km/hr), Cyclonic Storm (CS: wind speed 62-88 117 km/hr) and Severe Cyclonic Storm (SCS: wind speed 89-117 km/hr) is decreasing, the very intensive tropical cyclones (SCS-H: wind speed > 117 km/hr) are increasing. Like that of Sidr with a 100 mile long front covering the breadth of the country and with winds up to 240 km per hour, hit Bangladesh in November 2007.

Change in natural disturbance regime (Flood): GED (2009) calculated a cycle of 10 years inundating 37% of the area, however, in last 30 years such types of flood occurred 5 times and in last 10 years event of such flood occurred 3 times (Table 1.1 & 1.2). Similarly can be said for a flood return period of 20, 25, 50 years. GED (2009) based on the analysis concluded that the frequency and intensity of flood has increased significantly in last 30 years.

Table 1.1: Return period of flood according to affected area

Flooded Area	Return Period (in 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: GED 2009

Table 1.2: Frequency of different types of hazards

Decades	No of Events				Total
	Flood	Cyclone	Tornado	Drought	
1980s	1	7	2	3	13
1990s	3	4	1	3	11
2000s	9	7	6	1	23
2010 (up to 08)	6	1	5	0	12
Total	19	19	14	7	

Source: GED 2009

Saline water intrusion: Salinity intrusion will result from less availability of freshwater and sea level rise. The coastal zones are the most vulnerable areas to salinity intrusion. Soil Resources

Development Institute (SRDI, 1998) compared salinity map for the period of 1967 and 1997 and found evidance on insutions in the soil of Jessore, Magura, Narail, Faridpur, Gopalgonj and Jhalokati in two decades.

Sea Level Rise (SLR): The SLR study by Khan *et al*. (1999) using the tidal data for the tide gauges in Hiron Point, *Char* Changa and Cox's Bazar found relative SLR at the rate 4.0, 6.0 and 7.8 mm/year respectively mm/year during the last two decades (1977-1998). Alam (1996) has shown that around the city of Dhaka, average subsidence is about 0.62 mm/year, elsewhere, it can exceed 20 mm/year due to tectonic subsidence in the Ganges-Brahmaputra delta of Bangladesh. Khan *et al*. (1999) have pointed out that the relative sea level rise in this coast is the composite of sea level rise due to global warming and that due to physical subsidence of the tectonic plate due to huge amount annual sediment loading by the Ganges- Brahmaputra-Meghna (GBM) system into the Bay of Bengal.

1.3 PROJECTIONS OF REGIONAL CLIMATE FOR SOUTH ASIA AND BANGLADESH

Temperature change scenarios for tropical Asia reported by Whetton (1994) suggest an increase, where the coastal regions would expect less rise compared to continental regions. The scenarios (Whetton, 1994; Climate Impact Group, 1992) with respect to rainfall suggest an increase in rainfall during April to September. In these scenarios, the average rainfall intensity also has found to increase, i.e., there will be more heavy rainfall events (Whetton, *et al*., 1994).

According to World Bank report (2000) (used in MoEF, 2002), predictions for 2030 and 2050 showed increasing trend for sea level, temperature, evaporation and precipitation (fluctuation compared to 1990) for both in monsoon and winter period. Climate Change 2007, the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), is the fourth in a series that presents an exhaustive and detailed summary of the prevailing climate change situation along with future projections for different regions all around the globe. The summary report concludes in two important statements:

- Warming of the climate system is unequivocal.
- Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.

According to the report, projected global average surface warming at the end of the year 2100 under different scenarios (Table 1.3) (based on AOGCMs) will be in the range of 1.1-6.4^{o}C and global sea level rise will be in the range of 0.18 to 0.59m (presented in Table 1.4). Projected precipitation change in Southeast Asia during the 21st century based on AOGCMs will be in the ranges of -16% to 31% in different seasons under different SRES scenarios (presented in Table 1.5).

Table 1.3: Scenario explanations

Abbreviation	Explanations
A 1	The A1 scenarios are of a more integrated world and the A1 family of scenarios are characterized by: ✪ Rapid economic growth; ✪ A global population that reaches 9 billion in 2050 and then gradually declines, the quick spread of new and efficient technologies; ✪ A convergent world - income and way of life converge between regions Extensive social and cultural interactions worldwide.
A1B	A balanced emphasis on all energy sources.
A1FI	An emphasis on fossil-fuels (Fossil Intensive).
A1T	Emphasis on non-fossil energy sources.
A2	The A2 scenarios are of a more divided world. The A2 family of scenarios is characterized by: ✪ A world of independently operating, self-reliant nations; ✪ Continuously increasing population; ✪ Regionally oriented economic development; ✪ Slower and more fragmented technological changes and improvements to per capita income.
B1	The B1 scenarios are of a world more integrated, and more ecologically friendly. The B1 scenarios are characterized by: ✪ Rapid economic growth as in A1, but with rapid changes towards a service and information economy; ✪ Population rising to 9 billion in 2050 and then declining as in A1; ✪ Reductions in material intensity and the introduction of clean and resource efficient technologies; ✪ An emphasis on global solutions to economic, social and environmental stability.
B2	The B2 scenarios are of a world more divided, but more ecologically friendly. The B2 scenarios are characterized by: ✪ Continuously increasing population, but at a slower rate than in A2; ✪ Emphasis on local rather than global solutions to economic, social and environmental stability; ✪ Intermediate levels of economic development; ✪ Less rapid and more fragmented technological change than in A1 and B1.

Table 1.4: Projected global average surface warming and sea level rise under different scenarios

Item	Scenarios					
	B1	A1T	B2	A1B	A2	A1FI
Temperature	1.1 - 2.9	1.4 - 3.8	1.4 - 3.8	1.7 - 4.4	2.0 - 5.4	2.4 - 6.4
Sea Level Rise	0.18- 0.38	0.20-0.45	0.2-0.43	0.21-0.48	0.23 -0.51	0.26-0.59

Table 1.5: Projected precipitation change in Southeast Asia during the 21st century

Sub-regions	Season	2010 - 2039		2040 - 2069		2070 - 2099	
		Scenarios					
		A1FI	B1	A1FI	B1	A1FI	B1
South Asia	DJF	-3	4	0	0	-16	-6
	MAM	7	8	26	24	31	20
	JJA	5	7	13	11	26	15
	SON	1	3	8	6	26	10

Note: DJF: December, January & February; MAM: March. April & May; JJA: June, July & August; SON: September, October &November (-ve : decrease)

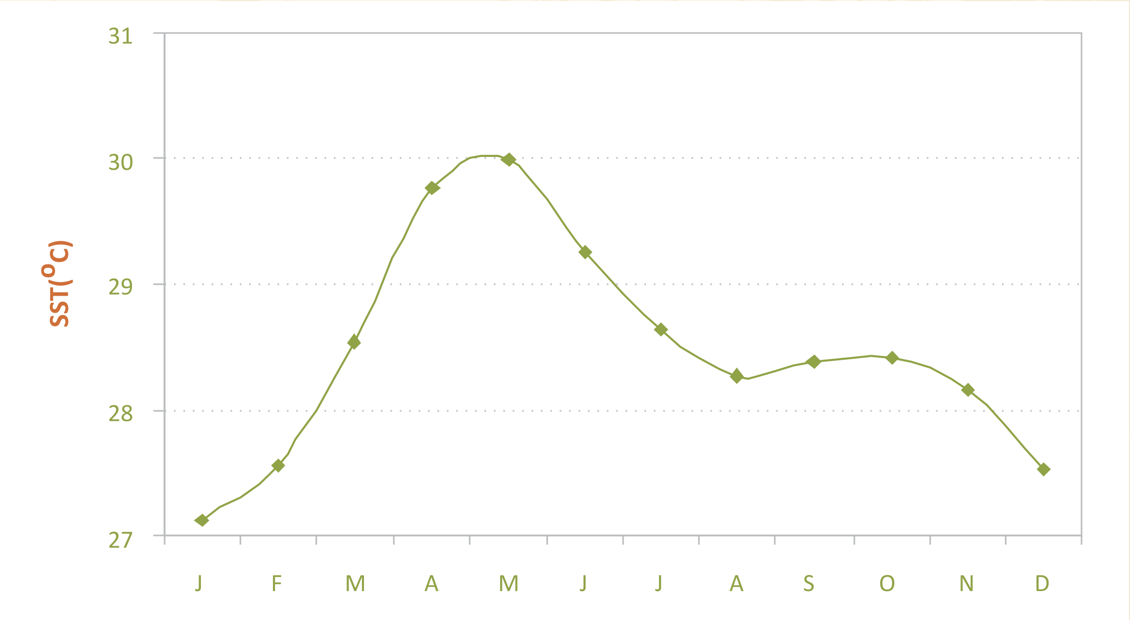
A recent study by BUET, 2008, cited by General Economic Division (GED, 2009) projected an increase in temperature and rainfall in Bangladesh with a comparison of coarse resolution GCM and fine resolution RCM results (Table 1.6). Dry season rainfall will be less and rainfall in monsoon period will be much higher. Rainfall is predicted to become both higher and more erratic, and the frequency and intensity of droughts are likely to increase, especially in the drier northern and western parts of the country (MoEF, 2009).

Due to coarser resolution of the GCM models (global circulation model), the prediction (higher confidence) with respect to cyclone cannot be made (IPCC, 2007; Achanta, *et al*., 2001). Bengtsson *et al*., 1995 found a decrease in number of cyclone, where Holland (1997) indicated that tropical cyclones are unlikely to be more intense except in areas, where sea-surface temperature (SST) is between 26^0C and 29^0C, which is generally the case (Figure 1.1) in Bay of Bengal (Quadir and Iqbal, 2008).

Table 1.6: Climate change scenarios for Bangladesh

Model	Year	Temperature Change (^{0}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	
RCM	2030 (min)	1.18	0.65	1.87*				
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	
RCM	2050 (min)	1.24	0.59	1.65*				

*Source: GED 2009; Note * = JJAS (June, July, August, September)*



Data source: Quadir and Iqbal 2008, NOAA NCEP-Reanalysis data archive

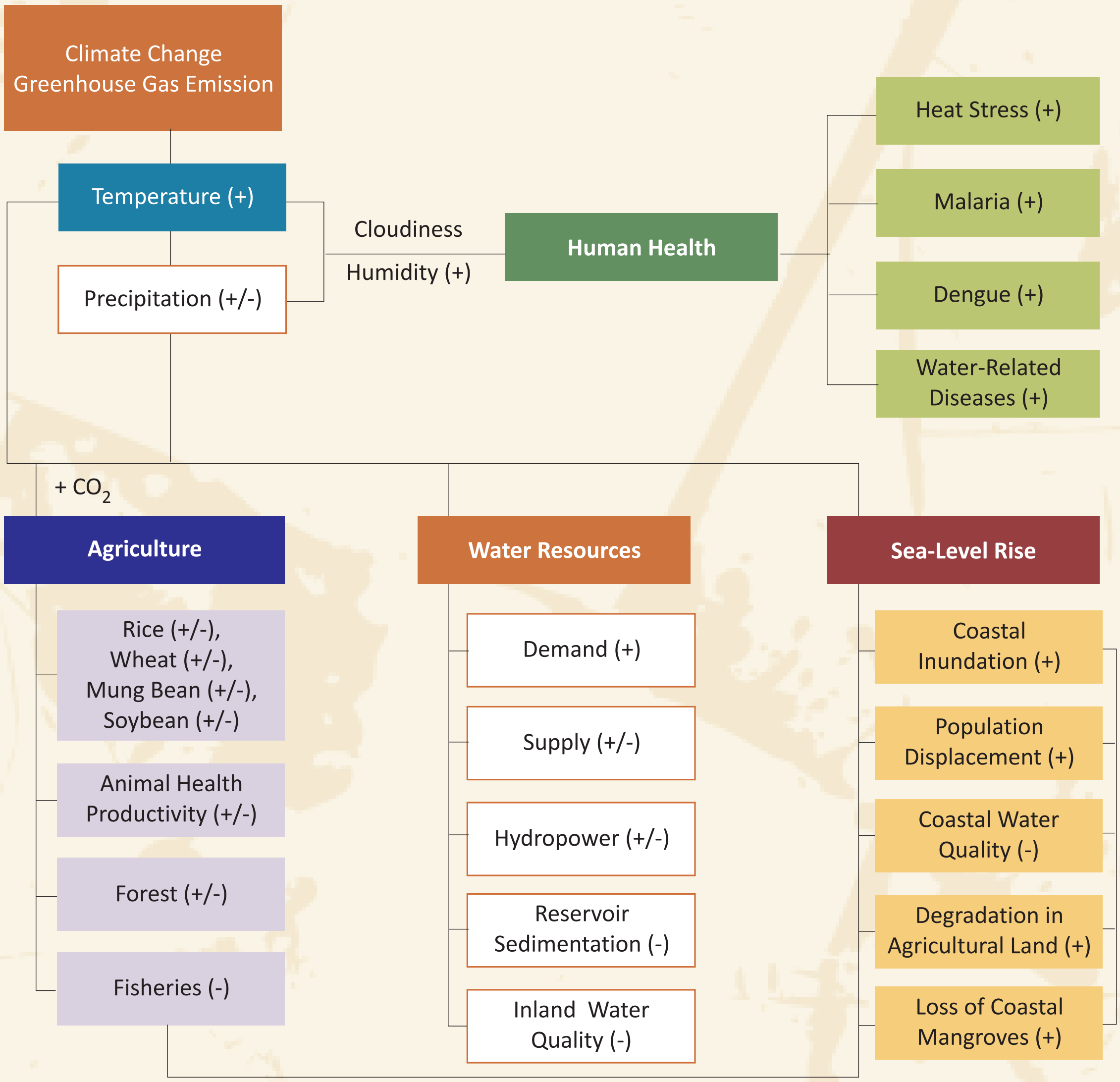
Figure 1.1: The climatology of mean SST in the Bay of Bengal from 1981-2007

1.4 POSSIBLE IMPACTS OF CLIMATE CHANGE IN BANGLADESH

As impacts of climate change, by the 2050s, freshwater availability in South Asia (of which Bangladesh is a part) is projected to decrease, coastal areas in this region will be at greatest risk due to increased flooding from the sea, endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise due to projected changes in the hydrological cycle (IPCC, 2007). These predictions are based on coarser models. More specific quantified impacts are less available apart from qualitative once (Achanta, *et al.*, 2001). Figure 1.2 below, shows the possible pathways of impacts on different sectors (Achanta, *et al.*, 2001) with rise in temperature and variability in rainfall for South Asia (Tropical). The major areas are – human health, agriculture, livestock, fisheries and forest, water resources, and coastal areas. Similar impacts can be expected at country level like Bangladesh.

According to the Bangladesh Climate Change Strategy and Action Plan 2009 (MoEF, 2009), followings are the possible impacts of climate change in the context of Bangladesh:

- **increasingly frequent and severe tropical cyclones,** with higher wind speeds and storm surges leading to more damage in the coastal region;
- **heavier and more erratic rainfall in the Ganges-Brahmaputra-Meghna system,** including Bangladesh, during the monsoon resulting in;
- **higher river flows**, causing over-topping and breaching of embankments and widespread flooding in rural and urban areas;
- **river bank erosion** resulting in loss of homes and agricultural land to the rivers;
- **increased sedimentation in riverbeds** leading to drainage congestion and water-logging;



(+ = projected increase, - = projected decrease). Source: (Achanta, et al., 2001)

Figure 1.2: Possible climate change-related impacts in Tropical Asia

- **melting of the Himalayan glaciers,** leading to higher river flows in the warmer months of the year, followed by lower river flows and increased saline intrusion after the glaciers have shrunk or disappeared;
- **lower and more erratic rainfall,** resulting in increasing droughts, especially in drier northern and western regions of the country;
- **sea level rise** leading to submergence of low lying coastal areas and saline water intrusion up coastal rivers and into groundwater aquifers, reducing freshwater availability; damage to the Sundarbans mangrove forest, and drainage congestion inside coastal polders, which will adversely affect agriculture;

- **warmer and more humid weather** leading to increased prevalence of disease and disease vectors;
- **shortage of drinking water** is likely to become more pronounced specially in the coastal belt and drought prone areas;
- **increased riverbank erosion and saline water intrusion** in coastal areas are likely to displace hundreds of thousands of people who will be forced to migrate, often to slums in Dhaka and other big cities.

1.5 NEED FOR MONITORING MECHANISM

Changes in the climatic parameters (temperature, rainfall, cyclone) and the resultant impacts in other system or other sectors needs quantification. The basic question for instance is - what is the impact of change in temperature in the productivity of agricultural crop. It ushers the need that a monitoring mechanism should exists to establish cause-effect relationship for impact evaluation with certain degree of certainty. For example, if there is an intensive rainfall (in mm), over short period of time (e.g., hr) resulting in flash flood in a season (i.e., pre-monsoon), with consequence of crop (species) damage (ha of area affected), evaluating the impact (cause-effct) requires recording of all the required data (in parenthesis) stated above.

The possible impacts referred by the national documents (e.g., MoEF 2009, MoEF 2005, MoEF 2002) as well as other studies need quantification in order to say with relative confidence that these are the impacts resulted due to climate change. Incidence of natural disasters may increase exponentially with the changing of climate and impact of higher temperature and other extreme events may have serious implications on crop production as well as other sectors.

These changes will threaten the significant achievements Bangladesh has made over the last 20 years in increasing incomes and reducing poverty, will make it more difficult to achieve the MDGs. In view of these expected changes, a systematic monitoring mechanism should be put in place to assess the impact of climate change. In Bangladesh, there is a lack of systematic monitoring to track the changes taking place. Pragmatic planning is needed based on authentic data and analysis which should be done from scientific studies to do so.

As an output of Bangladesh Climate Change Strategy and Action Plan 2009, initiative has been taken to set up a methodology for monitoring mechanism to detect and track the impact of climate change on vulnerable sectors. The ultimate objectives of developing methodology are to-

- help in selecting response measure to climate change;
- help in designing development plan to cope with climate change in future;
- use in developing a coordinated monitoring mechanism in the country.

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CHAPTER – 2

AN OVERVIEW OF SETTING UP MONITORING MECHANISM

Shahzia Mohsin Khan, Eshrat Sharmen, Md. Ahsanul Wahed, Ainun Nishat

2.1 CONCEPTUAL FRAMEWORK

The main feature for developing monitoring mechanism was stakeholder consultation (Figure 2.1). Consultation in various forms, layer and scale took place at various steps. Stakeholders ranged from sectoral experts and professionals from different educational and research institutions, government ministries, department and agencies, and NGOs.

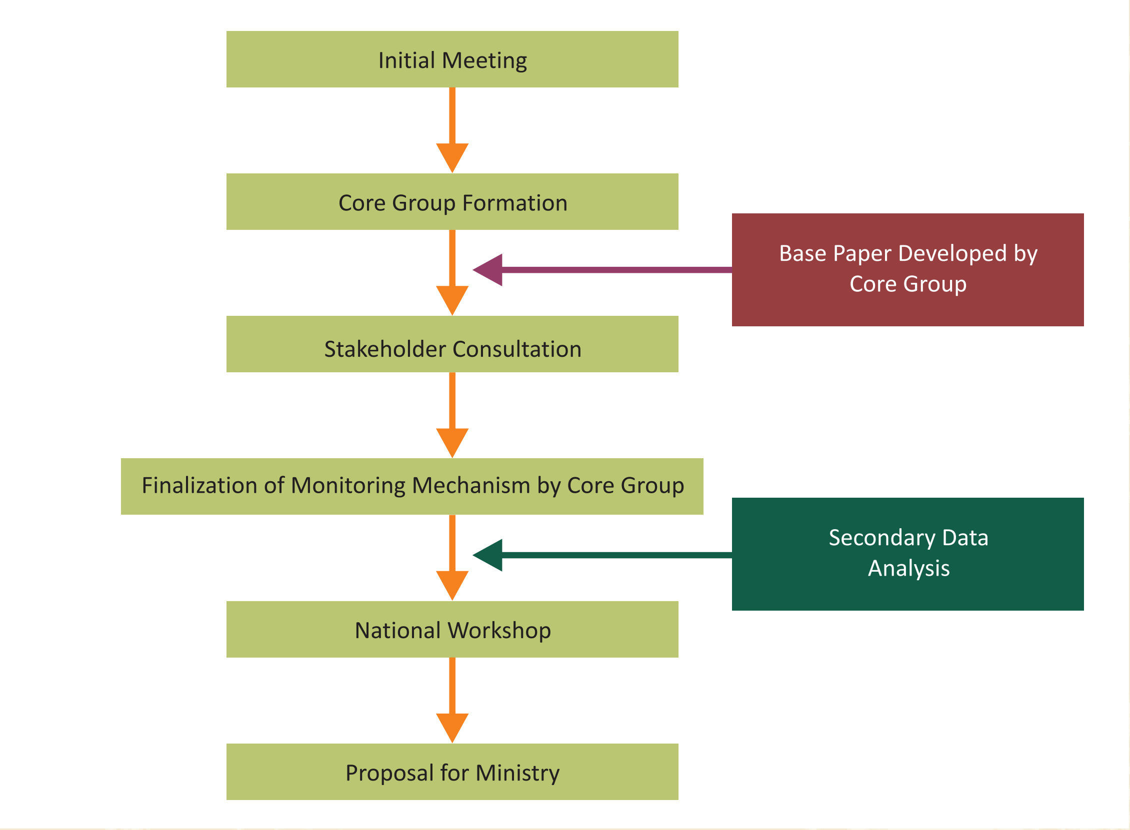

Figure 2.1: Conceptual framework for developing monitoring mechanism

At the initial stage, a tentative list of sectors were identified and consulted among researchers, professionals and government officials. Subsequently decision was made in favour of formation of two groups (Figure 2.1). They are - Core Lead Team (CLT) and the Working Groups (WGs). The CLT was responsible for overall supervision and guidance, comprised of reputed experts. This team was basically a multi-sectoral expert team. Sectoral experts again leaded respective sectoral/thematic teams (or WGs) responsible for developing the thematic methodologies. The each working group reviewed literature, consulted among and beyond and presented their preliminary findings to a wider audience during the first national consultation workshop held in 24th July 2010. Based on the feed back the WGs prepared a preliminary list of indicators and monitoring protocols which were again presented at 2nd and final national consultation workshop on 24th September 2010. List of the participants contributed through the two workshops are given in Appendix 1.

Correction, revision, addition and modification of the indicators and methodologies are conducted on individual reports.

Table 2.1: Snapshot information of whole process

	Task	Output
1	Initiating the planning process (Inception meeting)	Finalization of conceptual framework for developing methodologies Finalization of eight thematic areas based upon the severity of climate change impact and considering some basic aspects Involving two groups namely a) Core Group b) Working group
2	Formulation of high-level Core Group(Leading planning process and providing overall guidance) and working group	Selection of eight thematic group Leaders Finalization of ToR for group leaders Finalization of the names of participants of working group
3	1st Stakeholder consultation (Stock taking and gap identification)	Developed background paper Received feedback
4	2nd Stakeholder consultation. (Eight thematic areas)	Interactive discussion among group participants Come up with some concrete decision
5	Finalization of methodologies	Analyzing secondary data Including Scrutinizing laps and gaps
6	National Workshop (to present the final output)	Presented draft methodologies
7	Reporting	Report on the Monitoring Protocol

2.2 SELECTION OF EIGHT THEMATIC SECTORS

Under this study, different sectors have been identified based upon the severity of impact of climate change and climate variability as identified in key national documents (MoEF, 2002; MoEF, 2005; MoEF, 2009). As being observed and anticipated, the most vulnerable sectors are water, agriculture, biodiversity and forestry, health, ecosystems. In consultation with expert members, considering the abovementioned issues, eight thematic areas and respective team leaders have been clustered which are as follows:

Hydro-meteorology	Dr. Rezaur Rahman
Crop	Dr. Shahidul Islam
Livestock	Md. Abdur Razzaque Mia
Fresh water fisheries	Dr. Abdur Rob Mollah
Marine water fisheries	Mr. Md. Shamsuddoha
Forest, flora and fauna	Mr. Junaid Kabir Chowdhuri
Health	Dr. Md. Sayedur Rahman
Livelihood and poverty	Ms. Sharmind Neelormi

Thematic area "hydro-meteorology" was the first sector under selection in order to monitor climate and changes predicted. This sector is considered the first building block which impinges upon the other sectors – especially natural resources. The country is heavily dependent on agriculture (crop), fishery (inland & coastal), livestock and forest resources. Stresses on these NRM sectors due to climate, change and variability on the other hand have a bearing on the livelihood of the million and in health system.

2.3 APPROACH FOR SETTING UP MONITORING PROTOCOL

A very basic guideline to develop monitoring protocol was given to each team. These are - what are the impacts of climate change on thematic areas, what are the indicators & why selected viz justification, where to measure it (location) & when to measure including frequency of measurement, and in the end, how to analyze the data.

The team was asked to consider the following issues:

- Relevance - importance of the verifier;
- Responsive - change upon; impact/ intervention and easy to detect;
- Cross linkage - easy to connect with other verifiers/indicators;
- Accountability - ease of data collection;
- Ease of assessment - easy to record and interpret;
- Cost - cost of data collection.

The main guiding principle was - a manageable monitoring protocol designed to support adaptation options for the country.

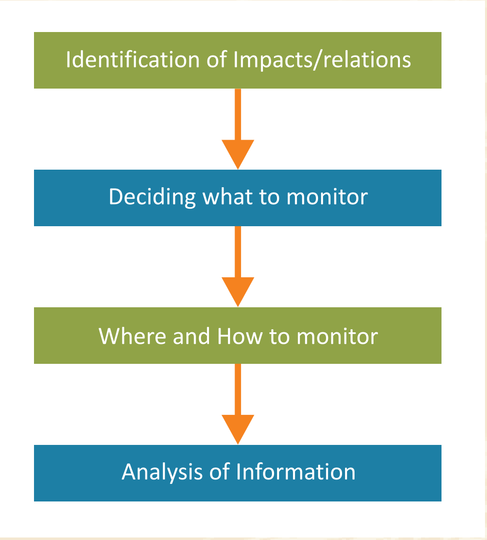

Figure 2.2: Basic guideline for developing monitoring protocol

2.4 CONCLUSION

The primary objective of monitoring methodology is to track changes in the climatic parameters and climate induced impacts on different sectors with the ultimate goal of protecting and managing the vulnerable sectors. In order to achieve this, monitoring methodologies developed to detect, demonstrate and quantify changes which are existing. The methodologies were developed by using available secondary information and through stakeholder consultations.

The long list of indicators identified for eight sectors and the methodologies described can be said the first significant achievement towards achieving the objective. It is apparent that a further assessment and field testing will be necessary towards a more manageable list of indicators and protocol keeping in mind institutional capacity required and cost involved.

Following issues will be critical for smooth operation of the monitoring methodology:

- Secure long term funding ;
- Institutional set up for leading, coordinating and undertaking data collation, storage, analysis and communication;
- Linking monitoring results to decision-making;
- Ensure adaptive mechanisms to allow the review and progressive refinement of the monitoring program e.g., regular critical peer review.

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CHAPTER – 3

INDICATORS TO ASSESS IMPACTS ON HYDRO-METEOROLOGY

Rezaur Rahman, Malik Fida A. Khan, Bushra Nishat,
Nandan Mukherjee, Sultan Ahmed

3.1 BACKGROUND

Intergovernmental Panel on Climate Change (IPCC) in one of its Technical Paper on "Climate Change and Water" identified that several gaps in knowledge exist in terms of observations and research needs related to climate change and water (Bates, *et al.*, 2008). Although observational data and data access are prerequisites for adaptive management, yet many observational networks are shrinking due to lack of available funds and also due to the unavailability of the human resources in the public organizations.

Now-a-days, there is an incremental need to improve understanding and modeling of climate changes related to the hydrological cycle at scales relevant to decision making. Information about the water related impacts of climate change is inadequate in Bangladesh – especially with respect to hydro-meteorological disasters like flood, drought, tidal inundation, storm surge etc. In addition to this, current tools to facilitate integrated appraisals of adaptation and mitigation options across multiple water-dependent sectors are also inadequate.

Thus, better observational data and data access are necessary to improve knowledge of ongoing changes, to enhance model performance, and facilitate adaptive management required under conditions of climate change. A strong and robust hydrometeorology monitoring network is therefore fundamental to further work on detection and attribution of present-day hydrological changes; in particular, changes in water resources and in the occurrence of extreme events.

Hydro-meteorological impacts may be categorized by disasters for understanding of climate change and climate variability. Hereby, monitoring of climate induced extreme events such as increasing frequency and magnitude of floods, cyclones, droughts, erratic rainfall, storms, cold spells etc. demand short-term trend analysis. This entails simulating changes for short-term weather pattern in seasonal cycles and observing trends of annual extremes. On the other hand, relatively short records may not reveal the full extent of natural variability and long term reconstruction can place recent trends and extremes in a broader context. Again, many of the climate change indicators are region specific. This means a reliable and comprehensive hydrometric network and associated climate monitoring for detecting and characterizing climate change and variability, needs to be designed taking into consideration spatial and temporal implications.

In Bangladesh, a hydro-meteorological data collection network maintained by different agencies is already present. Although climatic factors such as air mass volume from northern sub-continent, cloud covering with sunshine factor, emission concentration (GHGs, Sulphur) are missing; basic hydro-meteorological indicators are collected and maintained with these agencies. This existing network will be the foundation of a hydro-meteorological network for detecting and monitoring climate change in Bangladesh.

3.2 HYDRO-METEOROLOGICAL TRENDS

In Bangladesh there are four prominent seasons, namely, winter (December to February), Pre-monsoon (March to May), Monsoon (June to early-October), Post-monsoon (late-October to November). In the following sections, observed trend in the climate variability in terms of change in the temperature and rainfall is expressed in seasonal or four equal three-monthly slabs starting from December covering a complete twelve month to November (DJF, MAM, JJA and SON).

3.2.1 CHANGE IN TEMPERATURE

Increasing surface air temperature is most prominent in Bangladesh, where an increasing trend and temporal variation in the mean seasonal temperature is observed within the range of 0.4^{0}C - 0.65^{0}C during the past 40-year period (1967-2007). Over the past few decades, a warmer winter is being experienced by the country with a prominent increase in the minimum temperature. Similar to this, more hot summer is also experienced during the pre-monsoon and monsoon seasonal months when a prominent rise in the maximum and minimum temperature is observed over the last few decades. A rise in the minimum temperature by 0.45^{0}C and 0.52^{0}C is observed during the winter (DJF) and monsoon (JJA) season respectively. Maximum temperature is also observed to be increased during the pre-monsoon (MAM) and post-monsoon (JJA) month by 0.87^{0}C and 0.42^{0}C respectively. See Figure 3.1 for the trend in maximum and minimum temperature of the Dhaka and Sitakunda station.

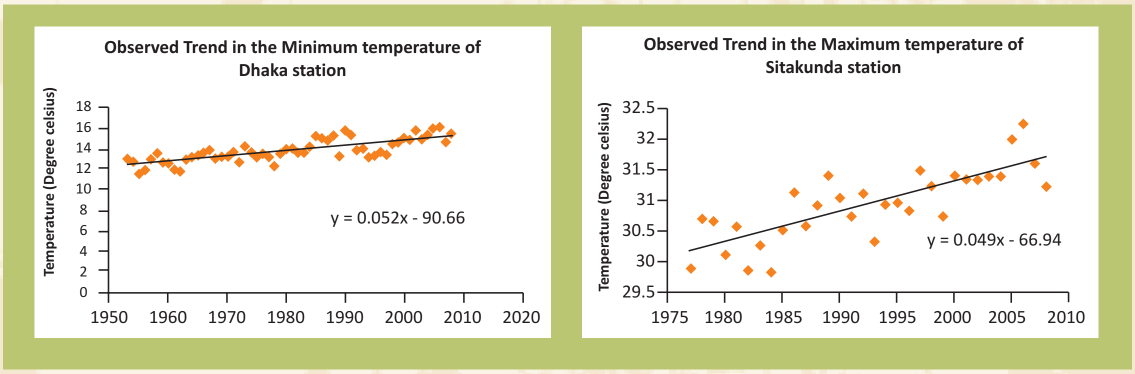

Figure 3.1: Observed trend in minimum & maximum temperature

3.2.2 CHANGE IN RAINFALL

In Bangladesh, in all the seasons an overall increase in the mean seasonal rainfall is observed, where it is found maximum during the pre-monsoon (MAM) and monsoon (JJA) season by around 100 mm increase in the mean seasonal rainfall. Although the winter season (DJF) experiences the minimum rainfall, historical trend is showing a positive inclination in 27 out of 32 rainfall observatories of the BMD. This trend is prominent in the coastal region in the range of 1.2 to 2.1 mm/year increase in the mean seasonal rainfall.

Increase in the Pre-monsoon (MAM) seasonal rainfall is also evident in 30 out of 32 stations of BMD, where it is also prominent in the coastal region in the range of 8-13 mm/year increase in the mean seasonal rainfall. Post-monsoon (SON) rainfall is also observed to be increase in 24 out of 32 meteorological stations, which is prominent in the coastal observatories of Khepupara, Kutubdia, Mongla and in Teknaf stations in the range of 12-24 mm/year (see Figure 3.2 for example).

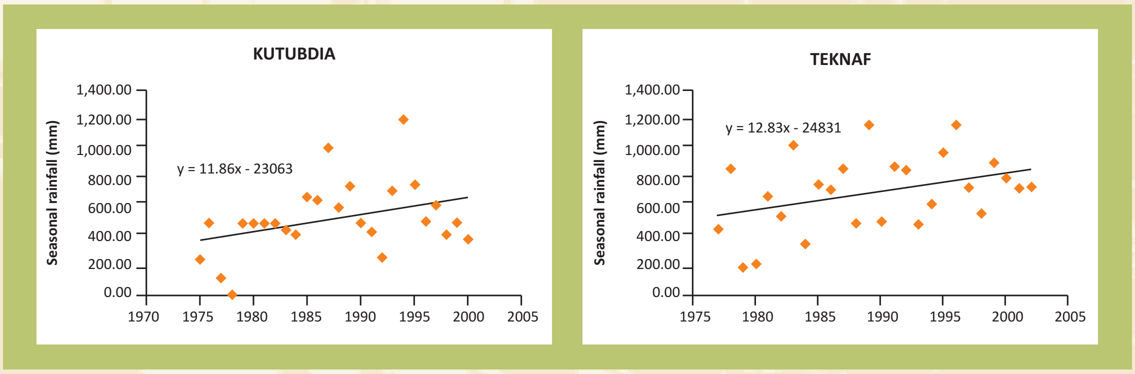

Figure 3.2: Observed trend in seasonal mean rainfall for post-monsoon seasonal month

Ten (10)-day zero rainfall is an index of meteorological drought. As evident from above that most of the regions are experiencing more rainfall in recent years, the overall occurrences of meteorological drought is also observed to be decreasing in the recent years. A decreasing trend is observed in a total of 26 out of 32 rainfall stations of BMD. It is also interesting to observe that the stations which are showing a decreasing trend four coastal zone stations can be ranked in the top (Khepupara, followed by Bhola, Rangamati and Sitakunda).

In recent years, the intensity of daily rainfall is also increasing. It is evident from 25 out of 32 rainfall stations of BMD. Out of these stations, coastal rainfall station in Kutubdia ranked highest in terms of the count of number of rainy days/year that exceeds the threshold of 95% non-exceedence probability rainfall value. It is followed by other coastal districts like Mongla, Feni, Khepupara, Teknaf, Sitakunda and Rangamati where the increasing trend is also observed. It is quite alarming to observe one evidence in the Kutubdia, where during the 80's, average annual incidence of exceedence is found as 13 days/year which just increases to doubled during the next decade (90's).

3.2.3 SEA LEVEL RISE

Bangladesh is highly vulnerable to sea level rise, as it is a densely populated coastal country of smooth relief comprising broad and narrow ridges and depressions (Brammer, *et al*., 1993). In the South West region at Hiron point station the mean annual change in the tidal water level has been found as 5.5 mm/year and 5.05 mm/yr in the Cox's Bazar stations (see Figure 3.3 and Table 3.1).

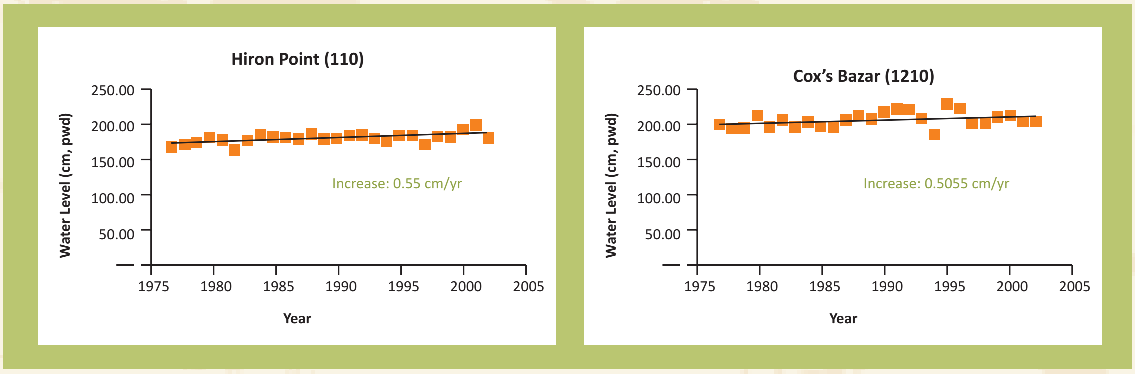

Figure 3.3: Observed trend in sea level rise as evident from different tidal stations along the coast

In the south western (Sundarban) and south eastern part (Cox's Bazar), the observed change in sea level is mostly free from any sort of artificial or man-made interventions and thus the most reliable estimate of mean sea level rise can be taken from these two stations.

Table 3.1: Periodic analysis of observed sea level rise at different tidal water level stations

Observed Water Level (m,PWD)				
Period of analysis	**Hiron Point**	**Moheshkhali**	**Cox's Bazar**	**Sandwip**
1968-1977		207.10		
1977-1986	177.35	214.35	199.87	279.31
1987-1996	182.76	214.97	213.68	337.75
Change in the mean sea level (from trend line)	**0.55 cm/yr**	**0.749 cm/yr**	**0.5055 cm/yr**	**0.7044 cm/yr**

3.2.4 EXISTING HYDRO-METEOROLOGICAL NETWORK IN BANGLADESH

Presently Bangladesh Meteorological Department (BMD) collects meteorological information viz., Evaporation, Humidity, Solar Radiation, Rainfall, Sunshine Hours, Temperature and Wind Speed from their 36 data collection stations allover Bangladesh. BWDB collects hydrologic information such as rainfall, water level and discharge data. Furthermore, BIWTA also collects water level data from 43 tidal stations. Brief profile of the category of hydro-meteorological data, corresponding period of data availability and total number of available stations along with their respective organization is summarized in the following (Table 3.2).

Table 3.2: Hydro-meteorological network in Bangladesh

Organization on	Collected data type	Data availability	Available station
BMD	Evaporation	1983 to 1996	12
BWDB	Evaporation	1964 to 1998	47
BMD	Humidity	1948 to 2008	34
BMD	Solar Radiation	1983 to 2008	10
B MD	Rainfall	1948 to 2008	34
BWDB	Rainfall	1957 to 2008	312
BMD	Sunshine Hours	1961 to 2008	34
BMD	Temperature	1948 to 2008	34
BMD	Wind Speed	1980 to 2008	34
BWDB	Discharge	1934 to 2003 (Non Tidal), 1964 to 2000 (Tidal)	134 (Non tidal), 16 (Tidal)
BW DB	Water Level	1910 to 2010 (Non Tidal), 1909 to 2009 (Non Tidal)	281 (Non Tidal), 181 (Non Tidal)
BIWTA	Water Level	1977 to 2002 (Tidal)	43 (Tidal)

Other than this, salinity data is measured by the following agencies along the coastal region in Bangladesh on a regular basis,

- Bangladesh Water Development Board (BWDB) – daily and fortnightly; and
- Department of Environment (DoE).

Local level salinity measurements are also done by-

- Khulna Newsprint Mills;
- Mongla Port Authority; and
- Chittagong Port Authority.

Additionally data can be collected on a project basis for defined periods and this data can be used for historical trend analysis. Some of the projects are-

- Delta Development Project;
- BWDB Benarpota Farm;
- Meghna Estuary Study;

- Land Reclamation Project;
- Sundarbans Biodiversity Conservation Project; and
- FAP 4 studies.

3.2.5 URGENCY FOR ESTABLISHING THE MONITORING PROTOCOL

Evidence from historical records and research findings from global scientific community has placed Bangladesh under the spotlight of being the worst victim of climate induced natural disasters. Both the adaptation planning and contingency managements ask for regular monitoring of climate variations which will facilitate applying the combating strategy through identifying the short and long term trend in the weather pattern and annual extremes, perturbation (change) in the seasonal cycle.

But till to date, despite of its repeated exposure to extreme climatic events Bangladesh has failed to setup a reliable and comprehensive network of climate observatory that can disseminate spontaneous hydro-meteorological information to the planners working under the domain of disaster management, water resources planning for agriculture and other important sectors. Given the advances in the monitoring system of the hydro-meteorological parameters, the overall portrayal of the existing hydro-meteorological observation network is somewhat scattered and often leads to confusion in selecting the most representative observation dataset for classifications of homogenous regions for impact assessment and monitoring. Moreover, the quality of dataset of the existing observatories often perturbed by human intervention.

Now-a-days it is imperative to verify results of the climatic forecasts and observations on a grid-by-grid basis, as the model simulated climate change scenarios are only available at some specific grid points. It is also important to track the extreme events (like cyclones) for efficient dissemination of the early warning messages. Monitoring the hydrometric parameters related to climate change viz., sea level rise, temperature in the urban areas are still lacking. Existing tidal water level stations in the coastal region are not adequate to indicate the amount of net sea level rise on a reliable basis, as those are not free from natural and human induced perturbations. Moreover, existing temperature station in and around the urban mega cities are grossly inadequate and not effectively addressing the effect of urbanization on the precipitation and temperature anomalies.

3.3 SELECTION OF PARAMETERS AND INDICATORS

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 of the country. 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 economic development of Bangladesh. The relationship between climate change/variability with the physical vulnerability context is shown below in Figure 3.4, which also acts the conceptual basis for the following methodological steps:

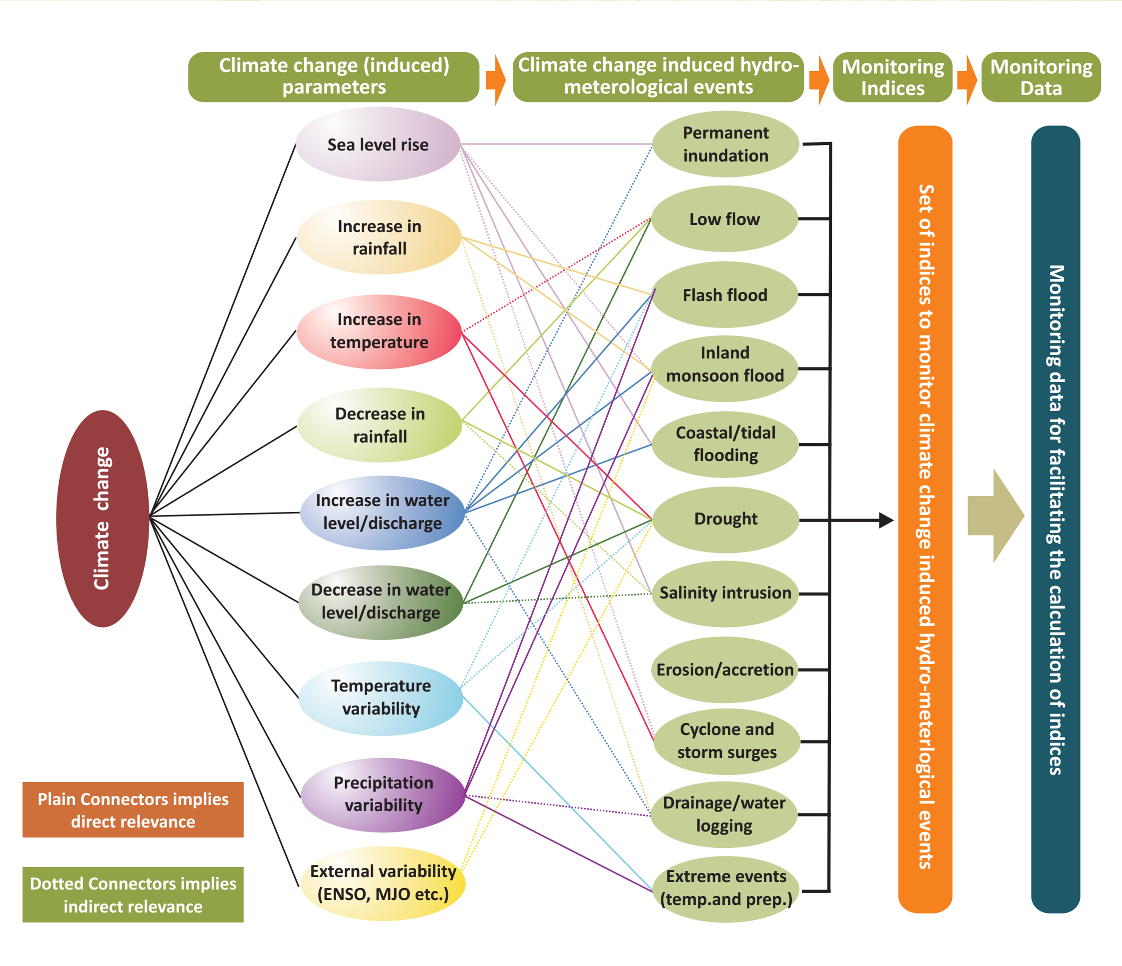

Figure 3.4: Relationship of climate change and variability with physical vulnerability context

A hierarchical methodological approach has been followed here for the selection of hydro-meteorology cal parameters and also to prioritize (rank) the parameters to facilitate the planners to monitor the impact of climate change in a more systematic and efficient manner. The steps are as follows:

STEP-1- SELECTION OF HYDRO-METEROLOGICAL EVENT

Based on this relationship diagram (Figure 3.4) the following hydro-meteorological events have been identified that may be impacted or altered by climate change/variability:

1. Permanent inundation
2. Flash flood
3. Coastal/tidal flooding
4. Inland monsoon flood
5. Cyclone and storm surges
6. Low flow
7. Drainage
8. Morphology
9. Drought
10. Salinity intrusion
11. Extreme events (temp. and prep.)

STEP-2: SELECTION OF MONITORING PARAMETERS

For the monitoring of the above-mentioned hydro-meteorological events, a total of eight monitoring parameters have been identified:

1. Sea level rise
2. Increase in evaporation
3. Increase in temperature
4. Erratic temperature
5. Decrease in rainfall
6. Erratic rainfall
7. Increase in rainfall
8. External variability (ENSO, MJO etc.)

It is to be noted that the effect of climate change (long-term mean) and the effect of climate variability (fluctuation/anomaly) is differentiated and proposed to be monitored separately. The effect of climate change is proposed to be monitored by change or trend (increase or decrease) in the meteorological parameters (see parameter 1,2,3,5,7 and 8). On the other hand, erratic behaviour in the hydro-meteorological extreme events is proposed to be monitored and analyzed separately (see parameter 4 and 6).

STEP-3: SELECTION OF INDICATORS

Derived indicators based on these collected data maybe necessary for a more comprehensive understanding of climate change and its impacts. For the derivation of indicators following principles have been followed:

- The indicator should be quantifyable, able to check statistically significance in the hydro-meteorological events.
- The indicator should check whether any trend exists or not in the past observations.
- The magnitude of change in a seasonal or annual basis and the deviation from the mean to delineate the extreme events should be captured from the derived indicator.
- The correlation between the global warming phenomenon and the change in the hydro-meteorological extremes should be interpreted by the indicator.

A total of 100 indicators have been derived covering all of the above-listed eight monitoring parameters. The list of indicator is given below (Table 3.3):

Table 3.3: Complete list of derived indicators for different event and for different monitoring parameters

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators
Permanent inundation	Sea level rise	Sea level (daily)	Historical trend in the change of sea level
		Sea level (daily)	Annual rate of change in the sea level
		Sea level (daily)	% (km) increase of inland propagation of sea level
Low flow	Increase in temperature	Temperature (daily)	Historical trend in the seasonal maximum temperature

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators
		Temperature (daily)	Magnitude and standard deviation of the seasonal maximum temperature
	Decrease in water level	Water level (daily)	Historical trend in the seasonal minimum water level
		Water level (daily)	Magnitude and standard deviation of the seasonal minimum water level
		Water level (daily)	Change in date and duration of each seasonal 1-day minimum
		Water level (daily)	Change in the frequency of the low flow event
		Water level (daily)	Count of days when water level <= 10th percentile
	Decrease in rainfall	Rainfall (daily)	Historical trend in the seasonal rainfall
		Rainfall (daily)	Magnitude and standard deviation of the seasonal rainfall
		Rainfall (daily)	Maximum number of consecutive days with rainfall <=1mm
Flash flood	Increase in rainfall	Rainfall (daily)	Historical trend in the pre-monsoon (MAM) maximum rainfall
		Rainfall (daily)	Maximum number of consecutive days in the pre-monsoon (MAM) with rainfall >=1mm
	Increase in water level	Water level (daily)	Trend in the maximum daily water level during the pre-monsoon season (MAM)
		Water level (daily)	Standard deviation in the maximum daily water level during the pre-monsoon season (MAM)
		Water level (daily)	Change in the date of occurrences of maximum daily water level during the pre-monsoon season (MAM)
		Water level (daily)	Change in the area of annual flash flood extent
		Water level (daily)	Count of days when seasonal (MAM) maximum water level >= 90th percentile
	Increase in evaporation	Evaporation (daily)	Trend in the pre-monsoon maximum evaporation

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators
		Evaporation (daily)	Magnitude of the daily total evaporation
		Evaporation (daily)	Standard deviation daily total evaporation
	Erratic temp.	Temperature Variability (daily)	Historical trend in the 1-day maximum temperature
		Temperature Variability (daily)	Annual count of days with at least 6 consecutive days when daily maximum temperature > 90th percentile
		Temperature Variability (daily)	Percentage of days when daily maximum temperature >90th percentile
	Erratic prep.	Rainfall Variability (daily)	Trend in the pre-monsoon (MAM) maximum 1-day precipitation
		Rainfall Variability (daily)	Deviation in the magnitude of the pre-monsoon (MAM) maximum consecutive 5-day precipitation
		Rainfall Variability (daily)	Deviation in the maximum number of consecutive days with rainfall>=1mm during pre-monsoon (MAM)
		Rainfall Variability (daily)	Change in the pre-monsoon (MAM) count of days when prcp>=10mm
		Rainfall Variability (daily)	Change in the count of days when prcp>=20mm during pre-monsoon (MAM)
Inland monsoon flood	Sea level rise	Sea level (daily)	Status of tidal water level in the coastal region during the occurrences of flood
	Increase in rainfall	Rainfall (daily)	Historical trend in the monsoon (JJAS) maximum rainfall
		Rainfall (daily)	Maximum number of consecutive days in the monsoon (JJAS) with rainfall >=1mm
	Increase in water level	Water level (daily)	Historical trend in the change of annual maximum water level
		Water level (daily)	Change in the frequency of annual maximum water level
		Water level (daily)	Change in date in the occurrences of each annual 1-day maximum
		Water level (daily)	Change in the area of annual flood extent

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators
		Water level (daily)	Count of days when annual maximum water level >= 90th percentile
	Erratic prep.	Rainfall Variability (daily)	Trend in the monsoon (JJAS) maximum 1-day precipitation
		Rainfall Variability (daily)	Deviation in the magnitude of the monsoon (JJAS) maximum consecutive 5-day precipitation
		Rainfall Variability (daily)	Deviation in the maximum number of consecutive days with rainfall>=1mm during monsoon (JJAS)
		Rainfall Variability (daily)	Change in the monsoon (JJAS) count of days when prcp>=10mm
		Rainfall Variability (daily)	Change in the count of days when prcp>=20mm during monsoon (JJAS)
	External variability (ENSO, MJO etc.	ENSO and MJO Index (Annual)	Annual occurrences of el niño and la niña event and correlation with flood occurrences
Coastal/tidal flooding	Sea level rise	Sea level (daily)	Historical trend in the change of sea level
		Sea level (daily)	Annual rate of change in the sea level
		Sea level (daily)	% (km) increase of inland propagation of sea level
	Increase in water level	Water level (daily)	Historical trend in the change of maximum tidal water level
		Water level (daily)	Annual rate of change in the tidal maximum water level
		Water level (daily)	Change in the tidal amplitude of the annual maximum tide level
		Water level (daily)	% (km) increase of inland tidal penetration
Drought	Increase in temperature	Temperature (daily)	Historical trend in the dry seasonal (pre-monsoon and post-monsoon: DJF, MAM) maximum temperature
		Temperature (daily)	Percentage of days when temp>=90th percentile
	Decrease in rainfall	Rainfall (daily)	Maximum number of consecutive days with rainfall<=1mm

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators
		Rainfall (daily)	Historical trend in the mean annual rainfall
		Rainfall (daily)	Magnitude and duration of the annual minimum rainfall
	Erratic temp.	Temperature Variability (daily)	Historical trend in the 1-day maximum temperature
		Temperature Variability (daily)	Annual count of days with at least 6 consecutive days when daily maximum temperature > 90th percentile
		Temperature Variability (daily)	Percentage of days when daily maximum temperature >90th percentile
		Temperature Variability (daily)	Monthly maximum value of daily maximum temp
	External variability (ENSO, MJO etc.)	ENSO and MJO Index (Annual)	Annual occurrences of el niño/la niña event
Salinity intrusion	Sea level rise	Salinity level (periodic)	Historical trend in dry seasonal salinity concentration
		Salinity level (periodic)	Change in the mean annual concentration
		Salinity level (periodic)	Propagation of salinity isoline during the dry season
	Decrease in discharge	Discharge (daily)	Change in the magnitude of the annual minimum discharge
		Discharge (daily)	Change in date and duration of each annual 1-day minimum discharge
	Decrease in rainfall	Rainfall (daily)	Deviation in the magnitude of the dry seasonal rainfall
		Rainfall (daily)	Maximum number of consecutive days with rainfall <=1mm
Morphology	Increase in rainfall	Rainfall (daily)	Historical trend in the monsoon (JJAS) maximum rainfall
		Rainfall (daily)	Deviation of the annual maximum rainfall
	Increase in discharge	Discharge (daily)	Historical trend in the change of discharge

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators
		Discharge (daily)	Annual rate of change in the discharge
		Discharge (daily)	Change in the duration of the occurrences of 1-day maximum water level >= 90th percentile
		Erosion and accretion extent (seasonal)	Trend and magnitude in the % of area under erosion and accretion
Cyclone and storm surges	Increase in temperature	Sea surface temperature (daily)	Monthly maximum value of daily maximum temp
		Sea surface temperature (daily)	Percentage of days when temperature >= 26° Celsius
	Increase in wind speed	Wind speed (hourly)	Trend in the maximum wind speed
		Wind speed (hourly)	Magnitude and deviation from the mean maximum wind speed
	Increase in depression	Signals (hourly)	No. of depressions formed (category wise)
		Signals (hourly)	
	Sea level rise	Sea level (daily)	Status of sea level during the season of cyclone formation
Drainage	Increase in rainfall	Rainfall (daily)	Historical trend in the mean annual rainfall
		Rainfall (daily)	Magnitude of the seasonal maximum rainfall
	Erratic prep.	Rainfall Variability (daily)	Monthly maximum 1-day precipitation
		Rainfall Variability (daily)	Monthly maximum consecutive 5-day precipitation
		Rainfall Variability (daily)	Maximum number of consecutive days with rainfall>=1mm
		Rainfall Variability (daily)	Annual count of days when prcp>=10mm
		Rainfall Variability (daily)	Annual count of days when prcp>=20mm

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators
	Increase in water level	Water level (daily)	Historical trend in the change of water level
		Water level (daily)	Historical change in the river water level outside the water logged area
		Water logging extent (Seasonal)	Change in the % of water logged area
Extreme events (temp. and prep.)	Erratic temp.	Temperature Variability (daily)	Historical trend in the 1-day maximum and minimum temperature
		Temperature Variability (daily)	Annual count of days with at least 6 consecutive days when daily maximum temperature > 90th percentile
		Temperature Variability (daily)	Annual count of days with at least 6 consecutive days when daily maximum temperature < 10th percentile
		Temperature Variability (daily)	Percentage of days when daily maximum and minimum temperature >90th percentile
		Temperature Variability (daily)	Percentage of days when daily maximum and minimum temperature <10th percentile
	Erratic prep.	Rainfall Variability (daily)	Trend in the annual maximum 1-day precipitation
		Rainfall Variability (daily)	Deviation in the magnitude of the annual maximum consecutive 5-day precipitation
		Rainfall Variability (daily)	Deviation in the annual maximum number of consecutive days with rainfall>=1mm
		Rainfall Variability (daily)	Deviation in the annual maximum number of consecutive days with rainfall <1mm
		Rainfall Variability (daily)	Change in the annual count of days when prcp>=10mm
		Rainfall Variability (daily)	Change in the annual count of days when prcp>=20mm
		Rainfall Variability (daily)	Annual count of days when prcp>=20mm

STEP-4: EVALUATION OF THE INDICATORS

Prior to the evaluation exercise, it is important to distinguish the key actor of the proposed monitoring protocol. Public agencies should be given the lead role in data collection and monitoring of the key indices. The proposed monitoring protocol should be robust, but not precise in such scale that it might not be implemented due to inadequacy of budget, technical insufficiency or lack of human resources. Understanding the reality, each of the indicators has been evaluated in terms of:

1. Relevance - evaluate the importance of the indicator qualitatively in terms of its significance in representing the hydro-meteorological event.
2. Responsiveness - relatively qualify the changes of the indicator upon impact/intervention and ease to detect.
3. Cross linkage - relative scoring to assess the connection with other verifiers/indicators.
4. Accountability - qualitative scoring of effort of data collection.
5. Ease of assessment - qualitative scoring of easiness to record and interpret.
6. Cost - qualitative relativeness of cost of data collection.

The principles and assumptions for scoring are illustrated in the following sub-sections.

RELEVANCE

A five-point scoring approach (1-5) is used here for qualitative categoraization of each of the indicators. For example, % (km) increase of inland propagation of sea level is scored as 5, based on its definitive or direct relevance for interpreting the monitoring parameter "Sea level rise". On the same scale, indicators like historical trend in the change of sea level and annual rate of change in the sea level is scored as 4 based on their probable relevance or indirect relevance in interpreting the same monitoring parameter. It is to be noted that, the scoring assumptions are notional and may vary depending upon the importance of the indicator for use in other disciplinary purpose.

RESPONSIVENESS

Maximum score of 5 is given for direct interpretation of the change in the value of the indicator with a direct change in the climatic changes. For example, low flow event in the rivers is a hydrological phenomenon which can most probably be occured only during the decrease of basin rainfall. The river water level is the first responsive parameter to interpret the occurances of low flow event, and hereby it is scored as 5 and basin rainfall and temperature indicators are scored as 4. Similar assumptions are used for the remaining clusters of indicators for each of the hydro-meteorological events.

CROSS LINKAGE

For assessing the cross-linkage, same 5-point scoring scale set above is used. At first, data requirement for each of the hydro-meteorological events and their corresponding indicators have been identified. Then cross-linkage for each of the data category is assessed from the respective multiple response as drawn in the relationship diagram (Figure 3.4). Assumption for relative scoring procedure is given in the Table 3.4 below:

Table 3.4: Relative scoring criteria for each of the monitoring parameter

Data requirement	Frequency of cross-connectivity	Relative scoring
Rainfall	7	5
Water level	5	5
Rainfall Variability	4	5
Sea level	4	5
Temperature Variability	3	4
Discharge	2	4
ENSO and MJO Index	2	4
Temperature	2	4
Evaporation	1	3
Salinity level	1	3
Sea surface temperature	1	3

ACCOUNTABILITY

Accountabily is an effort representating evaluation criteria for interpreting the easy to collect and ease of assessment. Here a 5-point scale is used representing the maximum score (5) for very easiness to the minimum score for very complexity (1).

For example, BMD and BWDB collect the rainfall and temperature data more uninterruptedly and more frequently than that of hydro-metric data (water level or discharge) collected by the BWDB and BIWTA. In this regard, easiness of rainfall data is scored as 5 and easiness of water level data collection is score as 4. Similar assumptions are used in other indicators while evaluating.

EASE OF ASSESSMENT

Ease of assessment is a technical effort representing evaluation criteria that interprets the easy of assessment of each of the derived indicators. Here the same 5-point scale used in the accountability evaluation is used.

For example, assessment of indicators for representing the change in the rainfall is relatively easier than that of assessing the status of tidal water level in the coastal region during the occurances of flood. In this regard, the rainfall dependent indicator is scored as 5 and the later is scored as 4. Similar assumptions are used in other indicators while evaluating the ease of assessment.

COST

Cost is one of the most important evaluation criteria and a reverse scoring chronology has been adopted here for qualitative evaluation.

For example, collection of tidal water level data in the coastal regional rivers are relatively less costly than establishing new monitoring station in the sea for collecting sea level rise data. In this regard, cost of collecting daily sea level data is scored as -2, whereas score for collecting tidal water level data is given as +1. Similar reverse scoring assumptions have also been used here for evaluation of other indicators.

STEP-5: SELECTION AND PRIORITIZATION OF MOST IMPORTANT INDICATORS

At first, the combined score for each of monitoring indicators based upon the six evaluation criteria have been assessed. The highest and lowest values a verifier can get are 26 and 0 respectively. The lowest value to accept a verifier can be 20 (80%). However, a verifier is rejected if it fails to achieve 20 points.

In the next step, the mean score of each of the eleven cluster of hydro-meteorological event is calculated and ranked in ascending chronology to identify the most important event that needs highest attention while monitoring (See Table 3.5).

Table 3.5: Monitoring parameters for observing hydro-meteorological impacts in Bangladesh

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators	Monitoring Priority (Rank)
Extreme events (temp. and prep.)	Erratic temp.	Temperature Variability (daily)	Historical trend in the 1-day maximum and minimum temperature	1
		Temperature Variability (daily)	Annual count of days with at least 6 consecutive days when daily maximum temperature > 90th percentile	
		Temperature Variability (daily)	Annual count of days with at least 6 consecutive days when daily maximum temperature < 10th percentile	
		Temperature Variability (daily)	Percentage of days when daily maximum and minimum temperature >90th percentile	

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators	Monitoring Priority (Rank)
		Temperature Variability (daily)	Percentage of days when daily maximum and minimum temperature <10th percentile	
	Erratic prep.	Rainfall Variability (daily)	Trend in the annual maximum 1-day precipitation	
		Rainfall Variability (daily)	Deviation in the magnitude of the annual maximum consecutive 5-day precipitation	
		Rainfall Variability (daily)	Deviation in the annual maximum number of consecutive days with rainfall>=1mm	
		Rainfall Variability (daily)	Deviation in the annual maximum number of consecutive days with rainfall <1mm	
		Rainfall Variability (daily)	Change in the annual count of days when prcp>=10mm	
		Rainfall Variability (daily)	Change in the annual count of days when prcp>=20mm	
		Rainfall Variability (daily)	Annual count of days when prcp>=20mm	
Low flow	Increase in temperature	Temperature (daily)	Historical trend in the seasonal maximum temperature	2
		Temperature (daily)	Magnitude and standard deviation of the seasonal maximum temperature	
	Decrease in water level	Water level (daily)	Historical trend in the seasonal minimum water level	
		Water level (daily)	Magnitude and standard deviation of the seasonal minimum water level	
		Water level (daily)	Change in date and duration of each seasonal 1-day minimum	
		Water level (daily)	Change in the frequency of the low flow event	
		Water level (daily)	Count of days when water level <= 10th percentile	
	Decrease in rainfall	Rainfall (daily)	Historical trend in the seasonal rainfall	
		Rainfall (daily)	Magnitude and standard deviation of the seasonal rainfall	

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators	Monitoring Priority (Rank)
		Rainfall (daily)	Maximum number of consecutive days with rainfall <=1mm	
Coastal/tidal flooding	Sea level rise	Sea level (daily)	Historical trend in the change of sea level	3
		Sea level (daily)	Annual rate of change in the sea level	
		Sea level (daily)	% (km) increase of inland propagation of sea level	
	Increase in water level	Water level (daily)	Historical trend in the change of maximum tidal water level	
		Water level (daily)	Annual rate of change in the tidal maximum water level	
		Water level (daily)	Change in the tidal amplitude of the annual maximum tide level	
		Water level (daily)	% (km) increase of inland tidal penetration	
Drought	Increase in temperature	Temperature (daily)	Historical trend in the dry seasonal (pre-monsoon and post-monsoon: DJF, MAM) maximum temperature	4
		Temperature (daily)	Percentage of days when temp>=90th percentile	
	Decrease in rainfall	Rainfall (daily)	Maximum number of consecutive days with rainfall<=1mm	
		Rainfall (daily)	Historical trend in the mean annual rainfall	
		Rainfall (daily)	Magnitude and duration of the annual minimum rainfall	
	Erratic temp.	Temperature Variability (daily)	Historical trend in the 1-day maximum temperature	
		Temperature Variability (daily)	Annual count of days with at least 6 consecutive days when daily maximum temperature > 90th percentile	
		Temperature Variability (daily)	Percentage of days when daily maximum temperature >90th percentile	
		Temperature Variability (daily)	Monthly maximum value of daily maximum temp	

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators	Monitoring Priority (Rank)
	External variability (ENSO, MJO etc.)	ENSO and MJO Index (Annual)	Annual occurrences of el niño/la niña event	
Flash flood	Increase in rainfall	Rainfall (daily)	Historical trend in the pre-monsoon (MAM) maximum rainfall	5
		Rainfall (daily)	Maximum number of consecutive days in the pre-monsoon (MAM) with rainfall >=1mm	
	Increase in water level	Water level (daily)	Trend in the maximum daily water level during the pre-monsoon season (MAM)	
		Water level (daily)	Standard deviation in the maximum daily water level during the pre-monsoon season (MAM)	
		Water level (daily)	Change in the date of occurrences of maximum daily water level during the pre-monsoon season (MAM)	
		Water level (daily)	Change in the area of annual flash flood extent	
		Water level (daily)	Count of days when seasonal (MAM) maximum water level >= 90th percentile	
	Increase in evaporation	Evaporation (daily)	Trend in the pre-monsoon maximum evaporation	
		Evaporation (daily)	Magnitude of the daily total evaporation	
		Evaporation (daily)	Standard deviation daily total evaporation	
	Erratic temp.	Temperature Variability (daily)	Historical trend in the 1-day maximum temperature	
		Temperature Variability (daily)	Annual count of days with at least 6 consecutive days when daily maximum temperature > 90th percentile	
		Temperature Variability (daily)	Percentage of days when daily maximum temperature >90th percentile	
	Erratic prep.	Rainfall Variability (daily)	Trend in the pre-monsoon (MAM) maximum 1-day precipitation	

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators	Monitoring Priority (Rank)
		Rainfall Variability (daily)	Deviation in the magnitude of the pre-monsoon (MAM) maximum consecutive 5-day precipitation	
		Rainfall Variability (daily)	Deviation in the maximum number of consecutive days with rainfall>=1mm during pre-monsoon (MAM)	
		Rainfall Variability (daily)	Change in the pre-monsoon (MAM) count of days when prcp>=10mm	
		Rainfall Variability (daily)	Change in the count of days when prcp>=20mm during pre-monsoon (MAM)	
Inland monsoon flood	Sea level rise	Sea level (daily)	Status of tidal water level in the coastal region during the occurrences of flood	6
	Increase in rainfall	Rainfall (daily)	Historical trend in the monsoon (JJAS) maximum rainfall	
		Rainfall (daily)	Maximum number of consecutive days in the monsoon (JJAS) with rainfall >=1mm	
	Increase in water level	Water level (daily)	Historical trend in the change of annual maximum water level	
		Water level (daily)	Change in the frequency of annual maximum water level	
		Water level (daily)	Change in date in the occurrences of each annual 1-day maximum	
		Water level (daily)	Change in the area of annual flood extent	
		Water level (daily)	Count of days when annual maximum water level >= 90th percentile	
	Erratic prep.	Rainfall Variability (daily)	Trend in the monsoon (JJAS) maximum 1-day precipitation	
		Rainfall Variability (daily)	Deviation in the magnitude of the monsoon (JJAS) maximum consecutive 5-day precipitation	
		Rainfall Variability (daily)	Deviation in the maximum number of consecutive days with rainfall>=1mm during monsoon (JJAS)	

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators	Monitoring Priority (Rank)
		Rainfall Variability (daily)	Change in the monsoon (JJAS) count of days when prcp>=10mm	
		Rainfall Variability (daily)	Change in the count of days when prcp>=20mm during monsoon (JJAS)	
	External variability (ENSO, MJO etc.)	ENSO and MJO Index (Annual)	Annual occurrences of el niño and la niña event and correlation with flood occurrences	
Drainage	Increase in rainfall	Rainfall (daily)	Historical trend in the mean annual rainfall	7
		Rainfall (daily)	Magnitude of the seasonal maximum rainfall	
	Erratic prep.	Rainfall Variability (daily)	Monthly maximum 1-day precipitation	
		Rainfall Variability (daily)	Monthly maximum consecutive 5-day precipitation	
		Rainfall Variability (daily)	Maximum number of consecutive days with rainfall>=1mm	
		Rainfall Variability (daily)	Annual count of days when prcp>=10mm	
		Rainfall Variability (daily)	Annual count of days when prcp>=20mm	
	Increase in water level	Water level (daily)	Historical trend in the change of water level	
		Water level (daily)	Historical change in the river water level outside the water logged area	
		Water logging extent (Seasonal)	Change in the % of water logged area	
Permanent inundation	Sea level rise	Sea level (daily)	Historical trend in the change of sea level	8
		Sea level (daily)	Annual rate of change in the sea level	
		Sea level (daily)	% (km) increase of inland propagation of sea level	
Salinity intrusion		Salinity level (periodic)	Historical trend in dry seasonal salinity concentration	9

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators	Monitoring Priority (Rank)
		Salinity level (periodic)	Change in the mean annual concentration	
		Salinity level (periodic)	Propagation of salinity isoline during the dry season	
	Decrease in discharge	Discharge (daily)	Change in the magnitude of the annual minimum discharge	
		Discharge (daily)	Change in date and duration of each annual 1-day minimum discharge	
	Decrease in rainfall	Rainfall (daily)	Deviation in the magnitude of the dry seasonal rainfall	
		Rainfall (daily)	Maximum number of consecutive days with rainfall <=1mm	
Cyclone and storm surges	Increase in temperature	Sea surface temperature (daily)	Monthly maximum value of daily maximum temp	10
		Sea surface temperature (daily)	Percentage of days when temperature >= 26^0 Celsius	
	Increase in wind speed	Wind speed (hourly)	Trend in the maximum wind speed	
		Wind speed (hourly)	Magnitude and deviation from the mean maximum wind speed	
	Increase in depression	Signals (hourly)	No. of depressions formed (category wise)	
		Signals (hourly)		
	Sea level rise	Sea level (daily)	Status of sea level during the season of formation of cyclone	
Morphology	Increase in rainfall	Rainfall (daily)	Historical trend in the monsoon (JJAS) maximum rainfall	11
		Rainfall (daily)	Deviation of the annual maximum rainfall	
	Increase in discharge	Discharge (daily)	Historical trend in the change of discharge	
		Discharge (daily)	Annual rate of change in the discharge	

Monitoring event	Monitoring Parameters	Data requirement and (frequency of data collection)	Indicators	Monitoring Priority (Rank)
		Discharge (daily)	Change in the duration of the occurrences of 1-day maximum water level >= 90th percentile	
		Erosion and accretion extent (seasonal)	Trend and magnitude in the % of area under erosion and accretion	

3.4 MONITORING MECHANISM

3.4.1 DATA COLLECTION MECHANISM

TEMPERATURE AND RAINFALL

At present, BMD monitors temperature and rainfall from 34 rainfall and temperature stations in eight hydrological regions spread over all over Bangladesh. One of the key activities for establishing an effective monitoring protocol is to delineate the whole Bangladesh into meteorological homogeneous regions. Following procedure can be followed in this regard:

- Total geographic boundary of Bangladesh should be gridded into a spatial resolution of 0.1^0 latitude by 0.1^0 longitude cells. Further, in order to capture the actual variation of meteorological parameters across the complex geographic terrains (like mountains in the NE and EH region) part should be sub-divided into finer grid cells (i.e., $0.05^0 \times 0.05$). It is intended to assess the variation of meteorological parameters along the parallels on several bands ranging from southern coast towards the northern portion of Bangladesh (covering the windward and leeward side).
- Homogeneity analysis should be carried out for ensuring the data quality.
- For the purpose of analysis, the mean meteorological parameters of each grid cell should be computed. When more than one station falls within a grid cell, either the most reliable station with longer record has been retained or the average of stations with sufficient periods of common record will be taken. This will enable to assign unique mean meteorological parameters values to each grid cell. Subsequently, the analysis will be carried out along different bands for comparing the meteorological parameters variation along the respective bands covering the windward and leeward sides.
- Cluster analysis of the mean meteorological parameters values of the grid cells should be carried out to identify distinct groups of meteorological parameters regimes.
- Analysis of variance will be performed to ascertain the statistical significance of the thus identified groups.

For example, key hydro-meteorological stations can be identified for each of the hydrological regions through Hierarchical Cluster Analysis which aims to build a hierarchy of clusters among the homogeneous hydro-met stations. Specifically, the agglomerative hierarchical clustering procedure can be followed which groups each of cases into progressively larger clusters. In the clustering process, Squared Euclidean Distance procedure can be followed which yields a numeric measure of the distance between two stations from the sum of squared differences in the decadal average statistics.

For demonstration purpose the clustering process is attempted here and a total of 18 homogeneous temperature and same number of rainfall stations have been selected which represents each of the hydrological regions exclusively. Choice among each of the member stations for identification of the key station is dependent upon the following points:

- Frequency of observation is the pivotal determinant in selecting a station. If the number of observation is higher for any station than that of others in the cluster, then it has been selected.
- To cover the heat island effect in temperature, deviation from the above principle is made for the stations located in the divisional head quarters.
- The list of key hydro-meteorological stations representing each of the hydrologic regions is given in the Table below (Table 3.6) and in Figure 3.5. Other than this, in the divisional head quarters it is proposed to place more temperature and rainfall stations at reasonable interval.

Table 3.6: Proposed list of meteorological stations to be included in the monitoring protocol

Region	BMD Station ID	Station name	Monitoring Parameter	
EH	11912	Sitakunda	Temperature	Rainfall
EH	11921	Chittagong		Rainfall
EH	11925	Kutubdia	Temperature	
EH	11927	Coxs bazar	Temperature	Rainfall
NC	10609	Mymensingh	Temperature	Rainfall
NC	12007	Rangamati	Temperature	
NE	11111	Dhaka	Temperature	Rainfall
NW	10120	Dinajpur	Temperature	Rainfall
NW	10208	Rangpur		Rainfall
NW	10320	Rajshahi	Temperature	Rainfall
NW	10724	Sreemangal	Temperature	Rainfall
RE	11814	Hatiya	Temperature	Rainfall
SC	11505	Faridpur	Temperature	Rainfall
SC	11513	Madaripur	Temperature	
SC	11704	Barisal	Temperature	Rainfall
SC	12110	Khepupara		Rainfall
SE	11313	Comilla	Temperature	Rainfall
SE	11316	Chandpur	Temperature	

Region	BMD Station ID	Station name	Monitoring Parameter	
SE	11805	Feni		Rainfall
SE	11809	Maijdee court	Temperature	Rainfall
SW	11407	Jessore		Rainfall
SW	11604	Khulna	Temperature	Rainfall
SW	11610	Satkhira	Temperature	

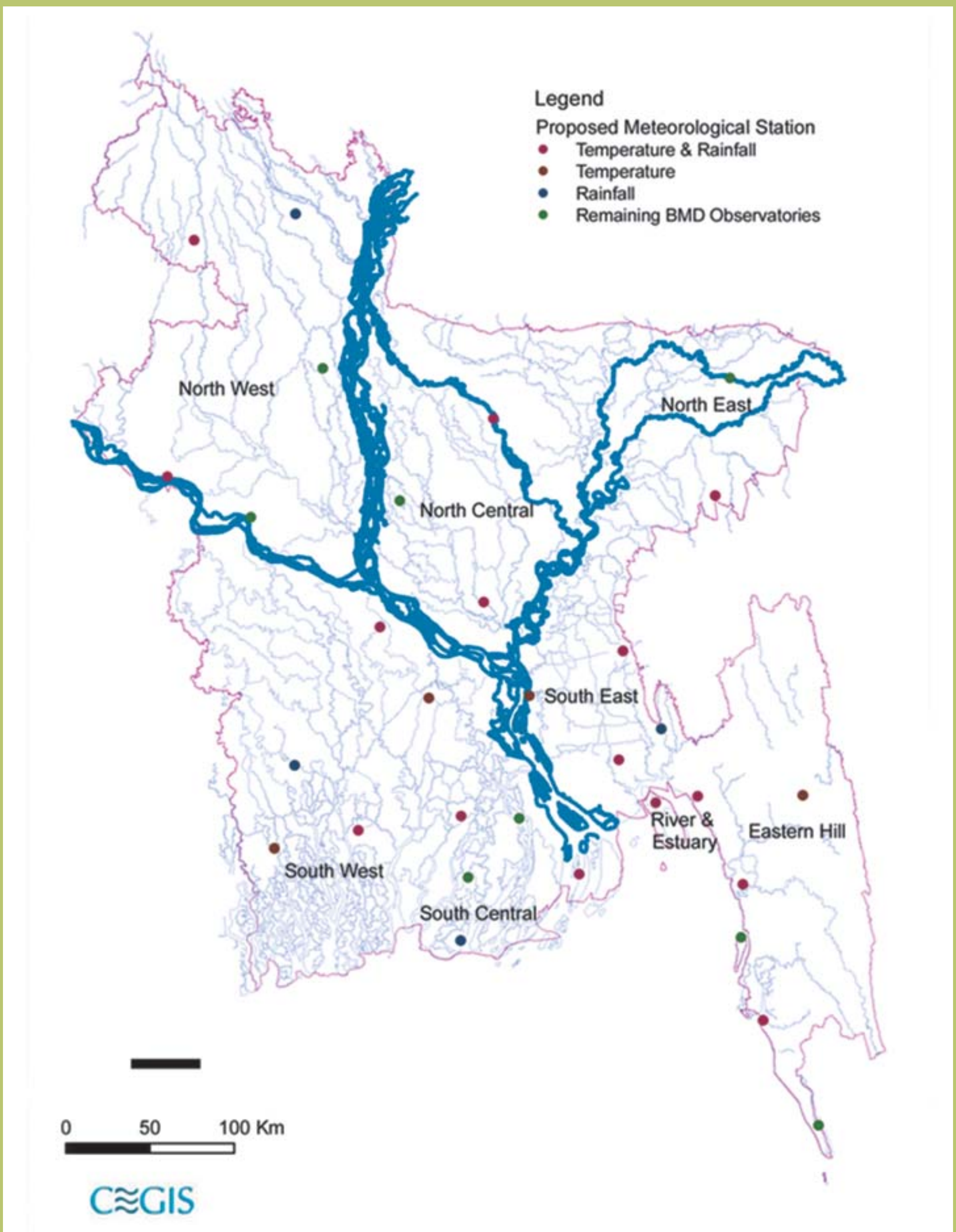

Figure 3.5: Layout of key stations to be included under the monitoring protocol

Data should be collected at a daily basis from the each of the meteorological stations listed above by the BMD for effective monitoring and assessment of climate change induced perturbation in the meteorological parameters.

SEA LEVEL RISE (SLR)

Out of the 181 tidal water level stations of BWDB, around 25 can be used for measuring the influence of sea level along the coast of Bangladesh. Specifically, the following stations (Table 3.7) are more representative among all the stations for measuring the SLR along the coast.

Table 3.7: Representative tidal gauge stations for assessing sea level rise

Station ID	Station Name	River Name
154	Patenga	Karnafuli
20.1	Choto-Bagi	Barisal-Buriswar
290.5	Rangabali	Tentulia
110	Hiron Point	Pussur
279.1	Charfession	Lower Meghna
108	Chardoani	Gorai-Madhumoti
185.1	Gulbunia	Lohalia
176	Lemsikhali	Kutubdia Channel
220.1	Kuakata	Nilakhi
39	Patharghata	Bishkhali
41	Cox's Bazar	Bogkhali

But these stations do not represent the true sea level rise due to the following issues:

- The SLR monitoring stations should be free from natural (especially morphologic) and human influences of infrastructural perturbations.
- Zone of morphological dynamism (sedimentation and subsidence) should be avoided while monitoring the SLR.
- Zone of freshwater influences should be avoided for monitoring of SLR.
- Tectonic influential zones should be avoided.
- Zone with infrastructural influence should be avoided for measuring the SLR.

In this regard, a total of three stations have been proposed (Figure 3.6) to monitor the true SLR in the Bangladeshi coast that can avoid the above-mentioned issues. One is selected 50 km down of Hiron Point Station (ID 110), another is at 53.25 km down of Kuakata station (220.1) and the remaining is at 52.0 km NE of Cox's Bazar location. The stations have been selected to be laid over a straight line to establish a common benchmark for monitoring of SLR in the Bay of Bengal.

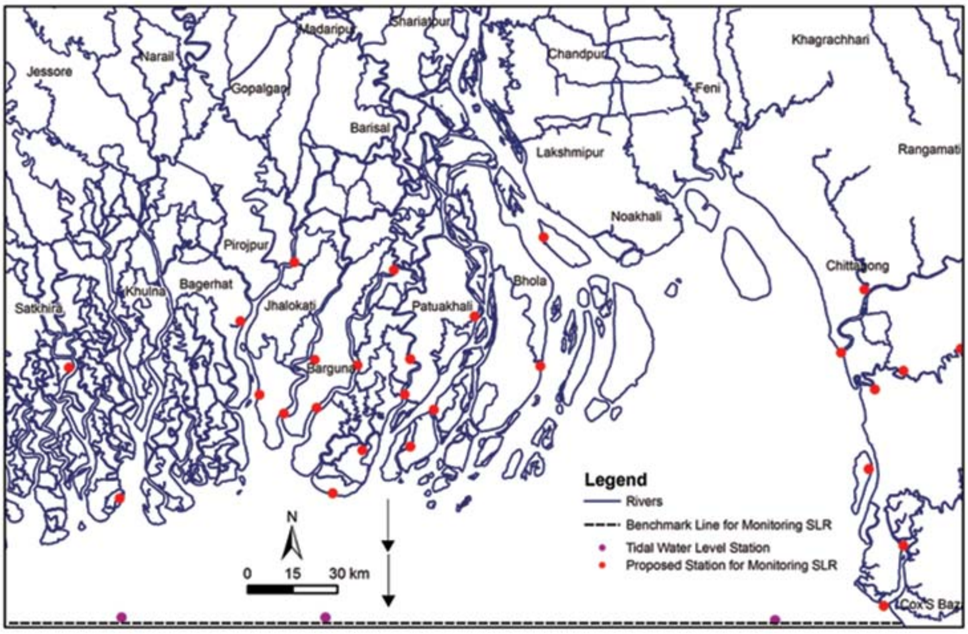

Figure 3.6: Proposed stations for monitoring of sea level rise and existing portray of non-tidal water level stations in the coastal zone of Bangladesh

Sea level rise should be measured by BWDB at hourly interval to cover the effect of tidal fluctuation and net sea level rise.

WATER LEVEL AND DISCHARGE

At present, Flood Forecasting and Warning Center (FFWC) of BWDB monitor the flood in 105 non-tidal and tidal water level stations. But monitoring of the 105 stations for investigating the effect of climate change will be highly expensive in terms of cost and time. In the final stage of monitoring, flood forecasting stations will be selected on the basis of availability of long period data sets and also based on statistically homogeneity.

In this regard, standard statistical testing procedures like the standard normal homogeneity test (SNHT) for a single break (Alexandersson, 1986), the Buishand range test (Buishand, 1982), the Pettitt test (Pettitt, 1979), and the Von Neumann ratio test (Von Neumann, 1941) can be adopted for final selection of the monitoring of flood through the hydro-metric observatories.

Daily water level and discharge data all over the year is adequate enough general purpose of flood frequency analysis. But for early warning system and message dissemination hourly data is crucial and hence it is proposed here to collect hourly data in a no of selected (homogeneous) stations for effective flood monitoring.

SALINITY

Salinity and its seasonal variation are dominant factors for coastal eco-system, fisheries and agriculture, and are expected to be exacerbated by climate change and sea level rise. Therefore it is essential to study the spatial and temporal variation of salinity at different places in the coastal region of Bangladesh.

Saline water intrusion is highly seasonal in Bangladesh, and during November-May deep landwards intrusion occurs through the various inlets in the western part of the delta, and through the Lower Meghna estuary. The dynamics of salinity intrusion in the Ganges-Gorai dependant south west coastal region, the Arial Khan and Lower Meghna dominated central coastal region and the coastal part of the eastern hilly region are separate with different driving forces. Therefore salinity monitoring network will take into consideration the following issues:

South West Coastal Region: The dynamics of salinity intrusion in this area is dominated by the Gorai, the major spill channel from the Ganges and coastal saline water inflow. As a result large parts of the south west region remain the most severely affected by salinity intrusion in November-May when the discharge in the Gorai reduces significantly and in fact in January-February the spill channel remains cut off from the Ganges most of the time. Again in the southern part of this region the coastal saline water inflow dominates over upstream discharge.

South Central Coastal Region and Meghna Estuary: On the other hand, the level of salinity in the south central hydrological region, remain very low even during low flows. This is because a considerable portion of the freshwater discharge is diverted into this region through Arial Khan and different branches of the Meghna at Ilshaghat and drain into the Bay of Bengal through the large rivers in this region.

Coastal part of the Eastern Hilly Region: This area possesses higher land elevation and the main rivers are the Karnaphuli, Matamohuri and Naaf. The salinity variation along the coast is negligible.

Again in each of these regions salinity gradually increases in the seaward direction. To understand the spatial variability salinity monitoring stations need to be identified at shore locations, and also in upstream locations of the rivers in the region. Based on these considerations the following stations can be recommended for monitoring of climate change impacts on salinity in Bangladesh:

South West Coastal Region: Hiron point, Mongla, Khulna and Baradia along the Rupsha-Pussur river system.

South Central Coastal Region and Meghna Estuary: Ilshaghat and Shahbazpur Channel.

Coastal part of the Eastern Hilly Region: Teknaf, Cox's Bazaar and Chittagong.
Timing of development of salinity, maximum salinity and gradual fall of salinity are important factors and any change in this temporal variation can cause severe consequences. The salinity levels in the coastal region show a distinct seasonal variation. Presently, salinity levels are at the minimum at the end of wet season, usually during end-September or early-October. Development of salinity can occur usually around November-January depending on the location and fall during pre-monsoon when upstream discharge increases.

Therefore salinity measurements in mentioned stations need to cover the period October-May.

Measurement of salinity in the aforementioned stations should be done at least on a daily basis. However, it is important to note that the mechanism for movement of water and salinity front in the dry season is very much dependant on the tidal activity. The tides in the coastal and estuarine areas are semi-diurnal with two high and two low periods per day and have maximum amplitude of 3-4 m at spring tide. As a result measurement time is also important, and during low or ebb tide salinity is usually the lowest.

River salinity needs to be measured on a daily basis during low tide.

CYCLONE AND STORM SURGE

At present all the data except the surge height data required for the monitoring of cyclone and storm surge is monitored by BMD (at Kuakata, Cox's Bazar and Dhaka) on a daily basis. Surge height data in the coastal rivers is monitored by BWDB. But for effective monitoring, wind speed and other relevant data should be monitored at a close frequency.

In this regard, wind speed data and monitoring the depressions should be monitored as usual by BMD at the existing stations and water level should be monitored in the proposed stations for monitoring of sea level rise in the Bay of Bengal.

3.4.2 INSTITUTIONAL RESPONSIBILITIES

The Government of Bangladesh recognises that tackling climate change requires an integrated approach involving many different ministries and agencies, civil society and business sector. Thus the monitoring of climate change impact also needs multi-disciplinary involvement. At present, the main Ministries of the Government of Bangladesh involved in climate change are the Ministry of Environment and Forests and its agencies (e.g., the Department of Environment (DoE) and the Department of Forest (DoF)); Ministry of Food and Disaster Management (MoFDM), which includes the Disaster Management Bureau (DMB) and the Comprehensive Disaster Management Programme (CDMP) and Directorate of Relief and Rehabilitation (DRR).

Hydrology Directorate of the Bangladesh Water development Board (BWDB) is responsible for hydro-meteorological data collection like water level, discharge, sediment sample, surface water quality, rainfall and evaporation etc. Flood Forecasting and Warning Centre (FFWC) of BWDB is responsible for flood monitoring and early warning dissemination at the national level.

Existing tidal water level monitoring stations for measuring the change in the sea level is grossly inadequate to represent the climate change induced sea level rise at local scale, as most of the stations are influenced by morphological and anthropogenic responses. Survey of Bangladesh measures sea level rise quite efficiently through only one existing station at the coast.

Other than this, Bangladesh Inland Water Transport Authority (BIWTA) is also responsible for measuring water level, both tidal and non-tidal at different locations. Soil Resource Development Institute (SRDI) is responsible for measuring the soil salinity level and so on. Thus it is clear that the monitoring the evidence and future of climate induced hydro-meteorological disasters has already built in with the day-to-day responsibilities of different organizations, but integration is grossly inadequate to reach a common consensus on the evidence of climate change and to combat the incremental risk exposures.

Bangladesh Government formed a Climate Change Cell in the Department of Environment (DoE). This Cell has been working at the DoE. The Ministry of Environment and Forests has established a Climate Change Unit with necessary staff and officials under a project of two years with a view to establish a permanent Climate Change Wing at the Ministry of Environment to look after the whole activities of climate change at the national level. These Cell and Unit may play a significant role in climate monitoring at national level. Multi-disciplinary experts from different organizations (BMD, BWDB, DAE, SRDI etc.) should be positioned under the same umbrella of Climate Change Cell to ensure integrated monitoring of climate change in Bangladesh.

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CHAPTER – 4

INDICATORS TO ASSESS IMPACTS ON AGRICULTURE SECTOR

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4.1 BACKGROUND

Sustainability of agricultural production systems in Bangladesh are already challenged by declining land and water resources, high input and energy costs, increasing food prices, depressing effective demand by the poor, slow technology generation and so on. On the top of all these, challenges of climate change i.e., floods, droughts, sea level rise, salinity intrusion, cyclones etc. are superimposed, meaning that the country will be exposed to a range of disaster risk and vulnerability and that the ongoing efforts to reduce poverty and hunger might be slowed to some extent. Though the natural disasters affect each and every sector in the country, their impacts are worst in the agricultural sector. The impacts of climate change on agricultural production are global concerns, and are very important for Bangladesh. Agriculture is the single most and the largest sector of Bangladesh's economy, accounting for about 21% of the GDP and about 61% of the labour force.

4.2 CONCERNS ON IMPACT ON AGRICULTURAL SECTOR

Negative impacts of climate change on Bangladesh agriculture as reported in various documents can be summarized as follows: (i) extended flooding of arable land narrowing scope for crop production, especially in the vast low land areas; (ii) increased temperature will lead to increased evapotranspiration and droughts, causing water scarcity for irrigation and domestic uses in north-west Bangladesh; (iii) increased inundation and salinity intrusion, limiting crop cultivation with the existing varieties, especially in the coastal regions; (iv) increased intensity of flash floods in Meghna basin and north eastern Haor area, damaging standing Boro rice crop; (v) increased loss of land through river erosion, reducing land-based livelihood opportunities, and increased drainage congestion and water logging due to sedimentation of rivers, limiting production options for the *char* dwellers/ settlers.

In quantitative terms, IPCC (2007) estimates that, by 2050, changing rainfall patterns with increasing temperatures, flooding, droughts and salinity (in coastal belt) could cause decline in rice production in Bangladesh by 8% and wheat by 32%, against 1990 as the base year (MoEF, 2009). At the country level, studies using crop models with various assumptions about temperature and CO_2 level predicted a general decline in yields and output of rice crop in all seasons in 2050, compared to base year 1990, the rate of reduction varying between crops and models used (Karim, *et al.,* 1996).

The recent estimates using different models with changed assumptions predicts for 2050 reduction in production by 1.5-25.8% for *Aus* rice, and 0.4-5.3% for *Aman* due to the effect of high temperature. For *Boro* rice, production could be increased by 1.2-9.5%, assuming the temperature would not exceed the 35^0C threshold limit for rice production (Hussain, 2008).

The entire area of Bangladesh is more or less prone to adverse impacts of climate change. Despite being a small country, there are some regional variations and differences in the sensitivity to climate change. The north and north-western drought prone areas and coastal regions are particularly sensitive due to specific geo-climatic and human induced conditions. Droughts are associated either with the late arrival or with an early withdrawal of monsoon rains. This phenomenon adversely affects rice crops, which account for more than 80% of the total cultivated land of the country and also causing damage to jute, the country's main cash crop.

The coastal region is composed of the land and the sea including estuaries and islands adjacent to the land water interface of south and southeast Bangladesh. The region covers about 710 km in length and extends along the Bay of Bengal. The coastline has been divided into three distinct sub regions – western (Khulna, Pirojpur, Potuakhali), central (Barisal, Borguna, Noakhali) and eastern (Chittagong). Heavily sediment-laden river water with very little salinity meets with the high saline seawater at the coastal area and creates a unique ecosystem that has given rise to a variety of agricultural systems. The combination of several factors such as monsoon rain, enormous run off and sea level rise due to monsoon wind and the tide creates a hydrological zone which often flooded the coastal region, particularly in the eastern and central region.

From Bangladesh perspective, floods are among the most regular and hazardous natural disasters in terms of human suffering and economic losses. It has been identified that, timely flood forecasts and warnings are key elements to aid disaster preparedness, which in turn will reduce flood damages and human sufferings to a great extent. Damage from flash flooding has been increasing each year resulting loss of crops, property and production as well as affecting agricultural activities in the flooded areas. The non-structural methods of mitigation of flood hazards are very cost effective compared to structural ones (dams and dikes). Among non-structural methods, modern flood forecasting and the use of the real-time data collection systems have increasingly been favoured by countries prone to flood hazards. Flood risk mapping is required to provide information concerning flood risk areas to residents in flood prone areas and to establish flood protection system. In determination of Decision Support System for flood risk assessment, it is of utmost importance to apply the people participatory methods in flood forecasting and warning system associated with real-time data collection system.

Climate change has impacted adversely in the north-eastern haor area and intensified severity of flash floods significantly in last few years. For example, in recent years, flash flood hits Sunamganj District and other haor areas about fifteen days earlier which was usually happened thirty to forty years before. This flash flood damages the *boro* rice (only crop in haor basin) just before the harvesting time of the crop. It even does harm tremendously to the economy and livelihood of the region.

To change the situation of locality's livelihood, the *boro* rice needs to be protected from the flash flood. Present farmers' practice of growing BRRI *dhan*-29 rice which is a long duration rice variety and highly exposed to damage by flash floods. The research has targeted to identify either a short duration but high yielding rice variety or any suitable alternative crop which is found suitable in the context of economically viability and can address issues of climate changes.

4.3 MONITORING PARAMETERS AND INDICATORS

Crop	Climatic variability/ Indicator	Crop Indicator	Monitoring parameters	Monitoring time	Monitoring area
Aus Rice	Erratic rainfall during seeding/ transplanting	Early/Delay crop establishment, Poor phenotypic acceptability	Seeding date/transplanting date, Crop growth behavior	April - May	Kushtia, Rajshahi, Faridpur, Comilla, Noakhali, Potuakhali,
	High temperature (Early Aus)	Occasional high temperature injury during anthesis	Sterility, Yield and yield components	May - June	Rajshahi, Patuakhali
Aman Rice (T. Aman)	Excess rainfall/flood/flash flood at early vegetative stage	Submergence, Poor plant population, Poor phenotypic acceptability	Inundation period, Frequency of inundation, Water temperature, water turbidity, Yield and yield components	August - September	Rangpur, Sirajganj, Sylhet, Barisal
	Drought at early vegetative stage (late rainfall)	Late seed bed preparation Late crop establishment	Seeding and transplanting time	July - August	Rajsahi, Kustia, Faridpur, Jessore

Crop	Climatic variability/ Indicator	Crop Indicator	Monitoring parameters	Monitoring time	Monitoring area
	Drought at the reproductive phase	Poor crop growth, Sterility, low yield	Rainfall, soil crack, soil moisture, Yield and yield components	October	Rajsahi, Kustia, Faridpur, Jessore
Boro Rice	Flash flood	Crop damage during maturity	Area, Rainfall, Weather and Flood forecasting system during onset of flood, days of crop submergence	April - May	Haor areas
	Low and high temperature	Slow growth of seedling and early vegetative stage because of low temperature	Seedling vigor, Poor plant growth	December - January	Haor areas
		Reproductive phase of early established crop affected because of low temperature	Sterility, Poor panicle exertion, yield and yield components	February - March	Haor areas
	Salinity	Growth stunted, Poor phenotypic acceptability	Plant height, Yield and yield components	February - April	Khulna, Bagerhat Patuakhali, Satkhira
Wheat	Lack of moisture at CRI stage (Less precipitation)	Slow growth, Reduce tiller, Reduce spikes, Reduce grains per spikes	Plant height, Tiller number, Spike number, Grains per panicle	November/ December	Bogra, Jessore, Dinajpur, Chuadanga
	High temp. (> 25^{0}C) at heading stage	Increase sterility, Reduce seed size, Shriveled seed	Growth rate, Grains per spike, Unfilled grains per panicle, Seed morphology, 1000 seed weight	February	Bogra, Jessore, Dinajpur, Chuadanga
Lentil	High temperature (> 20^{0}C) at germination stage	Poor population, Low vigor of seedling,	Plant population, Seedling dry matter,	October - November	Jessore, Faridpur Kurigram
	High temperature (> 28^{0} C at reproductive stage	Flower dropping, Pod dropping, Reduce seed size	Pods per plant, Seeds per pod, 1000 seed weight	February - March	Jessore, Faridpur, Kurigram

Crop	Climatic variability/ Indicator	Crop Indicator	Monitoring parameters	Monitoring time	Monitoring area
	Foggy weather	Incidence of botrytis grey mold (BGM) disease	Disease scoring	December - January	Jessore, Faridpur Kurigram
Chickpea	Low temperature (< 12^0 C) at germination stage	Poor germination, Slow seedling growth	Plant population, Plant height, Seedling dry matter	November - December	Jessore, Kustia, Rajshahi
	High temperature (> 29^0 C) at reproductive stage	Reduce pod set, Reduce seed size	Pod number, Seeds per pod, 1000 seed weight	March - April	Jessore, Faridpur, Kurigram
	Foggy weather	Incidence of botrytis grey, mold (BGM) disease	Disease scoring	January - February	Jessore, Faridpur Kurigram
Mungbean	Less moisture (rainfall), high humidity	Slow growth, Flower dropping	Pod number, Seed per pod,Seed weight	March - April	Barisal
Potato	High temp. (> 20^0C) at tuberization stage	Reduce tuber number, Reduce bulking rate	Tuber number per plant, Tuber weight per plant	November - December	Debigonj, Bogra, Munshigonj
	Foggy weather	Early or late blight	Disease scoring	December - January	Debigonj, Bogra, Munshigonj
Mustard	Lack of moisture at sowing time (less precipitation)	Low plant population, Poor growth	Plant population, Plant height, Siliqua per plant, Seeds per siliqua	October - November	Manikganj Sirajganj, Faridpur
	Warm and humid weathe	Aphid infestation	Insect population, Degree of crop damage	February	Manikganj, Sirajganj, Faridpur
Mango	Erratic rainfall/high rainfall in short periodr	Vegetative flush instead of flowering, Pollen washout, Flower shedding, Reduce fruit setting, Increase disease and insect pests, Fruit cracking	Flowering (%), Fruit setting (%), Fruit dropping (%), Fruit cracking (%)	January - May	Chapai-Nawabgonj, Jessore, Gazipur, Rangamati

Crop	Climatic variability/ Indicator	Crop Indicator	Monitoring parameters	Monitoring time	Monitoring area
	Lack of moisture	Flower dropping, Fruit dropping, Reduce fruit size	Fruit setting (%), Fruit retention (%), Fruit size	January - May	Chapai-Nawabgonj, Jessore, Gazipur, Rangamiti
	Low temperature	Delay flowering, Reduce perfect flower, Erratic flowering	Time of flowering, Percent flowering, Perfect flowering	January - March	Chapai Nawabgonj, Jessore, Gazipur, Rangamiti
	Foggy weather	Increase insect pest and diseases ,Crop damage, Reduce pollination	Fruit setting (%), Pest & disease incidence, Panicle damage (%),	January - March	Chapai Nawabgonj, Jessore, Gazipur, Rangamiti
Jackfruit	Erratic rainfall/high rainfall in short period	Pollen washout, Reduce fruit setting, Fruit deformation	Fruit setting (%), Fruit deformation (%), Pest and disease incidence	January - June	Gazipur, Jessore Mymensingh, Khagrachari, Moulvibazar,
	Lack of moisture (drought)	Spike dropping, Fruit dropping, Reduce fruit size	Female spike dropping (%) Fruit dropping (%) Fruit weight and size	December - April	Gazipur, Jessore Mymensingh, Khagrachari, Moulvibazar,,
	High temperature	Fruit dropping Reduce crop period	Fruit dropping (%) Harvesting time Quality parameter (TSS%)	January - June	Gazipur, Jessore Mymensingh, Khagrachari, Moulvibazar,
	Flood	Wilting of tree	During flood, Wilted tree (%)	July - September	Gazipur, Jessore Mymensingh, Khagrachari, Moulvibazar,
Litchi	Erratic rainfall/high rainfall in short period	Vegetative flush instead of flowering, Pollen washout, Flower shedding, Reduce fruit setting, Increase disease and insect pests	Flowering (%), Fruit setting (%), Fruit dropping (%), Fruit cracking (%), Pest and disease incidence, Quality parameter (TSS %)	January - June	Chapai Nawabgonj, Jessore, Gazipur, Khagrachari, Moulvibazar

Crop	Climatic variability/ Indicator	Crop Indicator	Monitoring parameters	Monitoring time	Monitoring area
	Lack of moisture (drought)	Flower dropping, Fruit dropping, Reduce fruit size, Increase litchi mite, Fruit cracking	Fruit setting (%), Fruit retention (%),Fruit size, Fruit cracking (%)	January - April	Chapai Nawabgonj, Jessore, Gazipur, Khagrachari, Moulvibazar
	High temperature	Early flowering Reduce crop growing period	Flowering time, Harvesting time, Quality parameter (TSS %)	February - April	Chapai Nawabgonj, Jessore, Gazipur, Khagrachari, Moulvibazar
	Low temperature	Delay flowering Erratic flowering	Time of flowering Flowering (%)	January - Febraury	Chapai Nawabgonj, Jessore, Gazipur, Khagrachari, Moulvibazar
	Foggy weather	Increase insect pest and disease, Reduce pollination	Pest and disease incidence, Fruit setting (%)	January - March	Chapai Nawabgonj, Jessore, Gazipur, Khagrachari, Moulvibazar
Guava	Excess rainfall	Increase disease Deteriorate quality (Taste)	Fruit size and weight, Fruit weight, Insect pests incidence	March - July	Gazipur, B-Baria Barisal
	Lack of Moisture (drought)	Fruit dropping, Reduce fruit size, Increase insect pests	Fruit size (%), Disease incidence, TSS (%)	March - July	Gazipur, B-Baria Barisal
	High temperature	Fruit dropping, Reduce crop growing period, Poor pollination, Reduce fruit size	Fruit dropping (%), Harvesting time, Fruit weight and size	March - July	Gazipur, B-Baria, Barisal

Crop	Climatic variability/ Indicator	Crop Indicator	Monitoring parameters	Monitoring time	Monitoring area
Brinjal	Erratic rainfall	Delay planting,	Rainfall parameter,	Round the year	Gazipur, Norshingdhi
	Hypoxia	Leaf yellowing followed by wilting, Flowering delay, Flower and fruit dropping	Transplanting date, Plant height, Flowering time, Flower and fruit drop (%)		Jessore, Barishal Chittagong
	Lack of moisture/ Drought	Flowering delay, Stunted growth, Flower dropping, Hampered fertilization	Plant height, Fruits/plant, Seed production	November - May	Gazipur, Norshingdhi, Jessore, Ishardi, Chittagong
	High temperature	Increase aphid and jassid infestation, Flower dropping, Fruit discoloration, Increase FSB infestation	Fruits size, Fruit number and yield, Insect pest incidence	February - October	Gazipur Jessore, Ishardi Chittagong, Norshingdi
	Low temperature	Leaf cuffing, Decreased Photosynthesis, Low nutrient mobility, Failure of pollination	Plant height, Fruit setting (%), Seed production	December - February	Gazipur, Rangpur Thakurgaon
	Foggy weather	Delay establishment of seedling, Foot rot disease	Plant height, leaf number & size, Disease scoring	December - February	Rangpur and Thakurgaon
	Salinity > 10 dS/m	Seedling damage, Leaf defoliated, Growth stunted	Plant growth, Leaf scoring	December - May	Naoakhali, Sathkhira , Barguna
Tomato	Erratic rainfall	Delay transplanting,	Planting date, Leaf yellowing (%), Flower drop(%),	September - November	Gazipur, Chittagong
	Hypoxia	Flower dropping, Upper leaf twisted,	Twisted leaf (%)		

Crop	Climatic variability/ Indicator	Crop Indicator	Monitoring parameters	Monitoring time	Monitoring area
	Lack of moisture/Drought	Yellowing of whole plant, Blossom End Rot (BER)	Yellowing plant and BER (%)	December - June	Gazipur, Jessore, Ishardi
	High temperature > 37.5^0C	Flower bud abscission before anthesis, Blotchy ripening, Cease germination of pollen and inhibit tube growth	Fruit set (%), Scoring Blotchy ripening (%), Seed production (%)	February - August	Jessore, Chittagong
	Low temperature < 5^0C	Cease germination of pollen and inhibit tube growth	Fruit set, Seed production	December - January	Rangpur, Thakurganong
	Foggy weather	Increase intensity of late blight & early blight	Weather data, Disease scoring	November- January	Rangpur, Thakurgaong
	Salinity > 10dS/m	Reduce plant height, Reduced fruit weight	Plant height, Weight of fruit, TSS (%)	November - March	Shatkhira, Noakhali Patuakhali
Cabbage/ Cauliflower	Erratic rainfall Hypoxia	Delay planting, Wilting	Planting date , Wilting	September - October	Jessore, Norshingdi, Gazipur
	Lack of moisture/Drought	Wilting of seedling, Tip burn in cabbage,	Soil moisture data,Tip burn, wilting & buttoning	December - February	Tangail, Comilla. Jessore
	High temperature	Buttoning in cauliflower Head and curd, formation delayed, Increased leaf number	Harvesting time, Number of leaves	September - November	Ishardi and Jesoore
	Low temperature	Vernalization occurred, Ricey curd	Bolting data (%) Ricey curd (%)	November - January	Rangpur Thakugaon
	Foggy weather	Rotting of seedling, Leaf spot disease (%)	Rot (%), Leaf spot disease scoring	November - January	Rangpur Thakugaon

Crop	Climatic variability/ Indicator	Crop Indicator	Monitoring parameters	Monitoring time	Monitoring area
	Salinity 10 dS/m	Delay establishment of seedling , Leaf yellowing Decreased curd / head size	Seedling growth, Leaf color scoring, Head / curd size	December - March	Sathkhira and Noakhali
Cucurbits (Bottle gourd Pumpkin)	Erratic rainfall Hypoxia	Sudden death	Rainfall data Survivability (%)	June - November	Gazipur, Chittagong, Norshingdi
	Lack of moisture/ Drought	Fertilization failure, Stunted growth	Fruit set, Plant height, Yield data	December - June	Gazipur, Ishardi, Jessore
	High temperature> 32^0C	Inhibit female flower development	Fruit set, Plant height, Yield data	March - June	Ishardi, Gazipur
	Low temperature < 12^0C	Delay or low germination, Anther dehiscence	Fruit set (%), Plant height, Yield data	November - January	Rangpur Thakugaon
	Salinity>10 dS/m	Foliage scorching, Tip burn, Dwarf plant	Scoring of scorching , tip burn, Plant height	December - May	Sathkhira and Noakhali

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CHAPTER – 5

INDICATORS TO ASSESS THE IMPACTS ON LIVESTOCK SECTOR

Abdur Razzaque Mia, Morshedur Rahman, Jahanara Khanum, A.B.M Khaleduzzaman

5.1 BACKGROUND

The livestock sector is socially, culturally and politically very significant. It accounts for 40% of the world's agriculture Gross Domestic Product (GDP). It employs 1.3 billion people, and creates livelihoods for one billion of the world's population living in poverty. Climate change is seen as a major threat to the survival of many species, ecosystems and the financial sustainability of livestock production systems in many parts of the world. The potential problems are even greater in developing countries. There has been considerable interest in gaining an understanding how domestic livestock respond to climatic stressors.

Studies have for the most part been undertaken in developed countries. However little is known about the impacts of climatic stressors on many indigenous breeds used throughout Africa, Asia and South America. The uncertainty of climate change and how changes will impact on animal production on a global scale are largely unknown (Gaughan, *et al.*, 2009). As compared to other sector, there are very few economic analyses of climatic effects on livestock sector worldwide.

The reason behind this gap is the study of the effects of climate change on American livestock (Adams, *et al.*, 1999). American livestock appear not to be vulnerable to climate change because they live in protected environments (sheds, barns etc.) and have supplemental feed (e.g., hay and corn). In Bangladesh, by contrast, the bulk of livestock have no protective structures and they graze off the land. There is every reason to expect that livestock in Bangladesh will be sensitive to climate change. This assumption is also supported by a recent study in Africa (Seo and Mendelsohn, 2007).

The role of livestock sub-sector is very crucial for the economic development of agriculture based Bangladesh. The contribution of livestock to National GDP is 2.79% and which is 17.15% in Agricultural share. At present the country has about 47.5 million livestock and 246 million poultry of which 23 million cattle, 1.2 million buffalo, 21 million goat, 2.7 million sheep, 207 million chicken and 39 million duck. Among these species cattle, goat and poultry are the integral part of our farming system. It is estimated that there are 9 million cows in Bangladesh of which 4.12 million milking cows yielding 2.28 million tons of milk annually indicating 18.5 litres of milk consumption per head per year, or about 51 ml per head per day as against internationally accepted average consumption rate of 250 ml. According to Bangladesh Bureau of Statistics 50.9% of cattle are owned by small farmers as compared to the medium farmers (37.3%) and large farmers (10.2%).

It is well known that milk production of indigenous dairy cattle is very low. As a result, choice for crossbred cows has been increasing. However, the main limitation with crossbred dairy cattle is its susceptibility to diseases and limited ability to adjust with hot and humid conditions resulting in the reduced milk production to even much less than the half of their potential. In addition, heat stress level of crossbred and indigenous dairy cattle may not be same. A variation in heat stress level between small, medium and large farms due to different management practices may also be happened.

Black Bengal goat, one of the economically important breed, is considered as short term animal crop in Bangladesh. This breed is also considered as poverty reduction tool in our country. The Black Bengal Goat is famous for its breed characteristics such as quality of meat and skin, highly prolific and disease resistance. Consequently, it can be considered as flagship species too.

According to the economic review (2009) there are 22.4 million goats in Bangladesh, and the production trend has been increasing with the growth rate of 2.4%. Recent data shows that in Bangladesh among the total households 4.48 million (15.62%) are absolutely landless, about 52% of people have less than 0.50 acres of land, 48% live below the poverty line and 30% consume less than 1900 calories per day against the minimum desired level of 2300 calories.

5.2 POTENTIAL IMPACT OF CLIMATE CHANGE ON LIVESTOCK: LITERATURE REVIEW AND BANGLADESH CONTEXT

5.2.1 IMPACT OF NATURAL DISASTER ON LIVESTOCK POPULATION

In Asia the impact of natural disaster such as floods, droughts and cyclones has not been sufficiently analyzed in terms of livestock population. Bangladesh is considered as one of the most disaster prone countries in the world. It has suffered 170 large scale disasters between 1970 and 1998. The frequency of flooding episodes is growing, with catastrophic “once in a generation” floods occurring more regularly.

This includes eight major floods between 1974 and 2004, many of which are considered by hydrologists to be at a size expected only once in every 20 years (Pender, 2008). In another report, it is mentioned that Bangladesh was free of climate induced disasters only for 6 years between 1960 and 1992 (FAO, 2007). Although there are many evidences of declining the number of livestock due to natural disaster in Bangladesh, no attempt has been taken to analyze this impact.

5.2.2 HEAT STRESS AND LIVESTOCK PRODUCTIVITY (COW AS AN EXAMPLE)

All animals have a range of ambient environmental temperatures termed the thermo neutral zone. This is the range of temperatures that are conducive to health and performance. The upper critical temperature is the point at which heat stress effects begin to affect the animal. There are a number of environmental factors that contribute to heat stress.

These include high temperature, high humidity and radiant energy (sunlight). Heat stress can be simply defined as the point where the animal cannot dissipate an adequate quantity of heat to maintain body thermal balance. The animal has a number of mechanisms available to assist in trying to dissipate heat and maintain a normal body temperature (Chase, 2006). These mechanisms include conduction, convection, radiation and evaporation as shown in Figure 5.1 in a cow.

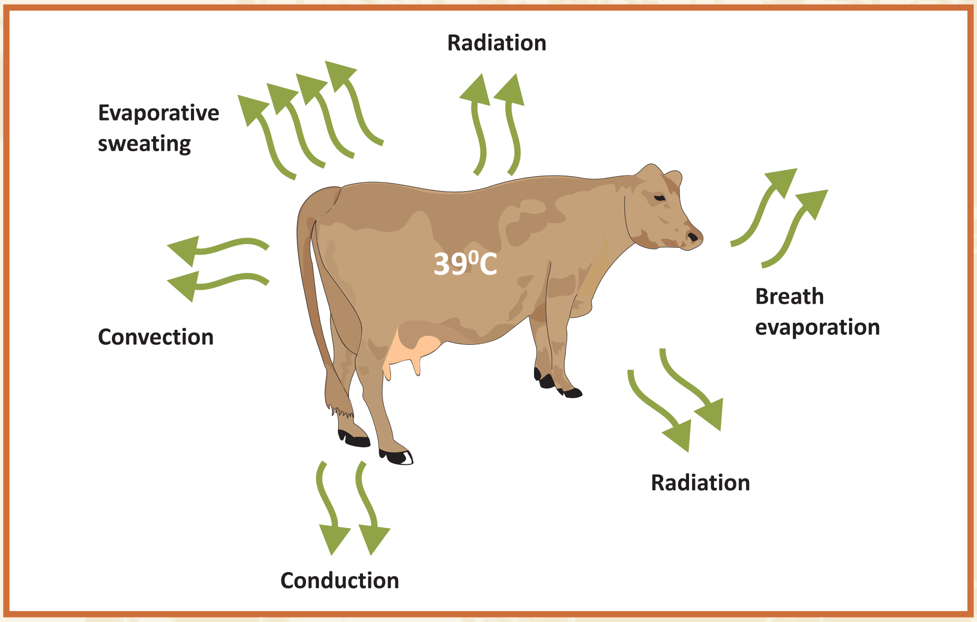


Figure 5.1: Mechanism by which animal dissipate heat at normal and stressed conditions

As a result of heat stress a number of changes occur in animal. These include elevated body temperature, increased respiration rates, increased maintenance energy requirement, increased feed nutrient utilization, decreased dry matter intake, reduced milk production, and hampered reproductive performance. The effect of hot, humid weather is costly to the dairy farmers in many ways.

Hahn *et al.* (1992) reported that in the east-central United States per animal milk production was found to decline 388 kg (~4%) for a July through April production cycle, and 219 kg (~2.2%) for an October through July production cycle as a result of global warming. In addition to reduced milk yield cows also have lower milk fat content during hot weather. Hahn (1995) also reported that conception rates in dairy cows were reduced 4.6% for each unit change when the Temperature Humidity Index (THI, an index of heat stress) reaches above 70. Amundson *et al.* (2005) reported a decrease in pregnancy rates of *Bos taurus* cattle of 3.2% for each increase in average THI above 70, and a decrease of 3.5% for each increase in average temperature above 23.4^{0}C. Physiological and behavioral changes and reduction in milk production of cows due to heat stress is shown in Figure 5.2.

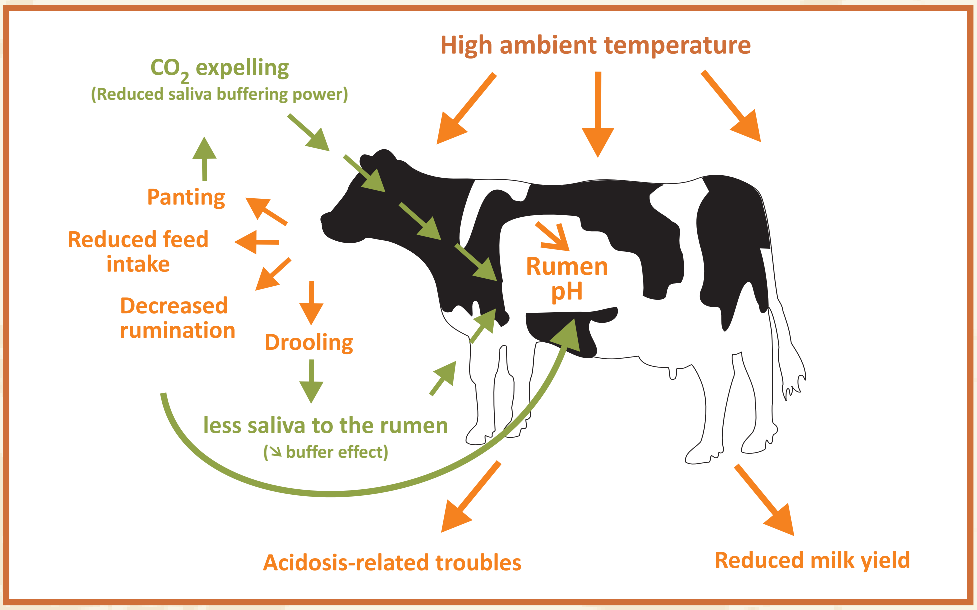


Figure 5.2: Physiological, behavioral changes and adverse effects on cows due to heat stress

5.2.3 QUANTIFICATION OF HEAT STRESS

Bangladesh is a hot, humid country. With the increase of global temperature, the intensity of temperature and humidity has been increasing. Severity of heat stress is quantified using a temperature humidity index (THI). Both ambient temperature and relative humidity are used to calculate a THI. Heat stress especially in summer is very common in human and animals. However, no attempt has been taken to measure the severity of heat stress on animal production in Bangladesh. Therefore, it is very important to find out the THI level at which livestock in Bangladesh are in stressed. At the same time the heat stressed area in Bangladesh should also be identified.

5.2.4 EMERGENCE OF DISEASES

One of the important areas of concern is the influence of climate change on diseases and parasites that affect domestic animals. Incidences of disease, such as bovine respiratory disease, are known to be increasing (Duff and Gaylean, 2007). However, causes for this increase can be attributed to a number of non-environmentally related factors. As for parasites, similar insect migration and over-wintering scenarios observed in cropping systems may be found for some parasites that affect livestock.

Baylis and Githeko (2006) describe the potential of how climate change could affect parasites and pathogens, disease hosts, and disease vectors for domestic livestock. The potential clearly exists for increased rate of development of pathogens and parasites due to spring arriving earlier and warmer winters that allow greater proliferation and survivability of these organisms.

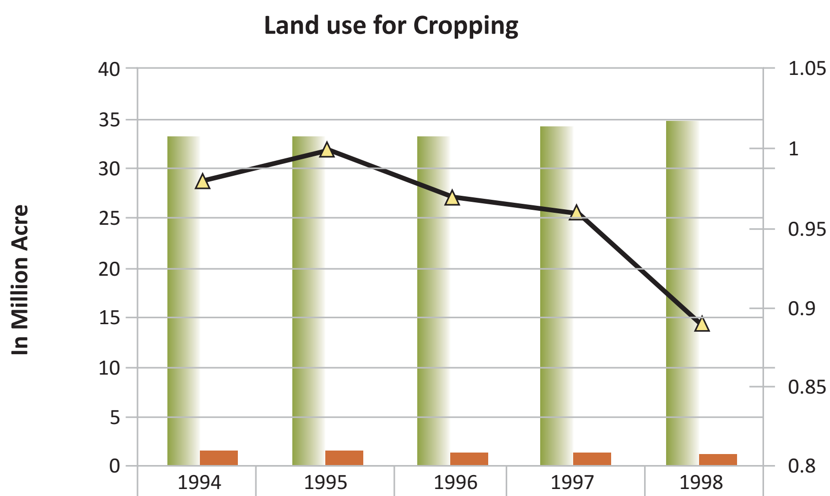
For example, bluetongue was recently reported in Europe for the first time in 20 years (Baylis and Githeko, 2006). Warming and changes in rainfall distribution may lead to changes in spatial or temporal distributions of those diseases sensitive to moisture such as anthrax, blackleg, haemorrhagic septicaemia, and vector-borne diseases.

Like livestock population, natural disaster has great impact on animal health in Bangladesh too. However, this area has not also been studied well. A report from FAO (2006) indicated the emergence of Peste des Petits Ruminants (PPR) Disease in the year of 1993. It is also said that livestock in coastal area has been suffering from liver fluke due to ingestion of huge number of snails. Therefore, it is logical to raise the question whether the PPR or other diseases are the impact of climate change on livestock in Bangladesh.

5.2.5 IMPACTS ON FORAGE RESOURCES AND CONFLICT OVER LANDS

It is difficult to measure the direct effects on forage production due to climatic change in Bangladesh. However, there are some indirect effects: a) the rising temperature seems to be increasing the frequency of droughts (water evaporates faster from soil when air is warmer) in the North and Northwest part of the country which is leading to decrease forage availability and total forage biomass production, b) On the other hand, the shortage of green fodder has been intensified mainly due to conversion of grazing lands into cereal and food crop lands.

Therefore, only 3290 acres of land are engaged in fodder cultivation and 2% of the farmers are cultivating HYV fodder and the area covered by fodder cultivation per farm is only 0.002 acres (BBS, 1999). The following figure (Figure 5.3) clearly indicates that the total lands for cropping cereals increased during the period of 1994 to 1998. In addition, land is also used for urbanization and industrialization in the country which is one of the reasons for decrease in the cultivable land for fodder production. Because of the high demand for cereal production for humans and maize grain for poultry legume and pulses production have been reduced and the place has been occupied by the winter variety of rice and maize.



	1994	1995	1996	1997	1998
Total cropped	33.32	33.41	33.39	34.09	34.81
Culterable waste	1.57	1.55	1.31	1.29	1.24
Current fallow	0.98	1	0.97	0.96	0.89

Courtesy: Khan Shahidul Huque

Figure 5.3: Land use for cropping

Paradoxically, the recent scientific literature continues to indicate that as the air's CO_2 content rises, grassland plants will likely exhibit enhanced rates of photosynthesis and biomass production that will not be diminished by any global warming that might occur concurrently. Fritschi *et al*. (1999) reported that a 275 ppm increase in the air's CO_2 content boosted photosynthesis and aboveground biomass by 22 and 17%, respectively, independent of air temperature. Thus, at elevated air temperature, CO_2-induced increases in rates of photosynthesis and biomass production are typically equal to or greater than what they are at ambient air temperature.

Another important concern is annual precipitation. Global warming is likely to produce much more erratic weather because a warmer atmosphere means the evaporation of more water from the oceans, leading to greater precipitation. Forage production was significantly related to both annual and seasonal precipitation but not temperature. Precipitation events between 15 and 30 mm accounted for most of the variability in production because they accounted for most of the variability in precipitation and because they wetted the soil layers that have the largest effect on production.

According to Bangladesh Climatic Change Strategy and Action Plan (MoEF, 2009), rainfall will increase resulting in higher flows during the monsoon season in the rivers, which flow into Bangladesh from India, Nepal, Bhutan and China thus creates higher precipitation in river basins, *chars* etc. Farmers are growing interest to cultivate summer feeds (Soy bean) and fodders (maize and sweet jumbo) on these river basin and *chars* etc.

5.3 SELECTION OF MONITORING PARAMETERS, INDICATORS AND MONITORING MECHANISM

In order to investigate the impacts of climate change on livestock, we divided the whole country into four zones such as coastal zone, drought zone, hilly area and flash flood affected zone.

Data will be collected from primary sources by direct interview with structured questionnaire and focused group discussion. Secondary data will be collected from DLS, FAO, UNDP, BAU, BLRI, NGOs etc. However, in the case of measuring Temperature Humidity Index (THI), THI will be calculated from the secondary data to be obtained from metrological department, and whether the animal in a specific THI level is heat stressed or not will be determined by observing body temperature and respiration rate of the animal. Sample size will be at least 10 to 15% of the total household of a study area depending on the project size and implementing authority.

Based on the above discussion, justification and literature review, we are proposing the following monitoring matrix for investigating the impact of climate change on livestock.

Sl No.	Climatic vulnerability/ variability	Monitoring indicator (Livestock)	Monitoring variables/para meters	Monitoring area	Monitoring time	Monitoring mechanism
1.	Natural disasters (cyclones, floods, tidal surges)	Cattle, Buffalo, Sheep, Goat and Poultry	Population	Potuakhali and Satkhira	Pre-monsoon, monsoon and post monsoon	a) Primary survey from randomly selected villages of monitoring areas b) Secondary data collection from DLS, FAO, UNDP, BLRI, BAU and NGOs
2.	Droughts	Cattle and Poultry	Disease prevalence	Rajshahi and Kurigram	Summer season	Do
3.	Rising temperature	Goat	PPR	Chuadangha and Satkhira	Summer season	Do
4.	Salinity	Cattle and Goat	Parasitic infestation (Liver fluke)	Bhola and Potuakhali	Rainy season	Do
5.	Heat stress	Dairy cattle, Goat and Poultry	THI index, Feed intake, Milk & Egg production, Conception rate and Parity	Sirajgonj, Rangpur, Gazipur	Summer season	Do
6.	Rising temperature, Flood, Droughts	Feeds and Forage	Soybean, Maize, Napier and Jumbo forage species	Noakhali, Sirajgonj and Gaibandha (Jamuna river basin)	Summer season	Do

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CHAPTER – 6

INDICATORS TO ASSESS IMPACTS ON FRESH WATER FISHERIES

Abdur Rob Molllah

6.1 FISHERIES: AN IMPORTANT SUB-SECTOR IN BANGLADESH ECONOMY

Bangladesh is a country of wetlands and has vast water resources in the forms of rivers, canals, beels, haors, floodplains, estuaries covering an area of about 4.34 million hectare. The total inland open water resources cover an area of 4.05 million hectare. The culture fisheries include freshwater ponds (0.15 million ha) and coastal shrimp farms (0.14 million ha) (DoF, 2008). These diverse freshwaters supports 260 freshwater fish species, 24 freshwater prawn species, 475 marine fish and 36 marine shrimp species (Rahman, 2005) in Bangladesh. The total production of fish from the country in the year 2007-2008 amounted to about 2.5 million mt, of which 1.06 million mt came from open water capture fisheries, and another 1.0 million mt from culture fisheries and 0.50 million mt from marine waters (DoF, 2008). In inland fisheries, Bangladesh ranks third (after China and India) among the top ten freshwater fish producing countries of the world.

In fact, fish and fisheries play an important role in the economy, employment, nutrition and culture of the people of the country. In Bangladesh, fish is the second staple food after rice and each and every people in Bangladesh eat fish. Per capita per annum fish intake in the country is about 17.23 kg against the demand of 18 kg per capita per year. Fisheries sector contributes about 5% to GDP and 6% to foreign exchange earnings (DoF, 2008). Compared to different sub-sectors of agriculture, the growth rate in fisheries sector is the highest ranging from 6-9% during the last ten years (1994-2003). Presently, 1.4 million people are engaged on full time basis and 12 million as part in fisheries sector of the country for livelihood and trade. Another 3.08 million fish and shrimp farmer are involved in aquaculture both at subsistence and commercial level. Therefore, fisheries have emerged as an important sub-sector in our rural economy.

Extensive resource base, huge internal demand, favorable climate and expanding global market offer a great opportunity to the country to generate more employment and income for rural population through fisheries and aquaculture activities. Most importantly, the resource is accessed by the poor rural people. Therefore, sustenance of this resource is important for sustainable livelihood of the poor fishers of the country. Unfortunately, climate change climate variability is posing a great threat to its future sustenance.

6.2 INFLUENCE OF CLIMATIC FACTORS ON FISH PRODUCTION: BANGLADESH PERSPECTIVES

The monsoon rains and annual flood cycle pattern in Bangladesh greatly influence the breeding, multiplication, growth and sustenance of the populations of fish and prawns in the inland open waters. All the open water components, i.e., rivers, canals, beels and floodplains become connected with each during monsoon and turns into a single biological production system. This integrated single production system lasts for about 5-6 months, providing suitable aquatic habitats for reproduction, migration, feeding and growth of aquatic organisms (Ali, 1991). The rise of water level in rivers and streams between February and April triggers physiological changes leading to sexual maturity of fish inhabiting the flowing rivers. Similarly, early monsoon rainfall in combination with early inundation of floodplains stimulates fish in beels and other similar static waters to become sexually mature. As soon as connection between the beels and flowing rivers are restored by rise of water in rivers, sexually mature river breeding fish from beels migrate to the floodplains through linking canals and breed there.

Some species of inland water fish and prawns make downstream migration to reach their spawning grounds in the estuaries. One such species is giant freshwater prawns (*Macrobrachium rosenbergii*). Adults of this prawn make their down stream spawning migration into the estuaries between January and July and breed there. Their fertilized eggs undergo early development in the brackish water environment. On attaining juvenile stage, they migrate upstream into the freshwater environment in the rivers and onto the inundated floodplains where they feed and grow (NAPA, 2005b).

The hilsa sad, the single most economically important fish species in Bangladesh, resides in the coastal waters of Bay of Bengal and moves into the freshwater habitat into the rivers for the purpose of breeding. Their biggest spawning migration coincides with the early monsoon and freshwater inputs from.

Young and juveniles of many finfish and prawns resulting from breeding in the flowing rivers and estuaries also migrate into the inundated land for feeding and completing early growth. At the end of monsoon, the fish and prawns return to the rivers and beels from the floodplains with receding of flood waters (Ali, 1995).

Therefore, timing, extent and duration of rains and floods greatly influence of reproduction, migration, growth of fishes. Similarly, intactness of the migratory channels and routes are also prerequisite for production and sustenance of fishes of Bangladesh.

6.3 IMPACTS OF CIMATE CHANGE AND VARIABILITY ON INLAND OPEN WATER FISHERIES

The increased aridity, reduced dry season precipitation and extended dry spell, particularly in the northwest region of Bangladesh, will lead to the drying up of or retain too little water (not adequate for survival of fish) in floodplain fish pits, depressions, ditches, etc. These aquatic micro-habitats provide dry season refuges to breeding stock of fish. The drying up of these fish refuges or reduced water in these water bodies will cause a recruitment failure in local fisheries resulting in the declined fish production from the area (NAPA, 2005b).

As the rains and flood cycle is finely tuned with fish reproduction and growth, delay in onset of rains and floods may affect the breeding and maturation success of fish, which in turn will result in the reduced fish production from rivers and floodplains (NAPA, 2005b).

Hilsa production inland waters is likely to decline further because of restricted upstream migration due to blockage in migration routes due increased siltation and construction of Farakkha barrage (Ahmed, *et al.,* 2005).

Intrusion of saline water further deep into the inland river system will cause a shift in the fish composition and dynamics in abundance (Ali, 1999). There could be a change in the fishing gears and fishing methods (Mollah, 2008). The freshwater species will be replaced by marine species.

Siltation of riverbed will cause a net reduction in the viable fish habitat. Many fishing grounds in the big river systems may be lost (NAPA, 2005b). Such effects of climatic events are presently evident in many areas of Bangladesh.

Every year hundred and thousand of culture ponds float due to floods resulting in the loss of fish and the poor fish farmers incur financial losses This effect of climate variability is causing a great threat to the substance of pond fish culture in many areas of Bangladesh, particularly in the north central, south central region of Bangladesh (NAPA, 2005a &b).

Shrimp culture in the coastal areas is already affected by tidal flood and storm surges, due to floating of the culture ghers and causes heavy loss financial to farmers. This situation is likely to increase in the future as sea level rises and cyclonic intensity and frequency increases due to perceived changes in climate and climate induced extreme events.

Salinity intrusion will cause great problems in the larval development of fishes. Migratory freshwater fish hatchlings will face severe difficulties in south-west Bangladesh as the saline intrusion deepens. Such fish cannot survive in water that is even moderately saline, and with reduction in brood stock, freshwater fisheries production can be expected to drop.

Meanwhile, pond production in the coastal zone, whether of freshwater fish or shrimp, will be affected by salt water intrusion, unless progressively higher protective embankments are constructed (Ali, 2000). Sea level rise is predicted to reduce freshwater fisheries production by decreasing the available freshwater fisheries habitat.

Decreased freshwater delivery alters food webs in rivers and estuaries and changes in the residence time of nutrients and contaminants. Reduced nutrient inputs during lean flow can be a major cause of the loss of productivity (both primary and secondary) of a river dominated estuary during and after dry season. Net violable photoperiod, changes in salinity, temperature dynamics, etc. are likely to bring changes in the composition production dynamics of phyto- and zooplanktion, upon which entire aquatic communities are dependant.

Freshwater dolphin, which are endangered, also likely to be affected, particularly due to low flow during lean period, availability of food, siltation of the river beds.

Production from floodplains is also likely to decline because of hindrance to spawning migrations due to FCD structures. In particular, production of carp is likely to decline due to contraction of the freshwater zone in the river systems.

Construction of a large number of flood protection embankments around and within the floodplain areas under FCD and FCDI projects adversely affected the ecosystem and habitat of fish population. It is estimated that 2.0 million ha of floodplains would be lost to fishery due to water development projects in near future with a loss of production of over 1.0 million mt / year.

6.4 THE NEED FOR A FISHERIES MONITORING PROTOCOL

It is apparent from the above that the open water fishery of Bangladesh is already adversely impacted by the climate change and climate variability with an anticipation of further exacerbated future impacts. This remains a potential threat to the sustenance of the resource and that of livelihood of poor rural communities historically dependant on it. The sector contributes significantly to the national economy. Therefore, there is need to track the changes in the resource bases so that appropriate strategies and actions could be formulated. Although, the Department of Fisheries (DoF) employs a method for estimating fisheries production, however, due to its inappropriate operational mode the reliability of the estimation is questioned. In fact, there is virtually no system that allows tracking the changes in the abundance, distribution and other dynamics of the country's fisheries. As the climate changes are likely to impact the growth, survival, reproduction, composition and abundance of fish, therefore, there should be some mechanisms that would allow the track the changes in these parameters of fisheries.

6.5 APPROACH AND METHODOLOGY

The identification and the development of corresponding methodology were based on the extensive literature survey, and an expert and stakeholder consultation process. Literature survey was undertaken to make a thorough appreciation of the following subject areas.

- Global warming and its consequences on climatic events;
- Climatic change and climate variability issues;
- Impacts of climate changes on various sectors;
- Potential impacts of climate change and climate variability on Bangladesh fisheries.

This appreciation process allowed us to grasp fully the requirement for the development of the monitoring protocol. An expert group having representatives from Department of Fisheries, GoB, Universities, Research Institutes, NGOs and individual experts was formed. The expert group held number of meetings and initially developed a monitoring framework and then detailed the methodology. The impact driven indicators were selected for monitoring. In the initial exercises, the various potential impacts on fisheries were identified through literature survey and through expert consultation. In practice, a number of indicators were selected for each of the impact area and then prioritization was done. The following general criteria were considered while prioritizing an indicator:

- the indicator should be responsive to climate change events;
- should be precise, specific and should avoid information overload;
- indicator should be impact driven, i.e. should reflect the changes in the aquatic biodiversity over time;
- should have relevance to the objective of the monitoring program;
- should be practical, easy to monitor and should avoid much laboratory analytical techniques/methods;
- should be reasonably reliable;
- feasible and cost effective.

Detailing of the Indicator and Methodology Development

The following steps were followed for the development of the methodology:

- To think about the purpose/objective of the monitoring program;
- Setting the performance questions;
- Assess the information needs;
- Define broad indicator areas;
- Decide on and define the precise indicators;
- Prepare a priority list;
- Assign appropriate measurement units and prepare precise definition of each selected indicators/and establish its relevance to objective of the protocol.

- Decide on tools to be used for data collection/monitoring;
  - Surveys
  - Appraisals (RRA/PRA)
  - Observations etc.
- Decide on data collection timeframe and frequency;
- Assess logistics and other inputs requirement;
- Decide on who, when and where to collect data (prepare protocol);
- Assess scope for community involvement in data collection.

6.6 LIST OF TENTATIVE INDICATORS

Indicator Reference Sheet – 1

Indicator 1: Changes in migratory routes and timings of Hilsha shad *(Tenualosa ilisha)*

Description

Meaning of Indicator: Recording of number of hilsa fish catch from selected gears at some selected sampling sites may display the changes in the migratory routes and migration over time, if any, and would allow interpreting the impact of climate change on Bangladesh fisheries.

Unit of Measure: Counts of fish in catches from hilsa gill net and shangla nets

Justification: Hilsa shad is an anandromous fish species. They migrate from the sea to the rivers during their breeding time. It has been hypothesized that migration route of hilsa fish in the sea may change due to climate change and this will in turn adversely affect the hilsa production and eventually affect the livelihood of fishermen. Therefore, monitoring the migration route and migration timing is urgently required to assess the impacts on hilsa production.

Methodology

The methods for sampling fish are as follows:

- **Rivers to be sampled and sampling stations:** The Rivers to be sampled are Meghna and Padma River system and Andarmanik-Payra river system. In Mehgna River system fish sampling stations will be Monpura, Chadpur and Fenchuganj, and that of along Padma River will be at Daultadia and Godaghari.
- **Gears to be sampled:** The gears to be sampled are gillnet (drifting) and shangla. In practice, the major gear used for hilsa fishing at each specific station will be considered.
- **Sampling period and frequency:** Monthly sampling from November to October (year round) during full moon.
- **Sampling techniques:** During the sampling day, catches from at least 5 individual gears representing each selected sampling gear will be sampled. A data collection proforma will be used for recording the data. The number of fishes from each individual catch will be recorded with time required for catching the fish (In practice, this will include recording start time and end time (usually sampling time). The proforma will have provision for recording sampling date, time and sampling station. In addition, each year local fishermen will be interviewed to know the trend in hilsa fisheries, particularly about the abundance and timing of fish availability. This gives a qualitative idea about changes in migration pattern.

Methodology

Data processing and data output: A database program compatible to data collection proforma will be developed and be linked to any statistical package. Data will be regularly fed into computers. The data will be processed to calculate the number of fish caught in an hour (cpue) by month by sampling stations and by gear. Number of fish caught per unit time during different times of the year at different places along known migratory route will be the outputs.

Institutions

Possible collaborating institutions: Bangladesh Fisheries Research Institutes (BFRI) (already they hilsa sampling program at Chadpur), Universities and NGOs.

Indicator Reference Sheet – 2

Indicator 2: Changes in breeding period of Jat puti *(Puntius sophore)* and spawns of major carps or / % changes in Gondo-somatic Index (GSI) of fish.

Description

Meaning of Indicator: The success in breeding and changes in time of breeding can easily be determined by examining the gonads of gravid fishes and observing whether the fish has been able to breed or not. Sampling of fish for gonadal observation and collection of hatchlings from the nature over a time during breeding season will allow tracking the changes in shift in time of breeding. Any shift in breeding time will be easily detected by simple comparison of data between years. The gonadosomatic index is an indirect measure of the maturation stage of the gravid fish and is directly related to breeding performance of fish and facilitates to track the gonadal development with time and will indicate the possible time for breeding. *Puntius sophore* is an available fish species in all types of freshwater bodies and cheap. Therefore, the species would be a potential candidate for monitoring. Similarly, hatchlings/swans are collected from river during season and could easily be monitored.

Unit of Measure: Counts of no. of fish successfully bred and grams (g) of spawns/hatchlings obtained in hatchling collection net.

Justification: In Bangladesh, reproduction of floodplain and migratory fish species is finely tuned with the climatic and hydrological events, like rainfall, inundation level, thunderstorms, temperatures, low hardness levels, etc. For example, many fish species cannot breed unless there is a rain or the floodplains are inundated, while many other species require thunderstorms to initiate breeding activities. Therefore, if there is any changes in these climatic and hydrological factors, that are likely to cause corresponding changes in gonadal development (maturation) and breeding performances of fish, particularly this may alter the timing of breeding and/or successful breeding of fish.

Methodology

The methods are as follows:

Sampling sites: For gonadal observation on punti fish, 4 beels, viz., Hakaluki Haor (Moulvibazar), Beel Gawha (Chapai Nawabgonj), Bagiar Beel (Madaripur), an open beel in Daudkandi (Comilla) area can be sampled. Hatchling/spawn collection can be done at 3 known places of the Jamuna River, viz., Arichaghat, Bahadurabad and Fulchari. Fish from two rivers, namely Megnha and Jamuna River will be sampled. In Meghna sampling could be done at Bhairab and in Jamuna sampling could be done at Bahadurabad ghat.

Carp hatchling samplings will also be carried at three strategic sites in Halda river.

Sampling time and frequency: Sampling can be done on a weekly basis during the period mid April to mid July each year.

Sampling techniques: For gonadal study: about 100 randomly selected fish can be sampled each time from each sampling site. The individual sampled fish will be dissected to examine gonad to determine whether the fish has bred or not (whether fish has already laid eggs or not). The number of spent (bred) fish and unbred fish will be recorded. The coloration of fish will also be recorded. The weight and the corresponding length of each individual fish will be recorded to calculate the gonado-somatic index. For hatchling study, hatchling from at least 3-4 hatchling collection nets will be sampled and weights, size of nets and time taken to catch the hatchlings will be recorded.

Data processing and data output: Counts of spent and nunspent fish will be recorded and be fed into computers using a database. The data will be processed to obtain the % of bred fish and non-bred fish. Gonadal weight and fish length will be used to calculate the gonado-soamtic index. The hatchling weight data will be used to calculate the grams of hatchling caught in unit area of the net in an hour time (cpue). The data collected between years would show the shift in breeding of fish, spawning success of fish and maturation of fish.

Institutions

Possible collaborating institutions: Universities, Research Institutes and Fisheries Department, NGOs

Indicator Reference Sheet – 3

Indicator 3: Spatial changes in availability and abundance of stenohaline fish species like Chiring *(Apocryptes* sp,*)*, Parsia *(Mugil parsia)*, mudskipper *(Baleopthalmus* sp*)*., and Topshe *(Polynemus paradiseus)*.

Description

Meaning of the indicator: The purpose of monitoring of this indicator is to show whether there is any changes/shift in distribution of some low salt tolerant fish species along upstream areas indicating intrusion of salt intrusion in upstream areas compared to earlier time.

Unit of Measure: No. of fish observed in fish catches and relative abundance of fish in local markets.

Description

Justification: Stenohaline fish are found in marine and estuarine areas and can tolerate varying degrees of salinity. Salinity intrusion along the coastal rivers will extend their habitat range and these species could be found further upstream areas. Therefore, measurement of this indicator may thus give an important clue about the impact of the climate change on fish distribution. Observations on the availability and abundance of these indicator species in catches form different sampling sites along a river length, from the downstream to upstream, over time will allow display the changes/shift in their distribution in the river system with time.

Methodology

The methods for sampling fish are as follows:

Sampling sites: Fish sampling will be done in 2 river systems, viz. (i) Lower Meghna and Andarmanik and Paira. In lower Meghna, sampling will be done in 3 sites, viz, Ramgati, Chadpur and Bhairab. Similarly, 3 sampling stations will be selected along the Andarmaik-Pyra River system.

Sampling frequency: Sampling will be done on a monthly basis round the year.

Sampling techniques: At each sampling station, a number of individual gears representing different gear types intended for catching the mentioned fish species needs to be observed to record the number of the mentioned fishes by species. Samplings to be done during the mid-moon period for an entire day. Local markets will need visits to observe fish. However, in this case the source of fish should be ascertained before recording. In addition, local fishermen can be interviewed to gather information on the availability and abundance of the mentioned fish species withn the river system.

Data processing and data output: A database program using Access software will be developed for data entry. Data will be regularly fed into computers and processed to obtain the percent abundance (number) by species by sampling stations and by sampling months.

Institutions

Possible collaborating institutions: BFRI, Fisheries Department, universities.

Indicator Reference Sheet – 4

Indicator 4: Changes in percent composition of fish catches from certain gear types by species /or, Shift in species dominance and species richness.

Description

Meaning of the indicator: This indicator focuses to determine the percent abundance within the fish catches from a particular sampling site. These data will allow comparison between years in determining whether the climate change has brought any changes in fish composition and its relative abundances.

Unit of Measure: counts of no. of fishes in the catches by species.

Description

Justification: Changes in temperature, salinity, siltation, rain patterns, etc. are likely to bring qualitative and quantitative changes in primary productivity. Again, each individual fish has its own trophic niche, i.e., feed on particular type of food organisms. Therefore, changes in the composition of and abundance of planktonic organisms will cause a corresponding change in the composition and abundance of fish dependant on them. Similarly, every individual fish species has its own physiological settings dependant on the environmental factors. Therefore, changes in the environmental factors, like temperature, salinity, rain patterns and other water qualities likely to cause changes in growth, survival and reproduction of fish. As a result, there will be a change in the composition and abundance of fish and would reflect the impact of climate change.

Methodology

The methods for sampling fish are as follows:

Sampling sites: Two river sites, viz. Meghna (sampling station: Bhairab) and Padma (sampling station: Gualondo) and four beel sites, viz., Hakaluki (Kulaura), Beel Gawha (Chapai Nawabgonj), Chanda Beel (Faridpur) or Baghiar Beel (Madaripur), and an open beel from daudkandi (Comilla).

Sampling frequency: Monthly, year round sampling.

Gears to be sampled: All available major gear types, including katha (brush pile), dewatering, gill nets, berjal, etc.

Sampling techniques: During sampling day, in each site, catches from at least three gears, representing each selected gear types, operating within each selected sampling site will be observed .The number of individual fishes belonging to each individual fish species will be recorded using a data collection format. Each gear type will be sampled at least in triplicates.

Data processing and data output: A database will be developed compatible to data collection proforma (catch assessment) using Access software. Data will be fed regularly into computers. Data will be processed to obtain the percent composition of each fish species by month by sampling sites. The comparison of data will display the trend in changes in the composition of the fish population of the site.

Institutions

Possible collaborating institutions: BFRI, DoF (District Office), universities and NGOs.

Indicator Reference Sheet – 5

Indicator 5: Percentage (%) changes in abundance of zooplankton and phytoplankton by species / or, All zoo- and phytoplanktonic species richness or any other equivalent (e.g., Shanon-Weiner Index) in sample waters.

Description

Meaning of the indicator: This indicator focuses on the determination of percent contribution of different species of zooplankton and phytoplankton in sample waters, which will allow comparison of data over time to display whether there is any qualitative and quantitative change in percent contribution of different species.

Unit of Measure: counts of no. of individual by species in sample waters.

Justification: Planktons are passively floating minute organisms and very responsive to any environmental perturbations. Changes in temperatures, fogginess, rain pattern, photoperiod, siltation etc. are very likely to cause changes in the composition and abundances of zooplankton and phytoplankton. Plankton forms the lower tier in food chain. Different animals, fish in particular, utilize different groups of zoo- and phytoplankton species/groups as their food. Therefore, any changes in the composition and abundance in different planktonic species/groups are likely to bring changes in the growth, survival and reproduction of different species of fauna, fish in particular, directly and indirectly dependant on them.

Methodology

The methods for sampling fish are as follows: Water samples from selected sites will be analyzed for planktonic organisms.

Sampling sites: Plankton samples will be collected from 2 rivers sites (Meghna at Bhairab) and Padma at Gualondo) and 4 beel sites in 4 geographical regions (Hakaluki Haor in Moulavibazar); Beel Gawha in ChapaiNawabgonj; Chanda Beel(Fiaridpur) /Baghiar Beel (Madaripur) and an open beel in Daudkandi (Comilla).

Sampling period and frequency: Fortnightly sample collections during the months of May, August and December each year.

Sample collection: Water sample will be collected on spot by sieving 30 l water samples using a plankton net having 68 *um*. The samples in net (about 50 ml) will be transferred in plastic bottle and preserved in 5% buffered formalin, and brought to laboratory for analysis. From each sampling spots samples will be taken in triplicate. Samples will be taken from the same spots each time.

Sample analysis: Identification and enumeration of samples will be done under compound microscope using S-R cell.

Required equipment, chemicals and logistics: Compound microscope, S-R cells, plankton net, formalin, sampling bottles, plastic buckets, etc.

Data processing and data output: Counts of number of individual species/groups will be recorded and fed into computer using an appropriately designed database in Access program and be processed to obtain no. of individuals of plankton species/litre water sample. Data will be displayed to show the changes over time and comparisons will be made by using appropriate statistical packages.

Institutions

Possible collaborating institutions: Universities and Research Institutes.

Indicator Reference Sheet – 6

Indicator 6: Percentage (%) changes in abundance of benthos by species / or, Species richness or any other equivalent (e.g., Shanon-Weiner Index) of all macrobenthic fauna in sediment sample.

Description

Meaning of the indicator: This indicator focuses on the determination of percent contribution of different species of benthos in sediment samples, which will allow comparison of data over time to display whether there are any qualitative and quantitative changes in species composition and percent abundances of different species of benthic fauna.

Unit of Measure: counts of no. of individual by species in sampled sediment.

Justification: Macro-benthic fauna live on and in sediments and play major role in energy cycling in aquatic systems and contribute greatly in fish production. They are very responsive to any environmental changes. Changes in temperatures, rain patterns, siltation, etc., greatly influence the dynamics of the macrobenthic community. These climate change factors may bring a change in this community. The changes in benthic organisms may thus impact the animals, fish in particular, directly and indirectly dependant on them. Therefore, the measurement of the proposed indicator would indirectly reflect the likely impact in the aquatic animals including fish. This indicator could successfully be used for climate change induced impact monitoring.

Methodology

The methods for sampling fish are as follows: Sediment samples from different sampling sites will be analyzed for benthic organisms.

Sampling sites: Plankton samples will be collected from 2 rivers sites (Meghna at Bhairab) and Padma Gualondo) and 4 beel sites in geographical regions (Hakaluki Haor in Moulavibazar); Beel gawha in ChapaiNawabgonj; Chanda Beel (Fiaridpur) /Baghiar Beel (Madaripur) and an open beel in Daudkandi (Comilla).

Sampling time and frequency: Fortnightly sampling during the months of May, August and December each year.

Sample collection and analysis: Sediment samples will be collected by using a sediment dredger on spot, sediment samples will be passed through a series of sieves having varying meshs. Benthic organisms will be sorted out, preserved in containers and to be brought to laboratory for subsequent identification and enumeration following standard methods. Benthic samples will be identified under microscope when required. Samples will be taken from the same spots each time.

Required equipment and logistics: Ekman dredger, Seives with different mesh sizes, sampling bottles, formalin, etc.

Methodology

Data processing and data output: Counts of number of individual species/groups will be recorded and fed into computer using an appropriately designed database and be processed to obtain no. of individuals of benthic species/m^2 surface area. Data will be further processed to calculate the percent composition of individual species/groups and be displayed to show the changes over time and comparisons will be made by using appropriate statistical packages.

Institutions

Possible collaborating institutions: Universities and Research Institutes.

Indicator Reference Sheet – 7

Indicator 7: Changes in abundance and timing of sightings of dolphins (*Platinista gangetica*) in river system

Description

Meaning of the indicator: Monitoring of this indicator will show whether the climate change has any impact on the declining/increasing incidences of dolphin and its seasonal movement pattern in the river system of Bangladesh.

Unit of Measure: Number of counts of sightings of dolphin

Justification: Dolphins are very sensitive to hydrological, climatic events and availability of food. Climate change is like to cause changes in water dynamics, like volume, velocity, flow pattern. The activities of dolphins are directly influenced by these parameters. Similarly, increases in temperature, turbidity etc. also impact the activity of dolphins. It has been hypothesized that climate change is likely to reduce the production of fish, particularly during lean season. This is likely to adversely affect the growth, survival and reproduction of dolphins. As a result, there could be changes in its abundance and activity pattern. The monitoring of the proposed indicator therefore will track the changes in population abundance and timing in movement.

Methodology

The methods for sampling fish are as follows: The monitoring of the indicator will be based on the counting of sightings of dolphin at selected sites of rivers at different time periods of the year.

Sampling sites: Sightings will be made at different sampling sites along the upper Mehgna and Upper Padma. The sampling sites along Mehgna would at Chadpur, Bhairab and Fenchuganj and that along the Padma will be at Maoa , Hardinge Bridge and Godagari.

Sampling time and frequency: Samplings will be done monthly round then year at selected sites and an entire day will be devoted during sampling day.

Observation techniques: One person (observer) will keep sitting on the river bank at the selected site on the sampling day, observe and record the number of dolphins pass across him. A binocular will be used to aid viewing the dolphin. In case of wide river, a imaginary viewing field could be made and observation could be made within that field. In case of narrow river, the entire cross section of the river should be considered for viewing. Binoculars and counters will be necessary during sampling.

Methodology
Data processing and data output: A data entry program using access software compatible to data collection proforma would make and be linked to any statistical package. The data will be regularly fed into computers. The data will be processed to obtain number of dolphin observed to pass per hour by month by sampling sites. These data could be used to calculate the percent changes in abundance and timing of appearance.
Institutions
Possible collaborating institutions: Universities and Research institutes, Forest Department, Fisheries Department.

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CHAPTER – 7

INDICATORS TO ASSESS IMPACTS ON MARINE AND ESTUARINE FISHERIES

Md. Shamsuddoha, Shahadat Hossain, Yusuf Hasan

7.1 BACKGROUND

It is widely accepted that human-induced climate change is under way (IPCC, 2001) and the future climate of Bangladesh, like much of the world, will be warmer. Obviously, coastal areas are one of the most vulnerable places due to sea-level rise, increased level of inundation and storm flooding, coastal erosion, seawater intrusion and increased temperature (Torresan, *et al.*, 2008). Evidence of the impact of recent global climatic changes on fisheries resources has already been observed, with reduced productivity in African lakes attributed to elevated late 20th century atmospheric temperatures (Vollmer, *et al.*, 2005), and increases in the frequency and severity of coral bleaching with rising sea surface temperatures in tropical and sub-tropical coastal zones (McWilliams, *et al.*, 2005).

The impacts of coral bleaching on fish communities include changes in their diversity, size and composition (Munday, *et al.*, 2008). Fish species distribution has also been altered in the North Sea due to recent increases in sea surface temperatures (Perry, *et al.*, 2005), and model projections show that climate change may lead to numerous local extinctions in the sub-polar regions, the tropics and semi-enclosed seas (Cheung, *et al.*, 2009).

Anthropogenic climate change is thus already affecting aquatic ecosystems and the human societies that depend on them (Perry, *et al.*, 2009). However, most research on climate variability, change and fisheries has in the past focused on documenting trends and fluctuations in fish abundance and distribution (Glantz, 1992), particularly in relation to oceanic regime changes and the major pelagic fish stocks of upwelling zones that are the target of large-scale industrial fisheries (Gutierrez, *et al.*, 2007; Yanez, *et al.*, 2001).

There are a number of studies that investigate the vulnerability and adaptive capacity of the fisheries sector and dependent communities to climate change (Allison, *et al.*, 2009; McClanahan, *et al.*, 2008). Nevertheless, until recently there has been little directed analysis at the local scale of how climate variability and change is affecting the lives and livelihoods of the ''tropical majority'' of small-scale fisherfolk, who make up more than 90% of the worlds' fishers and fish traders. There are compelling security reasons - both economic and nutritional - for investing in research to guide adaptation planning in fisheries.

Worldwide, fish products provide at least 20% of the protein intake of 1.5 billion people and support the livelihoods of approximately 520 million people (FAO, 2009). Fishery products are one of the most highly traded food and feed commodities, with an export value of 86 billion dollars in 2006 (FAO, 2009), contributing significantly to both total gross domestic product (GDP) and agricultural GDP as well as food security.

The sector is also an important source of livelihood for women: it is estimated that in countries such as India, Cambodia and Ghana they represent on average half of the fisheries work force (including post-harvesting activities) (World Fish Center, 2008). Additionally, many fisheries worldwide have declined sharply in recent decades due to over fishing (Pauly, *et al.*, 1998), and many major fishing grounds are concentrated in zones threatened by pollution, mismanagement of fresh water and habitat, and coastal zone modifications.

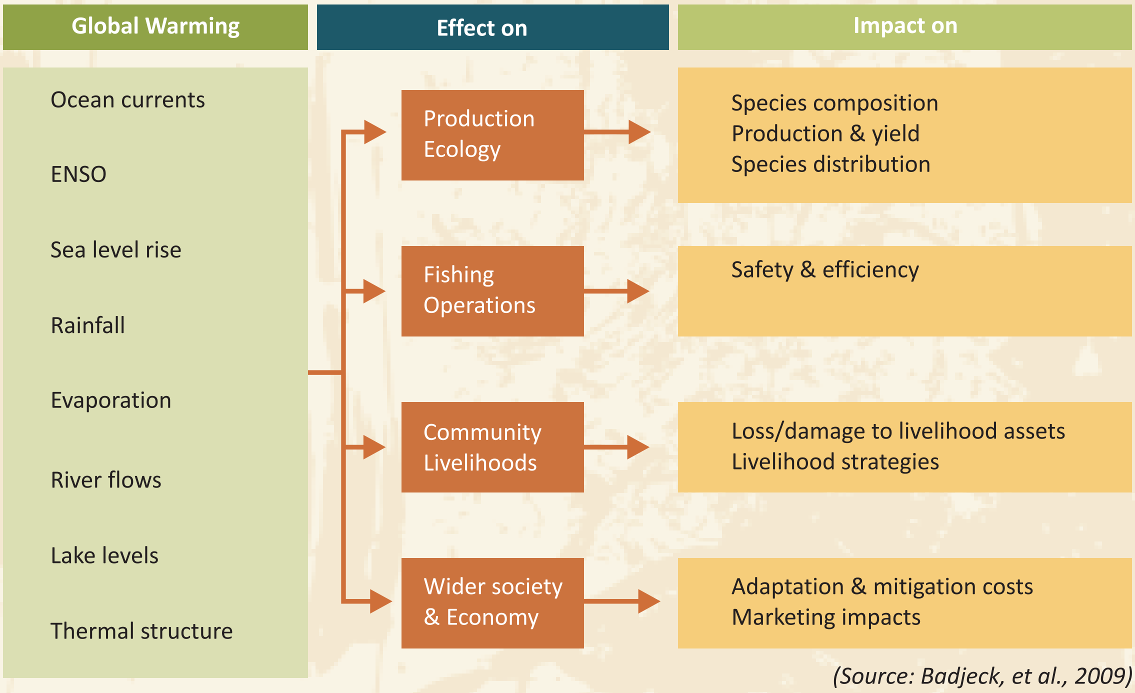
Climate change can impact fisheries through multiple path-ways (Figure 7.1). Changes in water temperature, precipitation and oceanographic variables, such as wind velocity, wave action and sea level rise, can bring about significant ecological and biological changes to marine and fresh water ecosystems and their resident fish populations (Cheung, *et al.*, 2009; Westlund, *et al.*, 2007), directly impacting peoples whose livelihoods depend on those ecosystems. Extreme weather events may also disrupt fishing operations and land-based infrastructure while fluctuations of fishery production and other natural resources can have an impact on livelihoods strategies and out comes of fishing communities (Coulthard, 2008; Iwasaki, *et al.*, 2009).

7.1.1 KEY CONCERNS ON IMPACT OF CLIMATE CHANGE

There are two main hypotheses concerning how populations and therefore communities change in response to climate. One suggests that changes in species distributions and abundances depend on 'bioclimatic envelopes' or 'climatic spaces', which are determined by the physiology of individuals (Pearson & Dawson, 2003).

The basis of this hypothesis is that changing climate should directly influence the survivorship, dispersal, fecundity and behaviour of individuals and these will directly transfer to species-level changes in abundance and distribution (Walther, *et al.*, 2002). Hence, future climate-induced changes may be predictable on the basis of current biogeographical information.

An alternative viewpoint places greater emphasis on inter-specific interactions, suggesting that individual level climate-induced changes in survivorship, dispersal, fecundity and behaviour will cascade to the population and community levels, both directly and indirectly (Ottersen, *et al.*, 2001; Stenseth, *et al.*, 2002; Pearson & Dawson, 2003).



(Source: Badjeck, et al., 2009)

Figure 7.1: Global warming and capture fisheries: impact pathways

Data from six meteorological stations of central and southeast coast of Bangladesh shows the trend of seasonal changes in 20 years (Figure 7.1). Length of winter shows irregular variation with increasing trends of 45 and 34 days in Sandwip and Hatiya respectively. Length of summer gives increasing trends in all the stations with 22 days in Maijdee but decreases 2 days in Chittagong. Length of rainy season indicates decreasing trend in all the stations with 19 days in Sandwip. Annual precipitation decreased in all the stations with particular concern in Feni (486 mm) and Cox's Bazar (222 mm).

7.1.2 TEMPERATURE

Changes in temperature, even small changes in water temperature are expected to exert strong pressure upon fish ecology (WWF, 2005). Temperature variations also affect people's health undermining their capacity for operating the fisheries. According to the statistical fixed-point observations in six meteorological stations (Maijdee, Hatiya, Feni, Sandwip, Chittagong and Cox's Bazar), it seems that the apparent warming trend has not been seen in Hatiya (Figure 7.3), as opposed to the world's expectation (IPCC, 2007). However, it seems that there is a slight warming trend of mean maximum and minimum temperature especially in the hottest month. In 20 years (1988-2008) variation, annual maximum temperature increased 0.08^{0}C, where annual minimum temperature decreased 0.89^{0}C and annual average temperature decreased 0.32^{0}C. Length of winter with temperature less than 15^{0}C has recorded 41 days and 55 days in 1988 and 2008 respectively, where first winter day shifted from 8 December to 18 November. Similarly, length of summer with temperature more than 35^{0}C has recorded 2 and 5 days in 1988 and 2008 respectively, where first summer day shifted from 14 February to 27 February (Table 7.1).

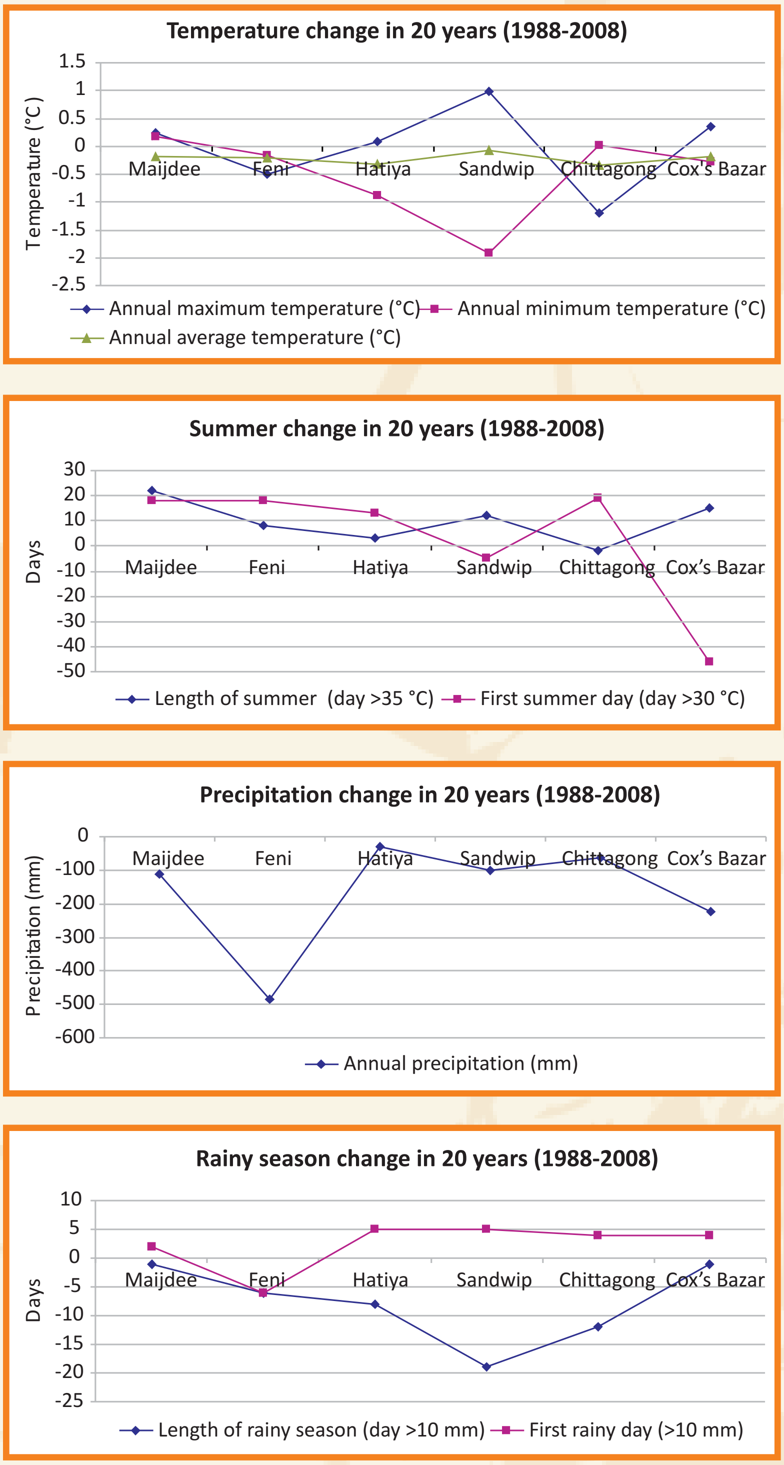
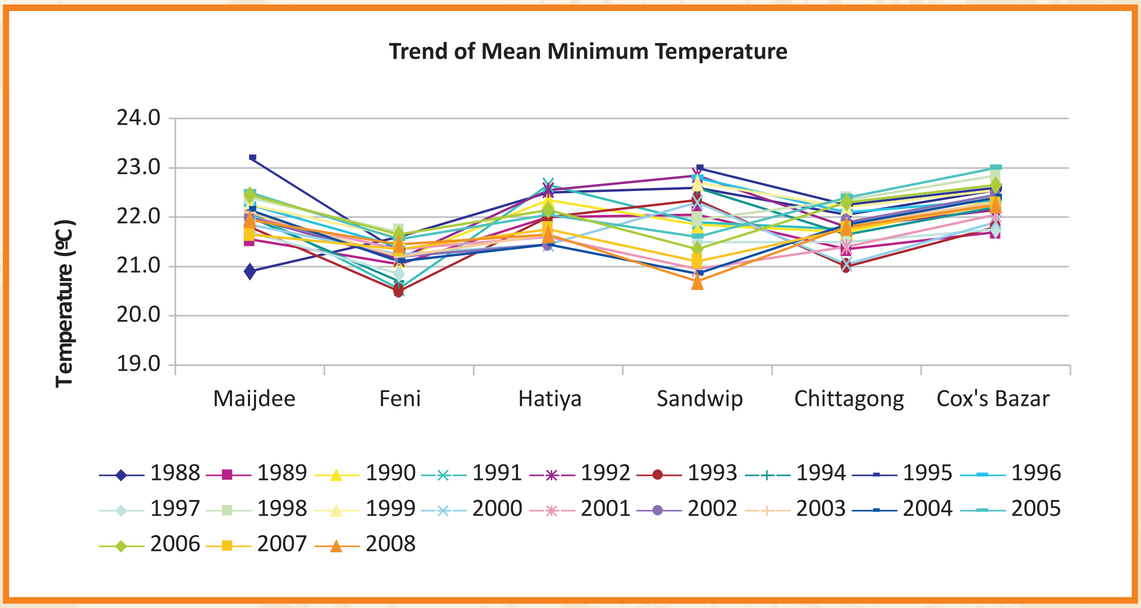


Figure 7.2: Trend of temperature, rainfall and seasonal changes in 20 years (1988-2008) in Maijdee, Hatiya, Feni, Sandwip, Chittagong and Cox's Bazar



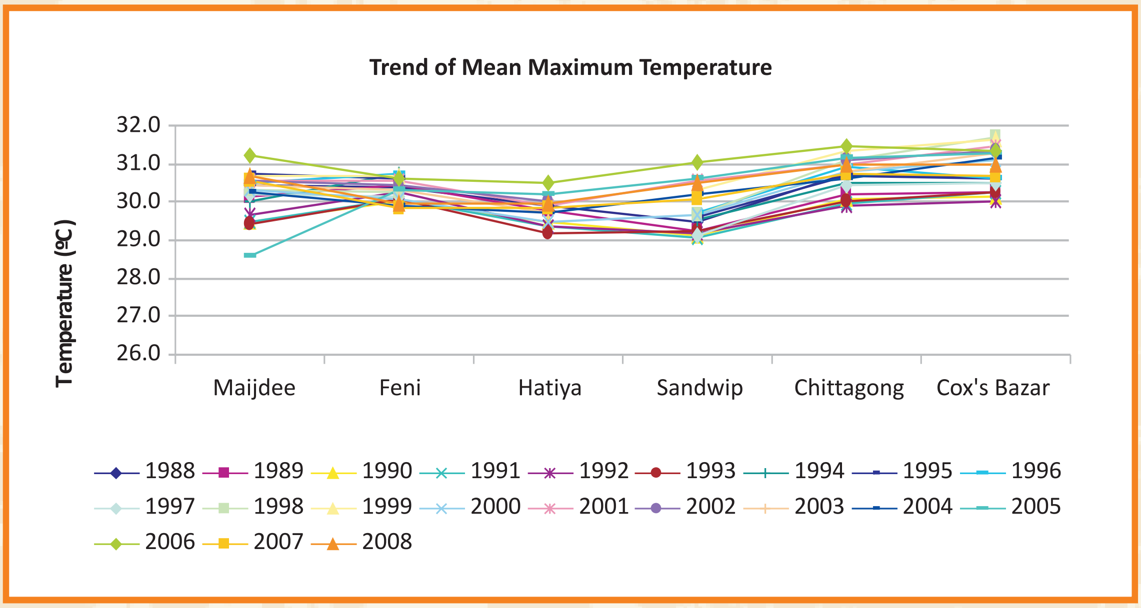


Figure 7.3: Trend of mean maximum and minimum temperature in Maijdee, Hatiya, Feni, Sandwip, Chittagong and Cox's Bazar

7.1.3 RAINFALL

The majority of the annual rainfall occurs from May to October. The southwest monsoon brings much rainfall from May to September while the northeast monsoon brings some rain in October and November. Mean annual rainfall in Hatiya Island is 3531 mm and 3004 mm in Maijdee. About 80-90% of annual rainfall is confined to the monsoon months (April-October). Annual mean total rainfall has decreased from 3561 mm in 1988 to 3531 mm in 2008. Length of rainy season with rainfall more than 10 mm has recorded 83 days and 75 days in 1988 and 2008 respectively, where first rainy day shifted from 13 May to 18 May (Table 7.1).

Table 7.1: Variation of climatic parameters in Hatiya Island of Noakhali District for a period of 20 years (1988-2008)

Parameters	1988	2008	Change
Annual max temperature (^{0}C)	29.91	29.99	0.08
Annual min temperature (^{0}C)	22.52	21.63	-0.89
Annual average temperature (^{0}C)	25.97	25.65	-0.32
Length of winter (day <15 ^{0}C)	41	55	34
First winter day (<18 ^{0}C)	8-Dec	18-Nov	10
Length of summer (day >35 ^{0}C)	2	5	3
First summer day (day >30 ^{0}C)	14-Feb	27-Feb	13
Annual Rainfall (mm)	3561	3531	-30
Length of rainy season (day >10 mm)	83	75	-8
First rainy day (>10 mm)	13-May	18-May	5

(source: Hossain, et al., 2010)

7.1.4 SALINITY

We have limited data sources on historical trends of water salinity. But scattered research, field visit and indigenous knowledge of local community has recognized the increasing trends of water salinity along the coast.

7.2 DEVELOPMENT OF MONITORING TOOLS

7.2.1 MONITORING FRAMEWORK

Historically, the monitoring of marine fish stocks has primarily taken species-level approaches. The objective is to develop monitoring tools to assess the impacts of climate change on marine and estuarine fisheries. Sea level rise and intrusion of saline water would result abundance of stenohaline and stenothermal marine organisms including fisheries in the upstream areas is the main assumption of this initiative. The operational structure of monitoring climate change effects on marine fisheries (MCCEMF) is outlined in Figure 7.4. MCCEMF is the integrated initiative involving government departments, non-government organizations, academic institutions and local community. The MCCEMF working group will be established with representatives from all the involved sectors, logistics and relevant scientific key-supervisors with AI/NGO as the secretariat.

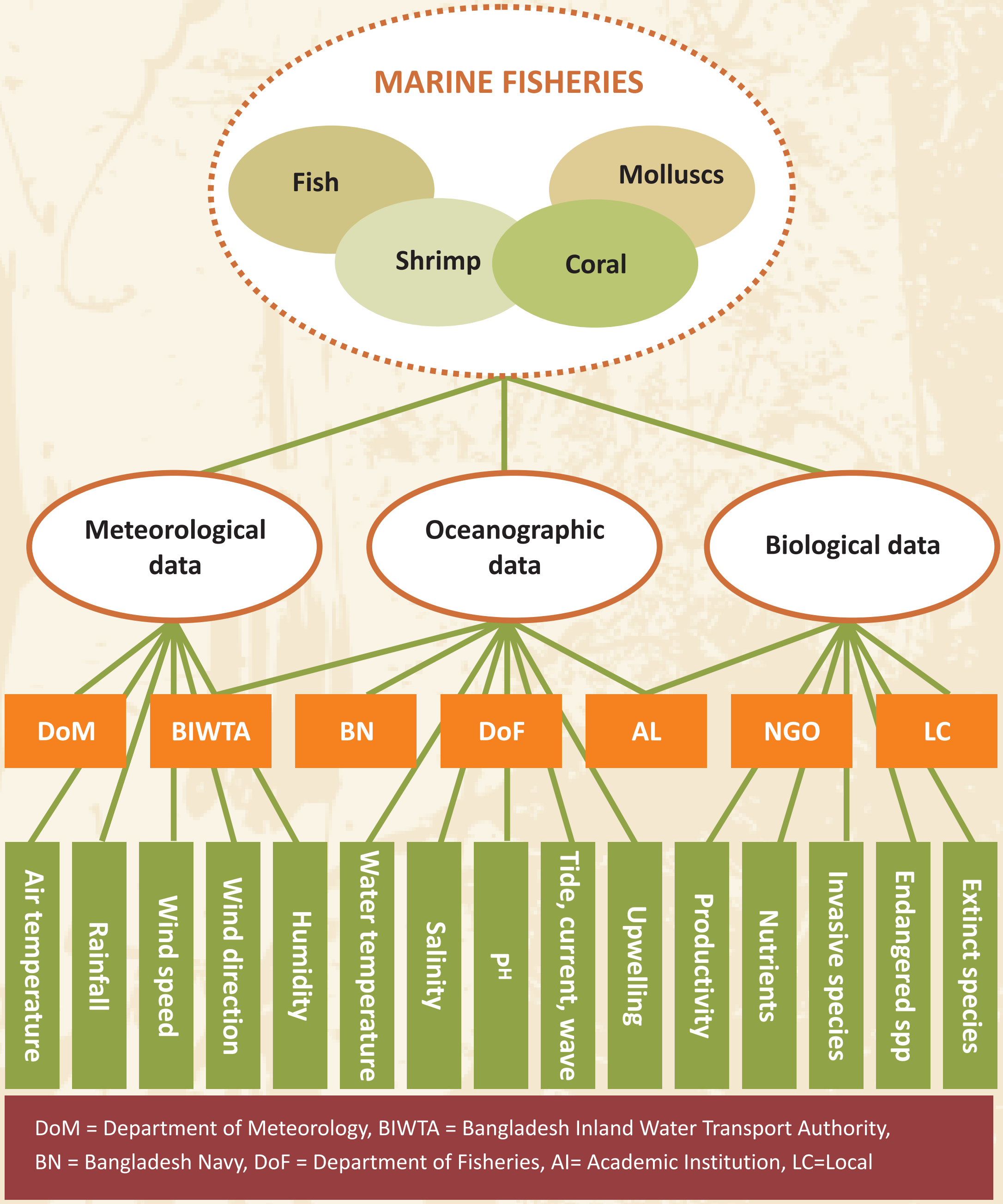


Figure 7.4: Operational structure for monitoring climate change effects on marine fisheries

7.2.2 INDICATOR IDENTIFICATION CRITERIA

Monitoring indicators should be identified for each species under the category of immigrant, invasive, endangered, vulnerable and extinct species based on the following criteria:

- Original distribution;
- Present existence and abundance;
- Probability of occurrence to the changes in ecological parameters (^{0}C, %); and
- Where will the species live in the future (2020).

7.2.3 MONITORING TEMPLATE

Monitoring parameters as well as the monitoring mechanism for each of the species under different category might be different. So, it is impossible to derive a common monitoring mechanism for a group of species as well as their location and way of data collection. In this regards, some example on monitoring mechanism using a standard template is given below:

Example 1. Immigrant species, *Liza* spp.

Endangered species	*Liza* spp. (English: Gray mullet, Local: Bata)
Original distribution	Coastal water including estuary, channel, creek, bay.
Present existence and abundance	In recent years the species found in the canals, tributaries and seasonal waterlogged areas of Feni-Noakhali regions due to saline water intrusion in the freshwater ecosystems.
Probability of occurrence to the changes in ecological parameters (^{0}C, %)	Continuous climatic variation may enhance saline water intrusion and permanently shift the freshwater ecosystem with brackish water characteristic. As a result the immigrant species (*Liza* spp.) will become the resident species in Feni-Noakhali region.
Where will the species live in the future (2020)?	More upstream with simultaneous saline water intrusion.
Monitoring options	Sample and related data can be collected from the local fishermen as well as market observation.
Field observation	Feni, Noakhali.
Remark	From our research experience and field verification, we can select this species as monitoring indicator.

Example 2. Immigrant species, *Penaeus monodon* postlarvae

Species	*Penaeus monodon* postlarvae (English: Tiger shrimp, Local: Bagda)
Original distribution	Coastal water including rivers, canals, tributaries and creeks.
Present existence and abundance	Saline water intruded upstream aquatic ecosystems including canals, tributaries and seasonal floodplain of central and southwest coastal regions.

Species	*Penaeus monodon* postlarvae (English: Tiger shrimp, Local: Bagda)
Probability of occurrence to the changes in ecological parameters (^{0}C, %)	In recent years saline water intrusion is a common phenomenon in coastal freshwater ecosystems in central and southwest regions. Thus, Penaeus monodon postlarvae are being migrated to the newly salinity-intruded areas.
Where will the species live in the future (2020)?	Salinity-intruded aquatic ecosystem in upstream regions of central and southwest coastal regions.
Monitoring options	Sample and related data can be collected from the local people, particularly wild fry collectors (using push net), fry traders, and fishermen from the central and southwest coastal regions.
Field observation	Feni, Noakhali, Laxmipur, Barisal, Khulna, Bagherhat, Satkhira.
Remark	It can be one of the potential species (postlarval phase) as monitoring indicators which will represent the commercially important species.

Example 3. Hinder regular growth pattern and farming of *Macrobrachium rosenbergii*

Species name	*Macrobrachium rosenbergii* fry (Giant river prawn, Golda)
Original distribution	Freshwater ecosystems e.g., river, canal, flood plain, pond.
Present existence and abundance	Freshwater ecosystems e.g., river, canal, flood plain, pond.
Probability of occurrence to the changes in ecological parameters (^{0}C, %)	The late and irregular rainy season in recent years has been hampered fry production and smooth farming. Farmers cannot stock fry in time due to scarcity of rain water and high temperature. Moreover, flood, cyclone, erosion and saline water intrusion are the remarkable risks for golda farming. As a result, most of the hatcheries stopped fry production that has created financial discrepancy of the investors and unsecured livelihoods of concerned stakeholders.

Species name	*Macrobrachium rosenbergii* fry (Giant river prawn, Golda)
Where will the species live in the future (2020)?	Irregular seasonality and fluctuation of environmental condition may permanently hindrance the growth, reproduction and farming.
Monitoring options	Related data can be collected from the recognized hatcheries and culture farms, particularly in the southwest coastal region.
Field observation	Visit the hatcheries and farming sites, particularly in the southwest coastal region.
Remark	Important species since time immemorial, easily monitor by the local farmers.

Example 4. Immigrant species, *Orcaella brevirostris*

Species	*Orcaella brevirostris* (English: Errawaddy dolphin, Local: Dolphin)
Original distribution	Offshore area of the Bay of Bengal.
Present existence and abundance	Coastal and near shore areas of Bangladesh.
Probability of occurrence to the changes in ecological parameters (^{0}C, %)	The abundance is positively correlated with ecological parameters and availability of feeds. Presence of dolphin in the coastal water indicates shifting offshore environment towards the coast, which is their favourable habitat.
Where will the species live in the future (2020)?	Upstream ecosystem with favourable environment.
Monitoring options	Sample and related data can be collected through participatory observation and interviewing the gill net fishermen, Bangladesh Navy and Coast Guard.
Field observation	Near shore and offshore areas of the Bay of Bengal.
Remark	It can be one of the potential monitoring indicators as the member of higher animal (Mammal).

Example 5. Vulnerable species of *Boleopthalmus viridis*

Species	*Boleopthalmus viridis* (English: Mudskipper, Local: Venda mach)
Original distribution	Muddy shore areas along the coast as well as offshore and near shore islands.
Present existence and abundance	Muddy shore areas along the coast as well as offshore and near shore islands.
Probability of occurrence to the changes in ecological parameters (^{0}C, %)	The species are in vulnerable condition in their habitat due to increased tidal magnitude along the coast, particularly during spring tide. It has been recognized that tidal behaviour changed along the coast in terms of magnitude but not in pattern (semi-diurnal). Abundance and distribution of the species has been extended to further upstream regions due to sea level rise and saline water intrusion. Moreover, irregular precipitation and seasonal change may hamper their natural reproduction and growth.
Where will the species live in the future (2020)?	The species is being migrated to salinity-prone further upstream and may become endangered in their original habitat i.e., coastal mud flats of Bangladesh.
Monitoring options	Sample and related data can be collected by transect analysis along the coastal mud flats.
Field observation	Cox's Bazar and Teknaf coast.
Remark	It can be one of the potential species as monitoring indicator.

Example 6. Endangered species *Chelonia mydas*

Species	*Chelonia mydas* (English: Green turtle, Local: Sabuj kachhap)
Original distribution	Sandy beach of the southern peninsula Teknaf including Saint Martin's Island.
Present existence and abundance	Five species of marine turtle are reported to occur in the coastal waters of Bangladesh: olive ridley *(Lepidochelys olivacea)*, green *(Chelonia mydas)*, hawksbill *(Eretmochelys imbricata)*, loggerhead *(Caretta caretta)* and leatherback *(Dermochelys coriacea)*. It has been reported that the sandy beach of Shahporir Dip in Teknaf Upazila is a suitable breeding ground for turtle. Among the five species *Chelonia mydas* has been selected as indicator being comparatively common.
Probability of occurrence to the changes in ecological parameters (^{0}C, %)	The ever changing ecological parameters may create unfavourable environment for turtles.
Where will the species live in the future (2020)?	The population of nesting turtles is reducing in recent years especially green turtle. In search of suitable feeding, breeding and nursery grounds they will migrate to further downstream i.e. Arakan coast of Myanmar and/or the islands of Indian Ocean, which is a trans-boundary issue for biodiversity conservation.
Monitoring options	Sample and related data can be collected from the local people, fishermen and transect analysis in sandy shore of the Teknaf Peninsula and Saint Martin's Island.
Field observation	Teknaf Peninsula and Saint Martin's Island.
Remark	Can be an excellent monitoring indicator.

Example 7. Endangered species gastropod *(Turrittella* sp.*)*

Species	Gastropod *(Turrittella* sp.*)*
Original distribution	Benthic zone of sub-tidal area along the coastal water.
Present existence and abundance	Species habitat changed to the inter-tidal zone.

Species	Gastropod (*Turrittella* sp.)
Probability of occurrence to the changes in ecological parameters (^{0}C, %)	The coastal physical processes, particularly wave action and current velocity forced the organism to the literal and supra-literal zones (inter-tidal area), where most of the species die and decay due to the exposed characteristics of the literal and supra-literal zones. The mass mortality of the species may create harmful condition as well as disease outbreaks to other aquatic organisms.
Where will the species live in the future (2020)?	Future habitat will be the inter-tidal zone. May also endanger and extinct.
Monitoring options	Sample and related data can be collected through field visit, interview of local fishermen, fish/shrimp farmer.
Field observation	Coastal zone of Cox's Bazar, Teknaf and nearby islands.
Remark	Coastal people of Cox's Bazaar use the dead shell to prepare ornamental goods for tourists. Monitoring is required to conserve the species.

Example 8. Endangered species, *Hippocampus* sp.

Endangered species	*Hippocampus* sp. (English: Sea horse, Local: Assogotok)
Original distribution	Coastal water, particularly along the southeast coast
Present existence and abundance	The presence of sea horse was common in the coastal water. But there was no report of their existence in the last 10 years. In 2006-07 an extensive exploratory survey was conducted in Southeast coast and the finding indicates that sea horse population reaches in endangered level. Only 5 individuals of *Hippocampus* sp. was counted in the Naaf river estuary during year round expedition.
Probability of occurrence to the changes in ecological parameters (^{0}C, %)	The climatic variation with the fluctuation of temperature, salinity, pH, etc as well as changes in seasonal pattern (precipitation, monsoon wind, current direction, coastal upwelling, etc) may create unfavourable environmental condition for their survival.

Endangered species	*Hippocampus* sp. (English: Sea horse, Local: Assogotok)
Where will the species live in the future (2020)?	Will extinct from the coastal water of Bangladesh.
Monitoring options	Sample and related data can be collected from the coastal fishermen, particularly ESBN operator.
Field observation	Naaf River estuary.
Remark	Ecologically important species, need to monitor.

Example 9. Invasive species, *Scoliodon sorrakowah*

Species	*Scoliodon sorrakowah* (English: Yellow Dog shark, Local: Hangor)
Original distribution	Offshore water of the Bay of Bengal
Present existence and abundance	The fishermen have been caught from the artisanal fishing zones of the Bay of Bengal i.e., about 10-15 km of the coastal water.
Probability of occurrence to the changes in ecological parameters (^{0}C, %)	The abundance is positively correlated with ecological parameters and availability of feeds. Presence of shark in the coastal water indicates shifting offshore environment towards the coast, which is their favourable habitat. Changing temperature, rainfall pattern and thus salinity distribution may hamper their breeding and reproduction.
Where will the species live in the future (2020)?	Near shore ecosystem with favourable environment.
Monitoring options	Sample and related data can be collected through participatory observation and interviewing the fishermen, Bangladesh Navy and Coast Guard.
Field observation	Near shore and offshore areas of the Bay of Bengal.
Remark	Due to high demand of shark fin, skin, bone and flesh in the global market fishermen have been caught shark. Shark can be a monitoring indicator.

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CHAPTER – 8

INDICATORS TO ASSESS IMPACTS ON FOREST FLORA & FAUNA

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8.1 FOREST AND FORESTRY IN BANGLADESH

The British crown for the first time promulgated Act VII in 1865 in connection with the Forests and Forestry of this country and established a rule of law in this sector. This was the first forestry related act for this part of the world. Many tracts within the territory of Bangladesh were declared as "Reserved Forests" under this act and were placed under the control of Forest Department for scientific management. Most of the existing Sundarban was notified as reserved forests during 1875-76.

The forests in the greater district of Sylhet were declared as 'Reserved Forest' under Assam Forest Regulations. The forests of Chittagong and Chittagong Hill Tracts were declared 'Reserved Forests' in early 20th century. Forest management followed such process of reservation. Professional foresters of the government forest department played the key role in the management of these reserved forests since inception.

About 2.52 million hectares, nearly 17.40% of Bangladesh, is regarded as forest, of which

- 1.52 million hectares is under the direct control of Forest Department (FD), Government of Bangladesh
- 0.73 million hectares is Unclassed State Forest (USF) under the control of district administration, and
- 0.27 million hectares is privately owned Village Forest (VF) and tea garden forests.

The forest area under the control of Forest Department, Government of Bangladesh is as under,

Hill forests	0.67 million hectares	4.65% of the country
Natural mangroves	0.59 million hectares	4.09% of the country
Mangrove afforestation	0.14 million hectares	0.97% of the country
Sal forests	0.12 million hectares	0.83% of the country

These are legally "Forest Land" but do not mean to have a complete tree cover. According to Forestry Master Plan (1993) the actual forest cover of the country will not exceed 6%. Per capita forestland in Bangladesh has shrunk to 0.022 hectares, said to be one of the lowest in the world. Annual deforestation in Bangladesh is reported to be 8,000 hectares. The annual deforestation rate in South Asia is 0.6% whereas in Bangladesh it is 3.3% (Gain, 2000).

Government of Bangladesh normally highlights “population pressure” to be the main cause of forest depletion in Bangladesh. The proceedings, on the regional consultation for South Asia Region under Forest Policy Implementation Review and Strategy (FPIRS) of World Bank held at Rajendrapur during 17 - 19 April 2000, complied by Dr. Ainun Nishat indicated that there was a tough debate among the participants on the issue of causes of forest degradation in Bangladesh. They did not agree that it was the poor who could be made solely responsible for degradation of the forests. They rather opined that it was the rich and influential quarters of the society whose role should be questioned. However the fact remains that forest depletion is continuing.

In the recent past FD has started laying emphasis on the community forestry, wherein the members of public are being involved as participants in afforestation, protection and maintenance of the tree growth. In 2005, Rules have been promulgated illustrating the details of sharing mechanisms of the yields with participants of various categories. In view of the paucity of government allocations for reforestation following the harvest 'Tree Farming Funds' have been created where in 10% of the sale proceeds are being deposited for meeting the required cash expenditures of reforestation following the felling. On the top of these FD has developed a mechanism to communities in the management of 'Protected Areas' as well and have acceded to share the forest revenue income with communities.

These attempts by the FD Government of Bangladesh have created a momentum of public participation in the forestry activities apparently leading to a better situation with respect to the protection of tree cover. It needs to be noted herein that all of these have the risk of bringing in an adverse impact on the forest ecosystem as a whole wherein the diversity is likely to be jeopardized and lost to commercial exotic pure tree grooves.

8.2 IMPACT OF CLIMATE CHANGE ON FLORA AND FAUNA

The temperature is increasing at an increasing rate. Higher temperature is causing increased melting of ice-caps and glaciers, leading to sea level rise, salinity intrusion further inland, and so on. Global warming is also enhancing the evaporation especially at sea surface, which in turn causing further increase (as long as it remains in gaseous form) of the global temperature. The components of climate change those are of concern with respect to the forest flora and fauna (wildlife) are

i. Higher temperature,
ii. Sea level rise,
iii. Salinity intrusion (further inland),

iv. Change in the seasonal rainfall pattern,
v. Prolonged dry periods,
vi. Declined total precipitation,
vii. Torrential rain in short span of time, leading to erosion, flooding, etc.

These components of climatic parameters, individually as well as jointly, shall be affecting the forest ecosystems and in turn shall cause impact on the flora and fauna (wildlife). The major forest types that are available in Bangladesh are located at

- Sundarban & Coastal Areas (Mangrove Forest),
- Chittagong & Chittagong Hill Tracts (Semi Evergreen Forest),
- Sylhet (Evergreen Forests) and
- Sal Tract (Central and North Western part of the country, Deciduous Forest).

It is anticipated that these different types of forests will respond differently under the climate change impact. Thus if we want to monitor the impact of climate change in the forests of Bangladesh, we need to bring at least these four types of forests under consideration.

Bio-indicators are useful tools for measuring changes over time, and can provide valuable insights on important issue like climate change. Both the flora and fauna of the forest ecosystems are very likely to be affected by the climate change. Once the climate change has been functional over a long period of time say over a period of 50 or 60 years, a given forest ecosystem will definitely exhibit a change.

The existing ecosystem if compared with that of its features & characteristics, 50 years back, will exhibit a definite difference. The forest flora and fauna, which are sensitive to climatic factors such as temperature rise, change in the precipitation regime, etc., can be tagged as “indicators”. Identification of not only the indicator species but also the parameter to be measured for monitoring the climate change impact if any is the required key.

The International Perspective of Climate Change (IPCC) predicted that the total rainfall may increase but its seasonal sequences will change and is very likely to be erratic and at time may be incessant leading to severe floods. Under the Bangladesh context, especially with respect to the forests, the precipitation is an important parameter. Any change in the total quantity of the precipitation (rainfall) and its distribution over the year are likely to affect the floral and faunal component of the forest ecosystem. IUCN identified a group of key experts having long experience and profound knowledge on forests and forestry as well as on forest ecosystem functions, to work together as a team to identify the indicators and its parameters for monitoring the climate change impact.

If we surf through literatures, a number of relevant literatures have been published that facilitates understanding on the impact of climate change on ecological components, viz. flora and fauna. It will also guide us to select the parameters that will be using for monitoring the climate change impacts. In the following list, a number of literatures are given with an annotated review:

- Morphological parameters of plants, such as leaf area, leaf ratio, stomatal density, shoot-root ratio, internodal length, etc., have been proven to be useful indicators for assessment of climate change impact in many studies (Turner, 1986; Beerling and Chaloner, 1992; Eamus, *et al.*, 1993; Steege, 1994; Farnsworth, *et al.*,1996; Kundu and Tigerstedt, 1997; Kundu and Tigerstedt, 1999; Apple, *et al.*, 2000; Balasooriya, *et al.*, 2009 and Wuytack, *et al.*, 2010).
- Moza and Bhatnagar (2005) found that parameters such as appearance of leaf-primordia, start of leaf-fall, timing of opening of flowers, anthesis and period of maximum bloom are affected by climate change impact.
- Menzel and Fabian (1999) reported that many tree species exhibit change in flowering pattern due to climate change impacts. Abu-Asab *et al*. (2001) have studied changes in first-flowering times of over 100 plant species, representing 44 families of angiosperms for 29 years (1970–99). They observed that most of the trees now flower 3–5 days earlier than they did some years ago. This is probably due to early warming of the ecosystem, as an impact of climate change.
- *Macrosiphoniella sanborni* (Gillette) is a common aphid that infests a number of plants in Indian subcontinent. The intrinsic rates of increase (Rm) for 9 generation of *Macrosiphoniella sanborni* (Gillette) infesting chrysanthemum plants were calculated in the Kalyani University campus, where the climatic condition was more or less same in many areas in Bangladesh. Das & Chakrabarti (1985) have found that temperature has definite impact on Rm of aphids. The relationship between Rm and available filed temperature was investigated. It was observed that Rm is inversely related to field temperature. Das & Chakrabarti (1992) found that impact of seasonal trends in temperature on the morphology of *Macrosiphoniella sanborni* (Gillette) (Homoptera : Aphididae) for their six generations in the filed (Rajshahi) was studied. Significant influence of temperature on the caudal length of the said aphid (second instar) was found. Biswas *et al*. (1993) reported that *Macrosiphoniella sanborni* (Gillette) (Homoptera : Aphididae) feeds on shoots and foliage, causing damage to chrysanthemum plants. Experiments were conducted to study the effect of temperature, relative humidity and dew point on the longevity of the said aphid species. Temperature and moisture had marked effect on the longevity of *M. Sanborni*. Biswas *et al*. (1994) reported that chrysanthemum is a common ornamental plant which is heavily infested by the aphid, *Macrosiptaniella sanbomi* Gillette (Homoptera : Aphididae) in Bangladesh. Experiments were carried out to study the nymphal duration of *M. sanbomi* for its six generations and the effects of temperature on the durations of nymphal instars. It was observed that there was no significant difference among the durations of four nymphal instars of any particular generation. But, except for the first instar of all generations, significant relationships were obtained among the rest of the instars, i. e., second instar ($p < O.O5$), third instar ($p < O.Ol$) and fourth instar ($P < O.Ol$). It was also observed that temperatures had negative effects on

the duration of each instar. Karim *et al.* (2000) while studying the biology of common aphids *Aphis gossypii* Glover (Homoptera : Aphididae) found relationships between different events of their lifecycles, such as temperature, moisture, photoperiod, rainfall and soil temperature. Karim *et al*. (2001a) while studying aphids *Aphis gossypii* Glover (Homoptera: Aphididae) at Rajshahi, Bangladesh found a significant negative effect of temperature on the Rm of the aphid species. Karim *et al* (2001b) while studying the population growth of aphids over different seasons having varied temperature found that there is strong negative correlation between the temperature and Rm. Karim *et al*. (2002) while studying the impact of temperature, relative humidity, dew point, rainfall, soil temperature and photoperiod on the morphology of *Aphis gossypii* Glover (Homoptera: Aphididae), concluded that temperature has significant impact.

- Since all of these above mentioned studies established the fact that aphids' Rm responses to ecosystem temperature. Population growth rate of aphids thus could be a good indicator of climate change impact.
- Siddiquee (2004) found that the species diversity and abundance of ground beetle vary with season, mostly due to temperature impact.
- Gegear *et al*. (2010) reported that instinct guides the migrating monarchs on their journey as they follow their host plant, the milkweed. But what is the underlying biological mechanism that monarch butterflies rely upon to sense where they are while they travel along their migratory flyway? A team of neurobiologists that has investigated the mysteries of monarch migration for many years now reports that photoreceptor protein found in monarch butterflies are linked to animal navigation. Their research finds that two types of photoreceptor proteins not only allow the butterflies to see UV light (light that is less than 420 nm long, and thus, is invisible to humans), but also allows them to sense the Earth's geomagnetic field. These photoreceptor proteins are known as cryptochromes. Since the migration of butterflies is guided by the host plants some change in the ecosystem is very likely to cause impact on the local abundance.
- Shajahan *et al*. (2008) while studying the butterfly diversity in Bangladesh forests found that the species diversity is highest during hot season i.e., March to July. Thus increase of temperature due to climate change may enhance species biodiversity of butterflies.

Now it is quite clear that all the forest areas of Bangladesh will be facing the climate change impact. However, some the areas such as Sundarban and Coastal Areas may face more severe impacts, mostly because of sea level rise and more so due to enhanced salinity situation. It was an important requirement to assess what could be the probable consequences of the forest ecosystems or the nature of impact-results, due to the climate change phenomenon. The key experts over long drawn brain storming sessions reached the following consensus in this connection:

a. The distribution and composition of species in the forests of Bangladesh is very likely to be affected by the climate change phenomenon in general.

b. Climatic change will cause shift of wetland forests to terrestrial ones and terrestrial habitats toward xeric habitat.

c. These impacts from climate change can broadly be accounted for by assessing the following attributes:

   i. Species composition and vegetation structure. These could be monitored through taxonomic survey and by making checklist as a baseline data.
   ii. Indicator tree species at different forest eco-types. Three important tree (above pole size) species available in the site could be selected
   iii. Presence and abundance of lianas and epiphytes. Presence of lianas and epiphytes (number and species) may be important parameter.
   iv. Insect abundance. Pollinating insects especially bees such as Apis dorsata and A. cerana are linked with flowering of plants.
   v. Phenology (flowering timing and consequently fruiting time). Leaf shading, leaf flushing, flowering and fruiting time and periodicity are influenced by environmental factors such as temperature and soil moisture etc.
   vi. Morphometric traits (leaf area, leaf ratio, stomatal density, etc.). Morphometric traits, such as leaf area, leaf ratio, stomatal density, inter-nodal length and root-shoot ratio could be monitored periodically of selected tree species to see the changes over periods, which are likely to indicate the impacts of climate change at a relatively early stage.

8.3 PARAMETERS FOR IMPACT MONITORING

Generally the overall impact will be on the ecosystem. The components of the ecosystem, may be species in this connection, those are more sensitive to the climate change components; need to be used for monitoring. In absence of valid research information on this topic, it was extremely difficult to pin point the indicator that may be used under this given context. It was agreed by all the participating 'Key Experts' that indicator species should preferably possess the following attributes:

- It possess the sensitivity to respond to climate change impacts;
- It has a causal linkage to climate change;
- It possess the capability to respond and differentiate in space and time;
- It is relevant regarding policy goals, for instance population trends of target species;
- It is representative of the given ecosystem and/or species group.

The ecosystem aspects such as phenology, succession, mortality, etc. will be major areas that may similarly be used under this given situation. However, based on long forestry experiences, of the participating 'key experts', through a few hours of long discussions, the followings have been suggested for use as the parameters for the given purpose.

8.3.1 MONITORING PARAMETERS FOR FLORA

Sl No	Parameters	Justifications
1	Natural regeneration, proportion of major species for the given forest, especially on hotter aspects	Under the impact of climate change phenomenon, the proportion of regeneration of wetter environment loving major species is likely to decline over a given period. This will change the structure of the forest composition in the long run. If the proportions of regeneration of these major species exhibit a decline, it may be taken as an impact of climate change. The hotter aspects have been suggested since they are likely to be affected first.
2	Species composition of the forest undergrowth	The probable climate change scenario is supposed to be higher temperature, reduction of soil moisture in general and at the same time there may be erosion due to heavy downpours. These are likely to cause some change in the composition of the undergrowth of the forest, to begin with. Thus it has been suggested to collect the data on the composition of the forest undergrowth to get an idea of the impact of climate change if any at the very initial stage.
3	Flowering and fruiting (time and abundance)	The probable scenario of reduced moisture and increased temperature due to climate change is very likely to affect the phenology, especially the flowering & fruiting time of the trees. Thus it has been suggested to keep note of the timing of flowering & fruiting to find out if any shift in the flowering and fruiting time is taking place, to read the impact of climate change if any.
4	Insect abundance, especially the pollinating insects, especially at the time of flowering	Under the probable climate change scenario the total water supply in a given ecosystem is likely to reduce while the temperature may increase. It is apprehended that these sort of changes may affect the reproductive cycles of the insects in general. If the pollinating insects are affected as such the production of fertile seeds may decline, which in turn will impair the forest composition in the long run. Reading of the abundance of pollinating insects, especially, is likely to give a clue of the climate change impact.

Sl No	Parameters	Justifications
5	Species composition of the major species at their pole stage	Species composition of the major species at pole stage (3 to 10 feet tall saplings) will give an indication of the composition of the future forest stand. Reading of the composition of the major species at pole stage and analyses of these data is likely to indicate if the composition of the future forest stand will continue to remain as it is during base line data. If any serious deviation is found that may be an indication of climate change impact.
6	For many of the forest ecosystems in Bangladesh orchids, lichens and ferns are indicative of healthy ecosystems. For such forest patches, occurrences and abundances of these, especially orchids, may be used	Presence of orchids, lichens and ferns indicate good health of the forest stand in general, especially in Bangladesh context. Thus it has been suggested to take note of these to find out if they are declining, which if noticed may indicate impact of climate change.

8.3.2 MONITORING PARAMETERS FOR FAUNA (WILDLIFE)

1. Identify the wildlife species (terrestrial), topping the pyramid, for the given forest ecosystem and use the following parameters of this species. Population, male female ratio and the growth rate of the population (the prediction is that under climate change scenario, the female population will increase while the overall population growth rate will decline)

2. Identify the preying birds such as Eagles, Vultures, etc. that are indicative of ecosystem health and look for the following parameters. Population abundance and the growth rate the population need to be noted. (If the population of these species seems to decline that may be an indication of the climate change impact.)

3. Aphids (Homoptera: Aphididae: Insecta: Arthropoda) are good indicators of the changing climate. Because of their short generation time, parthenogenecity, high reproductive capacity and low developmental threshold temperatures, the aphids respond particularly strongly to climate change. Climate influences aphids both directly and through impacts on their food plants and habitats. Strong relationships between aphid phenology/bio-ecology

and environmental variables have been found for many species. They have wide host range including forest/wild plants. Past 20 year data are available locally/regionally (Das & Chakrabarti, 1985, Das & Biswas, 1992; Biswas, *et al.*, 1993, 1994) for few most common species, viz. *Aphis gossypii*, *Aphis craccivora*, *Lipaphis erysimi*, etc. for comparison. Some groups of predators (coccinellids, anthocorids, chrysopids, spiders etc.) and parasitoids (aphidiine) abundance and distribution are primarily dependent on the density of aphids. Accordingly, one or two species may be selected and used for monitoring climate change impacts.

4. Butterfly (Lepidoptera: Insecta: Arthropoda) are sensitive to macroclimatic conditions are good indicators of environmental change. Local/regional data on butterflies if available can be used to understand the impact of climate change in Bangladesh.

5. Bees (Hymenoptera: Insecta: Arthropoda) are likely to exhibit changed behavior and physiology under the influence of climate change. They are vital pollinators for many forest species. Their population is likely to decline under climate change impact, which in turn will reduce the production of fruits and nuts, impairing the food supply to the other wild life. Scientists have suggested that climate change can make bee more vulnerable to CCD (Colony Collapse Disorder). *Apis dorsata* (wild honey bee) may be used for monitoring climate change impacts.

8.4 MONITORING MECHANISM

For ease of monitoring, it was suggested that the indicators to be used need to be robust and easily recognizable. On the other hand, monitoring has to be effective and efficient as well. To be effective it is necessary that the indicator species is sensitive to the climate change components. The species that possess wider tolerance range, to reach its point of elimination, may be a better one for prolonged use in connection with the monitoring. Such species may not exhibit any response in short period of time. The more sensitive species will response early.

8.4.1 INDICATOR SPECIES

The expert group discussed in details on indicator species and agreed upon the followings.

An environmental indicator is a species or group of species that responds to an environmental disturbance, predictably and sensitively, in ways that can be readily observed and quantified. Indicators are generally selected to act as surrogates of, at least a subset of other organisms present in the same habitat. Indicators have been classified into a number of categories such as:

- Sentinels Sensitive organisms introduced into the environment as early-warning devices;
- Detectors Species occurring naturally in an area of interest that may exhibit measurable responses to environmental change such as changes in distribution, behavior, growth, etc;
- Exploiters Species whose presence indicates the probability of disturbance or pollution;

- Accumulators Organisms that take up and accumulate chemicals in measurable quantities;
- Bioassay organisms Organisms selected for use as laboratory reagents to detect the presence of particular chemicals.

Of these five categories, it is anticipated that detectors will initially be the most useful type of indicator for the purposes of monitoring climate change impacts. However, monitoring programs using sentinels may also be an option.

The expert group through long discussions and brain storming sessions reached a consensus to use the following tree species as indicator under flora component of the given forest ecosystem (Table 8.1).

Table 8.1: Ecotype wise indicator tree species

Sl No	Forest eco-types	Indicator tree species
1	Hill forest: Chittagong Hill Tracts, Chittagong and Cox's Bazar	Dholi-garjan *(Dipterocarpus alatus)*, Kanak *(Schima wallichii)* and Dharmara *(Stereospermum personatum)*.
2	Hill forests: Sylhet	Chapalish *(Artocarpus chaplasha)* and Batna *(Castanopsis inidica)* and Rattan *(Calamus viminalis)*.
3	Sal forests: Dinajpur, Mymensing and Dhaka	Sal *(Shorea robusta)*, Haldu *(Adina cordifolia)* and Kanchan *(Bauhinia acuminata)*.
4	Sundarban Mangroves: Khulna and Bagerhat	Sundri *(Heritiera fomes)*, Gewa *(Excoecaria agallocha)* and Baen *(Avicennia officinalis)*.

It has been agreed by the expert group that these species are relatively more sensitive to water and temperature regime, than others growing along with them in the given ecosystem. That is why these species have been identified as such.

8.4.2 SELECTION OF SAMPLE SITES

Several discussions were held among the key experts, who possess long experiences of forests and forestry in Bangladesh. These discussions of experts transpired that under the climate change impact the most important aspect will be the shift of the water regime, which will affect the ecosystem. The wetter ecosystems will get subjected to less wet condition, the moist areas will get subjected to dryer conditions, and the less moist areas will start experiencing dry to very dry conditions. Keeping these under primary consideration, the key experts, using their past field experiences, have identified 14 sample sites (Table 8.2) in Bangladesh forest (ecosystems) areas covering the following.

- To have the flavor of varieties of forest ecosystems in Bangladesh as far as possible;
- To have a site that has the least anthropogenic interferences than similar other ecosystems;
- To secure best possible protection, so that the human interferences can be kept at its minimal;
- Existence of a typical floral and faunal composition in the given ecosystem, etc.

Table 8.2: Sample sites

Sl No	Name of the sites or beat etc.	Forest Division	Area of the sample site in hectares	Justifications for selecting this given site
1	Botanical garden, Chittagong.	Chittagong (North)	2.0	This area at present possesses scattered tree growth and partially degraded. This site has been declared as 'protected area'. Thus it is expected that it will be well protected from human interferences, and thus will be better site to monitor. Besides these, this is a partially degraded site the impact of climate change on this sort site will be reflected through monitoring over a long period of time. It will indicate the impact that may occur in most of our USF lands. This given site is highly accessible. Thus it will be easy to monitor and visit very frequently and quite easily.
2	Mochoni	Cox's Bazar (South)	5.0	This is an area within Teknaf Game Reserve (TGR) and is a protected area. Thus it is expected that the human interferences at this site will be minimal and that is why we have selected this site for climate change monitoring. This is a natural habitat of wild elephant. At present herds of elephants are often seen in this area. From the view point of fauna this is an important site and that is why we have selected this site as one our climate change monitoring sites.

Sl No	Name of the sites or beat etc.	Forest Division	Area of the sample site in hectares	Justifications for selecting this given site
				This site is dominated by *Grewia microcos, Pterospermum acerifolium, Artocarpus Chaplasha*, and *Dipterocarpus turbinatus* mixed with other species such as *Albizia procera* and *Artocarpus lachucha*. The low forest at this site is generally bushy and composed of mixed species such as *Ficus heterophylla*, and *Mocaranga denticulata*. The undergrowth comprises of species such as *Melastroma malabathrica, Mussaenda glabrata, Pavetta indica, Caryota urens,* grasses like *Thysanolaena maxima, Melocanna baccifera*. There are number of climbers such as *Mikania cordata, Discorea glabra*, and *Thurbegia grandiflora*. This area has herbs such as *Eupatorium odoratum, Curculigo recurvata, and Calocasia nymphaefolia*. The TGR possess high floral diversity with about 112 vascular plant species of 95 genera and 66 families. Because of of all these especial features of this area we have selected this site as one of our climate change monitoring site. More over this site possesses all possible aspects. Thus possible impacts of climate change on different aspects can be read from this site and that is why we have selected this site as on our climate change monitoring sites. The vegetation on this site is semi-evergreen. This site will thus help us to read the impact of climate change on semi-evergreen forest in Bangladesh.

Sl No	Name of the sites or beat etc.	Forest Division	Area of the sample site in hectares	Justifications for selecting this given site
3	Pythong mouza	Lama (District-Bandarban)	5.0	This is a site under USF. The site is degraded. The flora and fauna are subjected to various stresses mostly coming from human interferences. We have large areas under USF. We have selected this site to read the general impact climate change couple with the usual human interferences to assess what will be future of our USF lands under the impact of climate change.
4	Publakhali	Chittagong Hill Tracts (North)	2.0	This site is under a wild life sanctuary and is a protected site. The site that we want to monitor is the area near the Publakhali forest rest house, which is situated on the North and North East of the rest house, along the ridge. There is a inconspicuous foot trail along the ridge. The sample site area should cover either sides of this foot trail so that various aspects are included in the sample site. This site has old teak plantations along with a number of indigenous species. This site is rich not only in floral composition but also in faunal composition. Monitoring of this site will help us to read the impact of climate change on the natural habitat of Chittagong Hill tracts. Since this area is protected area it is expected that human interferences at this location will be minimal. In view of all these we selected this site as one our sample sites for monitoring climate change.

Sl No	Name of the sites or beat etc.	Forest Division	Area of the sample site in hectares	Justifications for selecting this given site
5	Tonkaboti	Chittagong (South)	2.0	This site has varied aspects. There are locations that are rich in species such as Garjan, Moose, Chapalish, Udal, etc. The species composition is typical semi-evergreen type. The site is accessible and near the beat office. The site that we were aiming is located just across the chara near the beat office. In view of all these we selected this site for climate change monitoring to read the impact of climate change on typical forest habitat of Chittagong area.
6	Adampur (Bamboo mohal)	Sylhet	2.0	The area that we have in our mind is located about 6 Km away from the Adampur Forest Rest House and is locally known as Lalchara. This area is predominantly a bamboo area but possesses some scattered growth of species such as *Michelia exselsa*, locally known as Shundi, which is a very important indigenous species of evergreen forest in Sylhet . The area possesses varied aspects of all possible types. There are perennial streams and steep to very strip slopes. These especial features of this site have led to select this site as one of our climate change monitoring sample site.
7	Rema	Sylhet	2.0	This site falls under Tropical Evergreen and Semi-Evergreen Forest Bio-geographic Zone. The forest consists of tree species such as *Artocarpus chaplash, Dillenia pentagyna, Bursera serrate, Castanopsis tribuloides*, and *Dipterocarpus turbinatus,* shrub species like *Macaranga roxburghii, Adhataoda zeylanica, Leea crispa, Schimawallichii,* and *Carya arborea,*

Sl No	Name of the sites or beat etc.	Forest Division	Area of the sample site in hectares	Justifications for selecting this given site
				bamboo species such as *Bambusa polymorpha, Bambusa tulda,* and Bambusa *longispiculata*, grass species such as *Melocanna baccifera, Daemonorops jenkinsiana*, and *Saccharum spontaneum*, climber species like *Piper sylvestre, Smilax macrophylla*, and *Dioscorea bulbifera*, and herbs like *Curculigo orchioides*, and *Alpinia nigra*. This forest supports mammal species like the *Muntiacus muntjac, Sus scrofa, Hylobates hoolock,* and *Macaca mulatta*, bird species such as *Nectarinia zeylonica*, *Psittacula alexandri*, and *Gallus gallus*, reptile species like *Mabuya carinata, Chrysopelea ornata, Cuora amboioensis*, and *Varanus bengalensis*, and amphibian species such as *Rana cyanophlyctis*, and *Bufo melanostictus*. The forest contains about 69 vascular plant species of 60 genera and 45 families. This has high biodiversity. The site that we have in our mind is near the Indian boarder. It has varied aspects. The accessibility is quite good and at the same time well protected and is expected to be continued as such since this is a protected area. It has varied aspects and possesses number of faunal species as well. This site has small wet grass land patches as well. Because of all these special features we have selected this site as one of our climate change impact monitoring sites.

Sl No	Name of the sites or beat etc.	Forest Division	Area of the sample site in hectares	Justifications for selecting this given site
8	Notabeki	Sundarbans (West)	0.25	There is no aspect variability at this site. The whole area is flat. This is a protected site and belongs to high saline zone of Sundarban. This area being a mangrove area the impact of climate change is likely to be eminent especially on its species composition, which may be due to salinity enhancement. The other aspects that may be impacted by climate change are siltation, tide heights, etc. Because of these especial features we have selected this site for climate change monitoring impact.
9	Dobeki	Sundarbans (West)	0.25	As above but this site belong to mid-saline zone.
10	Poramohal	Sundarbans (East)	0.25	As above expect that this area belongs to low-saline zone.
11	Singra	Dinajpur	2.0	This is a sal forest area. The main indigenous species is Sal. Other associates such as Koroi, Haldu, Bazna, Kumbi, Sheora, Bohera, Amloki, etc. There will be no aspect variability. This area is a representative site in the Northern part of the country. Because of these we have selected this site as one of our climate change monitoring sites.
12	Modhutila	Mymensingh	2.0	As above but is a representative site of central part of the country.

Sl No	Name of the sites or beat etc.	Forest Division	Area of the sample site in hectares	Justifications for selecting this given site
13	Bhowal National Park	Dhaka Wildlife and Nature Conservation	2.0	As above but is a representative site of central part of the country but subjected to some sort of impact of urban visitors. The site is highly accessible, and is intermingled with wet paddy lands and ditches, lakes etc. Because of these especial features we have selected this area as one of our climate change impact monitoring sites.
14	Doodpukuria	Chittagong North	2.0	The patch of forest near the forest rest house is rich in composition of indigenous species. This site may be termed as remnants of the original forest of Chittagong area. This area has all possible aspects and the existing species composition vary from aspect to aspect. This site has perennial streams as well. All the three species of Garjan found in Chittagong area are available at this site. The undergrowth is thick and rich in species diversity.

The size of the sample at each given sites is also to be decided so as to encompass all possible local variations, especially the physiographic aspects, species composition, species abundance, accessibility, etc., so that the measurement of the parameters of the indicators can be easy (without jeopardizing the goal of being indicative of climate change variability) and practicable under the given context and time.

Exhaustive field works will be necessary, initially under the leadership of a knowledgeable and well experienced forestry specialist, to physically locate the sites as precisely as is possible with multiple GPS readings. During the first visit the following steps are required to be taken at each location:

1. To collect the topo-sheets of each sample locations. This may take some time but in the mean time the process may be continued without waiting for the topo-sheets. Once the top-sheets are available, the delineations of the sample locations may be done on those. At the same

time a data-sheet format may be developed so that the required information can be recorded on that data-sheet from time to time.

2. Undertake a general reconnaissance of the site and select the area that possesses all possible variability, especially aspects, richer composition of indigenous species, varied topography, etc.
3. The area should be identified and roughly delineated on a map (may be the beat map), preferably on the "Topo-Sheets".
4. The approximate boundary of the sample site having the area as indicated in column 3 of Table 8.2 has to be identified. GPS readings at every turning point must be recorded and noted on the map (Topo-Sheet) as well as on the data-sheet.
5. One RCC pillar will be fixed at the North East corner of sample site to facilitate the relocation of the sample.
6. GPS reading of the location of this RCC pillar need to be recorded (both on the topo-sheet & on data sheet).
7. Area under each aspect (except for Sundarban area) within the given sample site need to be delineated physically and recorded on the map (topo-sheet). GPS readings along the delineation lines (boundary) of the aspects within the sample site are to be taken and recorded both on the map (topo-sheet) as well as on the Data-Sheet.
8. In case of all sites other than Sundarban, three important trees (above pole size, i.e., taller than 10 feet), preferably of indigenous species and if available of different species will be identified for monitoring in each aspect area (not applicable for Sundarban) within the given sample site. In case of Sundarban, five important species will be identified. Each of these trees is to be numbered and a color banded at DBH level and painted over its bark. GPS readings of each of these are to be noted approximately on the map (may be on the topo-sheet) as well as on the data-sheet. The DBH and height of each of these trees are to be noted on the data-sheet against the number of the tree with species noted down.
9. In the sample sites within Sundarban a graduated pole (silt and tide gauge) has to be fixed at a convenient location to collect the siltation data. The GPS reading of the location of the 'silt and tide gauge' has to be noted on the map (may be on the topo-sheet) as well as on the data-sheet.

Through these 9 steps the sample site identification and its physical establishment will be over.

8.4.3 MONITORING METHOD

As soon as a sample site is physically located, the monitoring data, as indicated in Table 8.3, are to be recorded on the data sheet and this will constitute the 'base line data' of the given sample site, for all future references.

Table 8.3: Monitoring materials & methods

Parameters	Traits to be measured	Materials and Methods
Phenology[1] *To be monitored for the 3 trees identified in each aspect location of the sample site. For Sundarban it will be 5 trees for a given sample site.*	Initiation of leaf shedding	Date of initiation of leaf shedding will be recorded for each selected tree in each sample plot. A periodic observation on percentage of leaf falling will also be recorded at 10 days interval till the leaf shedding is complete.
	Leaf flushing	Date of initiation leaf flushing will be recorded for each selected tree in each sample plot. Periodic observation at 3 days interval will be recorded to record the end date of flushing.
	Flowering	Date of initiation leaf, flowering will be recorded for each selected tree in each sample plot. Periodic observation at 3 days interval will be recorded to record the end date of flowering.
	Leaf area	Fully expanded ten mature leaves (at random) will be collected from a branch at the middle part of the canopy. These leaves will be sent at laboratory (may be at BFRI, Chittagong or to any University, Botany or Forestry laboratory) to measure the leaf area and oven-dry weight. The data need to be recorded properly in the data base (data-sheet).
Leaf[2] *To be monitored for the 3 trees identified in each aspect location of the sample site. For Sundarban it will be 5 trees for a given sample site.*	Leaf area	Fully expanded ten mature leaves (at random) will be collected from a branch at the middle part of the canopy. These leaves will be sent at laboratory (may be at BFRI, Chittagong or to any University, Botany or Forestry laboratory) to measure the leaf area and oven-dry weight. The data need to be recorded properly in the data base (data-sheet).

1. We have a general idea as to when the leaf shedding, leaf flushing and flowering start in the given species of the trees numbered for monitoring. These trees are to be visited twice a week from one month ahead of the known time of leaf shedding, leaf flushing and flowering till the event (leaf shedding, leaf flushing & flowering) is observed to have finished. The date of the occurrence of the event has to be noted on the data sheet.

2. To be monitored once a year. The sample may be collected on 15th of July, every year sent to BFRI for providing the data. The data so obtained are to be recorded on the data sheet.

Parameters	Traits to be measured	Materials and Methods
	Leaf ratio (length : width)	Leaf ratio (length and width) of these same leaf samples will be noted. The data need to be recorded properly in the data base (data-sheet).
	Stomatal density	Measurements of stomatal properties: The matured collected leaves after measuring the leaf-area and (length : width) ratio will be placed between two plain sheets of white paper and weighed down (300 g) for three days for flatten the leaf surface and absorb moisture. Thereafter, a piece of leaf about 0.5 cm^2 in area will be excised from the middle of the leaf close to the central vein and between two sub-veins. The occurrence of stomata will be examined under compound microscope. The number of stomata per square unit area is to be noted on the data-sheet. Normally in the forest trees, stomata occur only on the abaxial surface of the leaf.
Ground vegetation	In each aspect area (of a given sample sites, other than Sundarban. In Sundarban there will be 3 plots in the given sample site), 3 plots of 1 M X 1 M will be laid at random for data collection (to be recorded on data sheet).	Species wise numbers are to be recorded on the data-sheet with date.
Ground fauna	Do	Beetles and other important ground fauna are to be counted and recorded on the data sheet.

Parameters	Traits to be measured	Materials and Methods
Avifauna (especially birds)	In each sample site, at every full moon and new moon, in the month of January and June the data are to be collected using transacts covering all the aspects of the sample site.	Species wise numbers are to be recorded (dawn, noon, evening and night) on the data-sheet. The dates are to be noted as well.
Reptiles	Do	Do
Aphids	The data are to be collected on 15th June and 15th January every year in each sample site.	Number, foliage inspection, yellow sticky boards, etc. may be used.
Butterfly	Do	'Pollard walk', abundance & diversity, etc. may be used.
Honey bee	Do	Pan trap, nets, queen, etc. may be used.
Amphibians	Do	Transects and quadrates, NCS, EMS, etc. may be used.
Silt and tide gauge	Do	Read the silt gauge and record the siltation data on the data sheet. Observe the tide inundation (height) during high tide (when the high tide has just ended) and record the data on the data sheet.
Salinity	Water samples are to be collected on 15th June and 15th January every year in each sample site from near the silt and tide gauge at the end of the high tide.	While collecting the water sample the container has to be made full so that there no empty space within the bottle (container). The bottle has to be tightly corked while underneath the water. The samples so collected are to be sent to BFRI immediately. BFRI will analyze the sample to read the salinity. The data are to be recorded on the data sheet.

The ministry of Environment and Forest will require issuing an executive order so that (1) FD cooperates with the monitoring team and provide the best possible protection to the sample sites and (2) BFRI assists and undertakes the laboratory analyses on a regular basis as soon as the samples reach them and send the data to the monitoring team for proper recording of the information on the data sheets.

Before identifying the location and delineation of the sample sites, a local worker (for monitoring the data) has to be identified for monitoring. The data collecting personnel (the worker identified as such) of the given site must accompany the forestry expert while the later identities and delineates the given sample site. A simple training of one or two days shall have to be organized to train them so that they can undertake the assignment successfully.

Last but not the least, the process of monitoring has to be continued over years without any break and at the frequency indicated above and the data collected are to be carefully preserved. The data has to be viewed as time series data to identify the impact of climate change on flora and fauna more precisely on the forest ecosystems in Bangladesh.

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CHAPTER – 9

INDICATORS TO ASSESS IMPACTS ON HUMAN HEALTH

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9.1 BACKGROUND

Climatological researchers unanimously achieved a consensus that the rising atmospheric concentration of greenhouse gases due to human actions causes global warming and other climatic changes (McMichael, 2004; McMichael, *et al.,* 2006; IPCC, 2007; Reisinger and Dogra, 2008; Eriksson, *et al.,* 2008;). Far beyond the anticipation of scientists, climate continues to change at a quicker and louder pace (Haines, *et al.*, 2006).

Our health and survival depends on the natural environment that provides the processes and the products such as food, fresh water, cotton, timber, control on pathogens, access to natural medicines and a relatively stable climate. These determinants, rather than hospitals, doctors, diagnostic tools, genetic interventions and dietary advice, are the true foundations of population health (McMichael and Butler, 2009). However, diverse facets of consequences of climate change occupied the intellectual arena in such a dominant manner that health and survival of human being failed to receive much attention.

Altered temperature, extremes of rainfall, rise in the sea-level and more frequent extreme events affect directly on human health. While deterioration in the quality of water, air and food as well as changes in the human settlements and the economy indirectly affect the human health (Rahman, 2008). Whether direct and indirect, both cause suffering, disability and death. Climate change act through amplifying and extending the frequencies, magnitudes and verities of existing health problems, which consequently increase vulnerability and reduce the ability to adapt to climate change. Meta-analyses of epidemiological data from multiple countries and modelled estimates of their total health-effects have advanced the understanding of important climate sensitive health-risks (Ezzati, 2004).

The conceptual and methodological issues for quantifying the population health effects of climatic risk factors require knowledge from different scientific disciplines (Murray, *et al.,* 2003). The magnitude of the risk of climate change that endangers human health was not appropriately recognized up to 2009, when the Lancet and University College London Institute for Global Health finalized a report with an unambiguous statement "Climate change is the biggest global health threat of the 21st century" (Anonymous, 2009).

During last 12 years, many of the adverse impact of climate change on human health have been extensively studied in different parts of the world (Patz, *et al.,* 1997; Hales, *et al.,* 2002; WHO, 2005; Alam, *et al.,* 2007a; Hii, *et al.,* 2009; Ayres, *et al.,* 2009; Bhaskaran, *et al.,* 2010; Chang, *et al.,* 2010; Cheng and Su, 2010; Gething, *et al.,* 2010; Tagaris, *et al.,* 2010 Baccini, *et al.,* 2011;). Based on those studies a preliminary relationship is established between a number of clinical conditions and particular climatic challenges, and the clinical conditions/diseases are now considered as climate sensitive diseases.

9.2 HEALTH EFFECTS OF CLIMATE CHANGE IN BANGLADESH

9.2.1 CONCEPTUALISATION

Bangladesh, already facing concurrent environmental or socioeconomic stresses, is particularly at high risk of developing vulnerability to climate change. Vulnerability of Bangladesh is the consequence of a complex interrelationship among biophysical, social and economic characteristics of the country. Anticipated adverse impacts of climate change, such as sea level rise, higher temperatures, enhanced monsoon rainfall, reduced dry season rainfall, flooding, drought and increase in cyclone intensity would create severe hindrance to the path of development of Bangladesh.

Among the impacts of climate change on Bangladesh, adverse impact on public health might be one of the most significant one (Shahid, 2010). Only few studies have been conducted so far to identify the impacts of climate change on human health in Bangladesh (Rodo, *et al.,* 2002; Nelson, 2003; Patz, *et al.,* 2005; Hashizume, *et al.,* 2007; de Magny, *et al.,* 2008). Among the published articles, majority of were on diarrheal diseases and few were reviews describing the potential impacts of climate change on human health of Bangladesh (Huq, 2001; Rahman, 2008).

Detection of possible impacts of climate change on public health and their scientific monitoring is essential to implement necessary adaptation strategies. Problems related to change in climatic conditions, their consequences that might have impact on human health and the health outcomes in Bangladesh are discussed below. However, the information on Bangladesh are based on gross under-reported data because of the fact that the number of government medical college hospitals and specialized hospitals, private medical college hospitals, NGO hospitals, private clinics/hospitals and the private practitioners are not reporting through the routine surveillance system.

Climate change related problems pertinent for Bangladesh (Ahmed, *et al.*, 2007)

1. Temperature variation
2. Rainfall
3. Flood
4. Drought
5. Cyclone
6. Sea level rise and salinity intrusion

Consequences of the climate changes that might have impact on health

1. Altered transmission of infectious diseases
2. Changes in air pollution
3. Direct impacts of heat and cold
4. Water shortages
5. Population displacement due to natural disasters
6. Effects on food production via climatic influences on plant pests and diseases
7. Crop failure
8. Destruction of health infrastructure in natural disasters
9. Conflict over natural resources

Anticipated health hazards

1. Vector borne disease
2. Food and water borne disease
3. Bronchial asthma, ARI & other respiratory illnesses
4. Heat stress related problems
5. Cardiovascular disease
6. Skin disease
7. Malnutrition
8. Drowning
9. Snake bites
10. Unintentional fatal & nonfatal injuries
11. Psychological problems & social problems
12. Newly emerging disease

9.2.2 CLIMATE SENSITIVE DISEASES IN BANGLADESH

CLIMATE CHANGE AND DIARRHEA

This is generally assumed that the prevalence of heat stress, diarrheal diseases and aggravation of cardiovascular and respiratory diseases will increase during extreme temperatures and heat waves in Bangladesh. The seasonal peak of diarrhea due to E coli in Bangladesh corresponds with the period of higher bacterial growth caused by high temperatures (Rowland, 1986). Rotavirus diarrhea in Dhaka was reported to increase with rise of temperature above 29^0C (Hashizume, *et al.,* 2008).

Significant correlations were observed with temperature and the occurrence of cholera toxin-producing bacteria in Bangladesh (Huq, *et al.,* 2005). Among the poor people of Dhaka, number of noncholera diarrhea cases increases with higher temperature (Hashizume, *et al.,* 2007). Warmer sea surface temperatures along coastlines due to climate change encourage higher phytoplankton blooms, which are excellent habitats for the survival and spread of cholera (Pascual, *et al.,* 2002). Through the findings of abovementioned studies, it is very obvious that rise of temperature due to climate change will increase diarrheal diseases in Bangladesh.

This should be mentioned that diarrhea is already a highly prevalent communicable disease in Bangladesh with more than 5 million reported cases in 2009, which is double than that of the previous year. Moreover, 712 patients died due to diarrhea, which is also double of the last year. Regarding pathogen detection, result from the stool samples tested in ICDDR,B Dhaka hospital, 61.0% stool samples had pathogen, of which rota virus was highest (23.2%) followed by V. cholera (22.2%) and ETEC (10.2%) (Anonymous, 2010).

CLIMATE CHANGE AND VECTOR-BORNE DISEASES

Climate change is likely to have major impacts on outbreak of malaria, dengue and other vector-borne diseases (Hii, *et al.,* 2009; Tonnang, *et al.,* 2010). Changes in environmental temperature and rainfall will increase vector-borne diseases into temperate region like India and Bangladesh (Dhiman, *et al.,* 2010; Majra and Gur, 2009). Rise in surface temperature and changes in rainfall patterns might modify the distribution of mosquito as well as other vectors (O'Loughlin, *et al.,* 2008).

CLIMATE CHANGE AND MALARIA

Recent studies suggest that the abundance, distribution and transmission of different malaria vectors are determined by different environmental factors including diurnal temperature variation (Kelly-Hope, *et al.,* 2009; Paaijmans, *et al.,* 2009; Paaijmans, *et al.,* 2010). In Chittagong Hill Tracts of Bangladesh, many factors influences malaria, of which climatic factors show the most persuasive correlation to the change in the rate and risk of malaria. Particularly, increase in temperature and rainfall increases the risk of malaria (Alam, *et al.,* 2007b). Finally, this can be stated that the emergence, extinction, and transmission of malaria depend strongly on climate (Parham and Micheal, 2010).

This is important to note that malaria is one of the important locally endemic vector-borne diseases of Bangladesh already causing significant morbidity and mortality in 13 districts of eastern and northern parts of the country. During the last decade, the annual average of positive cases of malaria in Bangladesh was 57,365 cases. In 2009, 553,787 clinical cases were reported, which is lower than that of the last year. Only 47 patients died of malaria in 2009, which is less than one-third of the previous year death. Reported prevalence is 0.06% in the country; but 0.34% in the high endemic area. Estimated prevalence in the country is 0.24% but 1.34% in the high endemic area. Over 26 million people of Bangladesh are at high risk of malaria (Anonymous, 2010).

CLIMATE CHANGE AND DENGUE

Dengue incidences in different countries were found to have positive correlation with rainfall pattern (Wiwanitkit, 2006). Even human adaptation strategies to climate change were also accused to contribute in rise of dengue incidence (Beebe, *et al.,* 2009). An empirical model projected that people of this region including China will be at maximum risk of dengue fever (Hales, *et al.,* 2002).

The medical communities of Bangladesh were fairly unfamiliar about the presence of Dengue in Bangladesh before 2000. The outbreak started in summer of 2000 and since then every year some cases are being reported with a figure of 474 cases in the year 2009, less than half of the previous year (Anonymous, 2010).

CLIMATE CHANGE AND KALA-AZAR

Ecological models predict that climate change will exacerbate risk of human exposure to leishmaniasis in new areas outside its presently endemic zones. Besides direct intervention in disease cases, vector and reservoir control strategies were emphasized for further investigation (González, *et al.,* 2010; Aspöck, *et al.,* 2008). The increase of seroprevalence of canine leishmaniasis among the dog of the foothill villages was related to climatic conditions, as that corresponds with an increase of about 1^{0}C in the mean annual temperature (Dereure, *et al.,* 2009). In another study, positive association has been reported between the El Niño cycle and the annual incidence of visceral leishmaniasis in Brazil (Ready, 2008).

Kala-azar has been prevailing in Bangladesh for centuries as an endemic disease; though, with use of DDT as a control measure for malaria, prevalence of Kala-azar was remarkably reduced. Re-emergence of the disease was noticed since 1994-95 and from 1999 to 2009, a total of 67,758 cases and 225 deaths were reported from 34 districts of Bangladesh. In the year 2009, 4,263 kala-azar cases were reported, of which 13 died. Both the number of cases and death is lower that the previous year. Fortunately, according to recent reports, only eight upazilas of the country are hyper-endemic ($\geq$2.5 cases per 10,000 population) with respect to Kala azar. Of these, five in Mymensingh district, one in Gazipur, Jamalpur and Rajshahi district each (Anonymous, 2010).

CLIMATE CHANGE AND RESPIRATORY DISEASES

Fossil fuel combustion, primarily from motor vehicles and energy generation, is a major contributor to anthropogenic climate change. The key climatic factors that could potentially influence respiratory disease are extreme temperature events, changes in air pollution, flooding, changes in allergen disposition and consequent allergies (Ayres, *et al.*, 2009; Kinney, 2008). Among the environmental factor, air pollution has the greatest impact on health in Europe (Doherty, *et al.*, 2009).

There are evidences that relate quality of air to the premature mortality, particularly from cardiovascular and respiratory causes (Dennekamp and Carey, 2010). Current research revealed that carbon dioxide and increased temperatures increase pollen production (Reid and Gamble, 2009), which along with air pollution can exacerbate asthma or other respiratory illnesses (Shea, *et al.,* 2008). Exposures to higher concentrations of aeroallergens may lead to more severe allergic responses (Nielsen, *et al.,* 2002). The main diseases of concern are asthma, chronic obstructive pulmonary disease (COPD) and respiratory tract infections.

Respiratory diseases such as pneumonia and COPD constitute about 7.6%, 7.4% and 4.3% indoor patients of the Upazilla, District and Medical College hospitals respectively. The diseases of the respiratory system are the cause of mortality for about 14.2%, 9.6% and 4.7% at the Upazilla, District and Medical College hospitals respectively (Anonymous, 2010).

CLIMATE CHANGE AND SKIN INFECTIONS

High temperatures and reduction of relative humidity cause dry skin that may increase the prevalence of skin diseases including atopic dermatitis. Furthermore, the environment of various vectors of infectious disease would be altered (Llamas-Velasco and García-Díez, 2010; Patrizi, *et al.,* 2009). Skin infections are common in rural populations with poor socioeconomic conditions, moreover hot and damp coastal weather contributes much to the worsening prevalence (Allen and Taplin, 1974; Masawe, *et al.,* 1975). Impetigo has shown seasonal variation in African, Australian and UK population. The observations suggest a correlation between impetigo frequency and climatic temperature (Kristensen, 1991; Tewodros, *et al.,* 1992; Loffeld, *et al.,* 2005). Though not much relevant for Bangladesh, the UV-B radiation in combination with popularity of sunbathing may lead to higher rates of skin cancer and photo aging (Llamas-Velasco and García-Díez, 2010).

Skin diseases were the third most common reason to seek treatment at outpatient departments of government hospitals (WHO, 2005). In a recent climate focused study conducted in Satkhira, positive correlation was established between skin diseases and annual rainfall, annual average minimum temperature and salinity concentration (BCAS & NIPSOM, 2007).

CLIMATE CHANGE AND BLOOD PRESSURE (PRE-ECLAMPSIA AND ECLAMPSIA)

Blood pressure is known to vary at different time of the day and different day of the year and study results differ substantially on the magnitude of the effect (Thomas, *et al.*, 2008). Outdoor temperature and blood pressure are strongly correlated in the elderly population (Alpérovitch, *et al.,* 2009). Unusual decrease in temperature was found to be associated with incidence of myocardial infarction (Wolf, *et al.,* 2009).

Preliminary association was observed between ozone pollution level and ischemic stroke (Henrotin, *et al.,* 2007). A systemic seasonal variability was found with pre-eclampsia, which reached the peak during the rainy season (Okafor and Ezegwui, 2010). However, in another study, pre-eclampsia reported to occur more frequently in winter (Immink, *et al.*, 2008), which was similar in southern Nigeria with higher report of hypertension during the cold season (Ansa, *et al.,* 2008).

The ratio of salt to fluid intake has definite role in blood pressure rather than the total dietary sodium intake (Robertson, 1984). Increased salinity of drinking water is likely to exert a number of health effects including increased rate of hypertension. Significant numbers of pregnant women in the coastal areas were diagnosed with pre-eclampsia, eclampsia and hypertension (Khan, *et al.*, 2008) and that reported incidence was four to eight folds higher than earlier report from non-coastal area of Bangladesh (Sayeed, *et al.,* 2005). The increased incidences of these diseases in the coastal area are assumed to have association with rising salinity. A previous study mentioned hypertension due to rising salinity as one of the reason of involuntary fetus abortion in the coastal areas (MoEF, 2005).

Pre-eclampsia and eclampsia have been considered as a major problem causing maternal mortality and morbidity in Bangladesh. Approximately 40% of maternal death in hospitals occurs in patients admitting with eclampsia and 6% with pre-eclampsia. Among all childbirth related complications in hospitals, pre-eclampsia accounts for 12% and eclampsia accounts for 16% (MoHFW, 2001).

PSYCHOLOGICAL TRAUMA

Increased physical injuries and loss of properties due to extremes of climatic events or disasters will results in more psychological trauma leading to increased disease burden of the country.

OTHER CLIMATE SENSITIVE DISEASES, DISORDERS AND SYNDROMES

In addition to the climate-sensitive diseases mentioned above, there are other diseases, disorders and syndromes, which were also found to have association with the climate changes. However, on the basis of literature review these diseases are considered less suitable for monitoring, particularly in Bangladesh. To make the document more inclusive, the following diseases are now mentioned separately.

Heat-related mortality and morbidity

i. Heat syncope or collapse
ii. Heat cramps
iii. Heat exhaustion
iv. Heat stroke

Vector-borne, zoonotic, food and water-borne diseases

i. Filariasis
ii. Viral hepatitis
iii. Typhoid fever
iv. Malnutrition
v. Viral encephalitis
vi. Bacterial encephalitis

Air-related diseases/ syndromes

i. Respiratory tract infection
ii. Chronic obstructed pulmonary disease (COPD)
iii. Tuberculosis
iv. Meningococcal meningitis

Chronic non-communicable disease

i. Heart disease
ii. Diabetes mellitus
iii. Skin cancers

9.3 CONCEPTUAL FRAMEWORK OF MONITORING

Global temperatures have risen markedly during last three decades and consequently some health parameters already have been affected, which made it difficult to identify the health effects of climate change. The complexity of some causal pathways makes attribution complicated. Moreover, there are different activities directed towards control of the diseases or have influence on the disease and these confounders needs to be identified and properly addressed during analysis.

Therefore, monitoring of climate change impacts on health is not simply a matter of recording certain health indicators over time. It also requires the appropriate analytical tools to quantify the component of change in those health outcomes, which can be ascribed to measured change in the corresponding climatic conditions. Organized and systematic indicator selection and monitoring can only provide an evidence base for design and implementation of more effective and equitable technological interventions as well as policies for health impacts of climate change. The relationship or association between the exposure to climate factors (e.g. temperature, rainfall, humidity, salinity, air pollution) and response of the climate-sensitive diseases need to be established.

9.3.1 APPROACH FOR MONITORING OF THE HEALTH IMPACT

Key steps for monitoring the climate change induced health impacts are (Campbell-Lendrum and Woodruff, 2007):

- Obtaining measurement of exposure: the climate variables that are likely to change through time and space;
- Identifying health outcomes for assessment: should include the health outcomes that are known to be climate-sensitive and important in public health terms of the study population;
- Quantifying the relationship between the climate and each health outcome: data on each of the climate variation and on each of the health outcomes;
- Linking the exposure measurement to climate-health model: coupling the climate projections with the quantitative models to assess possible relative changes in health outcomes;
- Estimate the burden of disease in the absence of climate change: using existing projections of likely future trends of disease burden determined by non-climatic factors;
- Calculating the climate change attributable burden of specific diseases: applying the relative changes calculated above the estimates of burden of each disease in the absence of climate change.

9.3.2 MONITORING MECHANISM

Climate change represents one of the greatest environmental and health challenges of our times. Bangladesh is one of the most affected counties due to this climate change phenomenon. Through this proposed monitoring process, long term disease surveillance will be maintained or established in suspected areas of climate change and health risks to enhance detection and prevention of disease resulting in guidelines and recommendation for policy makers at government and international levels to tackle human health problems in Bangladesh due to climate change and variability. Apart from government agencies, public health and environmental health workers as well as clinicians should interplay in a nicely poised manner resulting in a proactive approach to combat the grave situation so that we can achieve long range and long lasting prevention of the impact of climate change and variability on health.

BASELINE ESTABLISHMENT

For monitoring of the impact of climate change on health in a geographically distinct area and/or different climatic zones of Bangladesh, a baseline disease profile would be needed. These baseline data would serve as the benchmark for the ongoing monitoring system. If such information is unavailable, a baseline survey might be required to collect data to develop the benchmark. Corresponding climate data (temperature, rainfall, humidity, salinity) will also be collected and compiled for further analysis. These data collected from baseline survey might be utilized to correct the existing unreliable or less authentic data (if available).

LOCATION OF MONITORING STATIONS

Based on available reliable data and studies, monitoring stations (sites) are chosen where change is most likely to occur. However, for climate data, existing Bangladesh Meteorological Department stations will be utilized as they already have the appropriate infrastructures and capacity. For collection of information on diseases, with support from the Directorate General of Health Services, offices of the Director (MIS), Civil Surgeon and Upazilla Health & Family Planning Officer, will provide the relevant information. For quality assurance of the information, motivation and training of the manpower will be arranged for particular cases.

OPERATIONAL DEFINITION

For this monitoring, every disease will be defined according to the operational definition of the national programs, or if unavailable, expert group will be consulted to formulate operational definition for the purpose of monitoring.

DATA COLLECTION MECHANISM

Data will be collected using pre-tested formats and the following points will be considered during data collection:

i. Age and Gender
ii. Geography of the area
iii. Type, frequency, severity, duration of the disease
iv. Nutritional status
v. Sanitation
vi. Water supply

FREQUENCY OF REPORT GENERATION:

Data will be collected and entered in a database on weekly basis. Initially, monthly report generation may be done. Any unusual event should be reported immediately, if warranted. Analyzing the initial reports, modification of frequency of report generation could be done.

9.4 MONITORING PARAMETER FOR ASSESSING IMPACT OF CLIMATE CHANGE ON HUMAN HEALTH IN BANGLADESH

Climate variables	Sensitive Health outcomes	Location	Disease Parameters	Climate Parameters	Confounding variables	Frequency of data collection	Source of data collection
Temperature Rainfall Humidity	Malaria	Hot and humid zone Rajasthali, Rangamati Jhenaigati, Sherpur	Point prevalence Incidence Morbidity Mortality Vector density	Maximum, minimum and mean temperature, Monthly average rainfall, Humidity	Insecticides treated bed net, house hold sprayed etc.	Weekly(disease) Daily(climate)	UH&FPO office Nearest BMD office (Rangamati, Mymensingh)
Temperature Rainfall Humidity	Dengue	Hot and humid zone Dhaka Metropolitan Khulna Metropolitan	Point prevalence Incidence Morbidity Mortality Vector density	Maximum, minimum and mean temperature, Monthly average rainfall, Humidity	Insecticides treated bed net, house hold sprayed etc.	Weekly(disease) Daily(climate)	Director (MIS) Nearest BMD office (Dhaka, Khulna)
Temperature Rainfall Humidity	Kala-azar	Drought-prone zone Godagari, Rajshahi Phulbari, Mymensingh	Point prevalence Incidence Morbidity Mortality Vector density	Maximum, minimum and mean temperature, Monthly average rainfall, Humidity	Insecticides treated bed net, house hold sprayed etc.	Weekly(disease) Daily(climate)	UH&FPO office Nearest BMD office (Rajshahi, Mymensingh)
Flood Temperature Rainfall Humidity	Diarrhea	Flood-prone zone Sirajgonj	Point prevalence Incidence Morbidity Mortality	Flood Maximum, minimum and mean temperature, Monthly average rainfall, Humidity	Tube well ORS Vaccination Water purifying tablet etc.	Weekly(disease) Daily(climate)	Civil Surgeon office Nearest BMD office (Iswardi) Water Development Board

Climate variables	Sensitive Health outcomes	Location	Disease Parameters	Climate Parameters	Confounding variables	Frequency of data collection	Source of data collection
Salinity Temperature Rainfall Humidity	Cholera, Diarrhea, Pre-eclampsia Skin infection	Salinity intrusion zone Mothbaria, Pirozpur Shyamnagar, Satkhira	Point prevalence Incidence Morbidity Mortality	Salinity of water Maximum, minimum and mean temperature, Monthly average rainfall, Humidity	Tube well ORS Vaccination Water purifying tablet etc.	Weekly(disease) Daily(climate)	UH&FPO office Nearest BMD office (Potuakhali, Satkhira)
Air quality Temperature Rainfall Humidity	Bronchial asthma	Hot, humid and air pollution zone Dhaka Metropolitan Iswardi, Pabna	Point prevalence Incidence Morbidity Mortality	Air quality Maximum, minimum and mean temperature, Monthly average rainfall, Humidity	Tube well ORS Water purifying tablet etc.	Weekly(disease) Daily(climate)	Director (MIS) UH&FPO office Nearest BMD office (Rangamati, Mymensingh)

9.5 DATA ANALYSES

Following statistical analysis and appropriate mathematical models will be used to evaluate different impacts, correlation and association of climate changes on human health:

- Correlation (regression analysis);
- Time series analysis;
- Comparative Risk Analysis.

9.5.1 RESOURCE REQUIRED

- Checklist to grip disease status influenced by climatic factors;
- Checklist to grip climatic data to observe change/variation;
- Computers, accessories and appropriate program for database;
- Trained manpower;
- Documentation and project management system.

9.5.2 OUTPUTS

- Annual reports will be generated based on data analysis.

9.5.3 POSSIBLE CHALLENGES

- Identification of the potential confounders and collection of data on those;
- Prevention of duplication of morbidity data may pose significant problem. National Identity Card/VGF card can be utilized to overcome the constraint;
- Careful scrutiny and quality control of data must be ensured.

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CHAPTER – 10

INDICATORS TO ASSESS IMPACTS ON LIVELIHOOD & POVERTY

Sharmind Neelormi, M. Asaduzzaman

10.1 BACKGROUND

Following the publication of the Fourth assessment Report of the Inter-Governmental Panel on Climate Change (IPCC), the global scientific community is in agreement that the Earth's climate has already been changing at an accelerated rate and the 'descernable changes' have already been observed in natural and human systems across the globe (IPCC, 2007a,b).This has been concluded by analyzing observations of increases in global average air and ocean temperature, physical and biological systems (IPCC).

It is feared that the Bengal (Mega) delta could become highly vulnerable to climate change and sea level rise that could increase the frequency and level of inundation due to storm surges and floods from river drainage (Cruz, *et al.,* 2007). Owing to a number of natural and man made factors, Bangladesh, a small deltaic country, is highly vulnerable to some water related extreme events (Ahmad, *et al.,* 2001; Ahmad *et al.,* 1994). In the wake of global warming and its associated changes in biophysical environmental conditions, it is feared that the country would most likely to be severely affected. The anticipated changes in hydrological regime would accentuate high intensity climatic events (Ahmed, 2005).

Livelihoods of majority of the people depend directly on prevailing precarious state of environmental conditions, which is likely to be perturbed significantly due to anticipated impacts of climate change. Adverse impacts of climate change will be detrimental, especially when the hydrological extreme events are likely to be exacerbated under climate change regime (Ahmed, 2005).

It is observed that, rapid increase in population has led to increased food demand that resulted into encroachment into floodplains and the significant changes of the drainage pattern of the lands (Ali, *et al.,* 1998). Urbanization and expansion of road networks, without appropriate drainage infrastructure, have also aggravated flood vulnerability of the landscape and reduced crop agriculture potential of the floodplains (Ahmed, 2005). Reduced flows of the river systems, especially during the dry season, have accentuated salinity ingress along the coastal rivers. The problem has been compounded by the diversion of flows of the Ganges system with the building of Farakka Dam in India (Mirza and Sarker, 2004). Continued deforestation in the upper catchments areas of the Ganges-Brahmaputra- Meghna basins has increased sediment deposition on the riverbeds in the downstream, leading to reduced drainage capacity and increasing flood vulnerability of Bangladesh. All these observed changes have adversely affected the agro-ecosystems of the country.

Global change is perceived to have been higher level of impacts on the agro-ecosystems of the country. Associated food demand with increasing population has very profound impacts on the remaining biophysical resource entitlements. Climate change will aggravate flood conditions, increase both salinity and moisture stress, and exacerbate cyclonic storm surge induced problems along the coast, while sea level rise will pose additional risks to coastal agriculture (Ahmed, 2005). Overall, the elements of global change may further reduce livelihood potential of the poor people of Bangladesh.

10.2 NEXUS BETWEEN NATURAL AND SOCIAL SCIENCE

10.2.1 CONCEPT OF SOCIAL VULNERABILITY

The physical and social impacts of climate change are not considered to be homogenous for two reasons. First, global circulation models project spatial deference in the magnitude and direction of climate change. Second, even within a region experiencing the same characteristics of climate change, the impacts are likely to vary because some ecosystems, sectors, or social groups are more vulnerable to climate change than others.

Vulnerability is varied across space, as well as across social groups. Each exposure unit has a unique sensitivity or resilience to climate change that is dependent on an array of factors (Parry and Carter, 1998). The most vulnerable are considered those who are most exposed to perturbations, who possess a limited coping capacity, and who are least resilient to recovery (Bohle, *et al.,* 1994). Other definitions of vulnerability focus on concepts of marginality, susceptibility, adaptability, fragility, and risk (Liverman, 1994). In further exploring the concept of vulnerability, Liverman (1994) distinguishes between biophysical vulnerability and social vulnerability.

The former refers to the physical conditions of the landscape and how they impact humans or biological diversity. The latter, referred to as a political economy approach to vulnerability, defines vulnerability according to the political, social and economic conditions of a society. The World Food Programme (1996) outlines five approaches to mapping food-related vulnerability:

Five approaches to vulnerability assessments

- Use poverty as a proxy indicator of vulnerability to food insecurity, drawing on national data to identify the number and location of socioeconomic groups judged to be vulnerable;
- Carry out surveys to collect information directly related to vulnerability. These surveys can incorporate the notion of coping strategies and levels of entitlements;
- Identify important determinants of vulnerability to food insecurity to create a proxy indicator based on available data. (The strength of this approach is dependent upon the selection of different indicators and knowledge about the context in which the indicators are being used);
- Conduct a rapid rural appraisal;
- Make use of individuals with expertise related to the issues addressed, and with extensive knowledge of conditions throughout the country.

Poverty is an important aspect of vulnerability because of its direct association with access to resources which affects both baseline vulnerability and coping from the impacts of extreme events. This aspect of the framework is akin to entitlements analysis, but forms only one component. It is argued here that the incidence of poverty, as observed through the quantifiable indicator of income, is a relevant proxy for access to resources, in its multifaceted forms. Resources and wealth in them do not constitute security since resources are mediated through property rights and access to them. Access in this context can be taken to mean ``involving the ability of an individual, family, group or community to use resources which are directly required to secure a livelihood.

Table 10.1: Collective and individual vulnerability to climate change: determinants and indicators

Type of Vulnerability	Causes in relation to climate extremes	Indicators of Vulnerability
Individual Vulnerability	Relative and Absolute poverty; entitlement failure, resource dependency.	Poverty indices: Proportion of income dependant on risky resources, dependency and stability
Collective Vulnerability	Absolute levels of infrastructure, development, institutional and political failures- insurance and formal/informal social security.	GDP per capita; relative inequality; qualitative indicators of institutional arrangements

Access to those resources is always based on social and economic relations (Blaikie, *et al.,* 1994). Access to resources is difficult to observe and measure directly however, and in that respect is similar to the concept of entitlements to resources (Sen, 1981; Leach, *et al.,* 1997). Both are difficult to measure because of their temporal and seasonal dimensions and because they involve transactions and exchanges between different members of households.

In addition, some aspects of access are spatially manifest, but again are correlated with poverty. Poorer people tend to live in more ``marginal'' and more hazardous areas, though the causality in this relationship is difficult to determine. Location affects the elements of poverty: in economic terms marginal areas have higher marginal costs of access. Transport to centers of distribution of government social security at times of hazard impacts, and the higher exposure of marginal areas to hazards, such as poor housing in cyclone prone coastal areas are susceptible to damage or land prone to flooding, are both elements in this spatial vulnerability-poverty interaction.

Access and entitlement to resources also have temporal dimensions, in that access to resources is a prerequisite for recovery from the impacts of hazards. In addition, entitlements to resources extend the period before which a hazard results in emergency coping strategies, such as migration or the selling of nonproductive assets. Access is secured through rights and responsibilities which themselves change over time. The impacts of hazards on households include injury or mortality; temporary or permanent migration due to perceived risk or actual loss of land or other resources; and the loss of other capital and infrastructure. The net result of all these impacts is therefore on changes in poverty, through resulting lack of labor or capital. Such temporal changes in access to resources lead to a ``ratchet effect'' (Chambers, 1983) in poverty, translating ultimately to changes in baseline social vulnerability over time.

Given certain conditions, poverty is a meaningful proxy for access to resources, and income is a good proxy for poverty. The state of income or consumption reflects, but is not exactly correlated with, the access to resources. The limits to this relationship are dependent on what Sen (1981) defined as entitlements, ``the set of commodity bundles that a person can command in a society using the totality of rights and opportunities that he or she faces,'' and which are in fact bound by legality or custom. In other words, opportunities to avoid poverty (such as by raising income) are often constrained by rights to buy or sell resources.

As an example, households in coastal areas may have rights to subsistence use of products extracted from mangroves, but are legally barred from trading in these commercially. The household's apparent income poverty does not in this case reflect lack of access to the resources, but rather lack of access to markets. Nevertheless, lack of income or lack of consumption captures many aspects of lack of resources, particularly where many goods and services are exchanged in markets.

Poverty is used in this study as an important indicator of individual vulnerability to climate extremes and to climate change, because poverty can be directly related to marginalization and lack of access to resources which are critical when faced with the risk of hazards and the resultant stress on livelihoods. Income is taken as an economic indicator of poverty, recognizing that this is an external measure but one which correlates with other aspects of poverty relevant for vulnerability, such as health indicators (Glewwe and van der Gaag, 1990).

Poverty definitions can both encapsulate ``basic needs'' in some absolute sense at one extreme, with `relative deprivation' as a subjective measure at the other extreme (Baulch, 1996; Blackwood and Lynch, 1994). Income is replicable and comparable across differing groups, however, and over time in particular locations, and thus a relevant indicator providing a picture of how baseline vulnerability changes over time and space.

Poverty is therefore one aspect of vulnerability which, given the assumptions here, can be quantified and to which perceptions of risk can be grounded. Poverty affects vulnerability through individuals' expectations of the impacts of hazards and their ability to invest to alleviate risks; and affects the coping and recovery from extreme events through directly constraining opportunities for coping and reducing the resilience to impacts.

10.2.2 MODALITIES THAT TRIGGER LOSS OF LIVELIHOODS

Sensitivity of people's livelihoods to non-military (i.e., environmental, socio economic, political, etc.) stresses is documented internationally (Homer-Dixon and Blitt, 1998; Ulman, 1983). Linkages between environmental degradation/stress and human security for South Asia and Bangladesh are also examined by Islam (1994) and Rahman *et al.*, (2003), respectively.

The relationship between frequently occurring hazards and their implications on livelihoods of poor people of Bangladesh are reasonably well researched and documented (Ali, *et al.*, 1998; Elahi, *et al.,* 1990; Haque, 2003). Hazards such as floods, river erosion, water logging, drought, cyclonic storm surges, etc., are known phenomenon in the monsoon influenced landmass, which also known for its high population density, flat topography and low elevation. Such hazards, most of which are water related, often give rise to to human miseries and bring disastrous consequences. As an aftermath of a hazardous event, often beyond the inherent coping capacity of poor households, it becomes difficult to maintain ecosystem based livelihoods.

However, people's indigenous knowledge towards coping, the advancement of early warning systems and subsequent support of infrastructure, and the positive influences of technology and extension services have played pivotal role in counteracting the adverse impacts of such environmental hazards and in shaping up poor people's livelihoods in a dreadful condition.

Intriguingly, climate change will tend to add additional elements of vulnerability of livelihoods at risk, especially for the poor section of the society. There are reasons to believe that traditional coping practices would not be adequate to safeguard threatened livelihoods, while established technological answers to past hardships will be severely constrained by climate change induced extreme events.

10.3 CLIMATE CHANGE, BANGLADESH AND FOOD SECURITY

Climate change is known to be a dynamic phenomenon, where the extent of change is likely to increase with time (Nakicenovic and Swart, 2000). For Bangladesh, limited efforts have been made to create plausible climate change scenarios on the basis of IPCC SRES Scenarios. Available literature suggests a few speculative "what if" scenarios, primarily based on assumptions (BCAS/RA/APPROTECH, 1994; Asaduzzaman, *et al.*, 1997). Model based scenarios for Bangladesh, considering a 1% transient increase in ambient concentration of carbon di oxide per annum provided time-bound scenarios on temperature and rainfall (Ahmed and Alam, 1998).

All these literature suggest that there will be a general rise in temperature, as well as an increase in monsoon rainfall. The latter also reported a diminishing trend of rainfall in drier months and a faster increase in winter temperature leading to a mild winter and wetter monsoon.The results from the models suggest that increasing variability and change in climate system and subsequent change in hazard potential will tend to decrease food grin production potential.

10.3.1 OVERALL IMPACT ON AGRICULTURE SECTOR

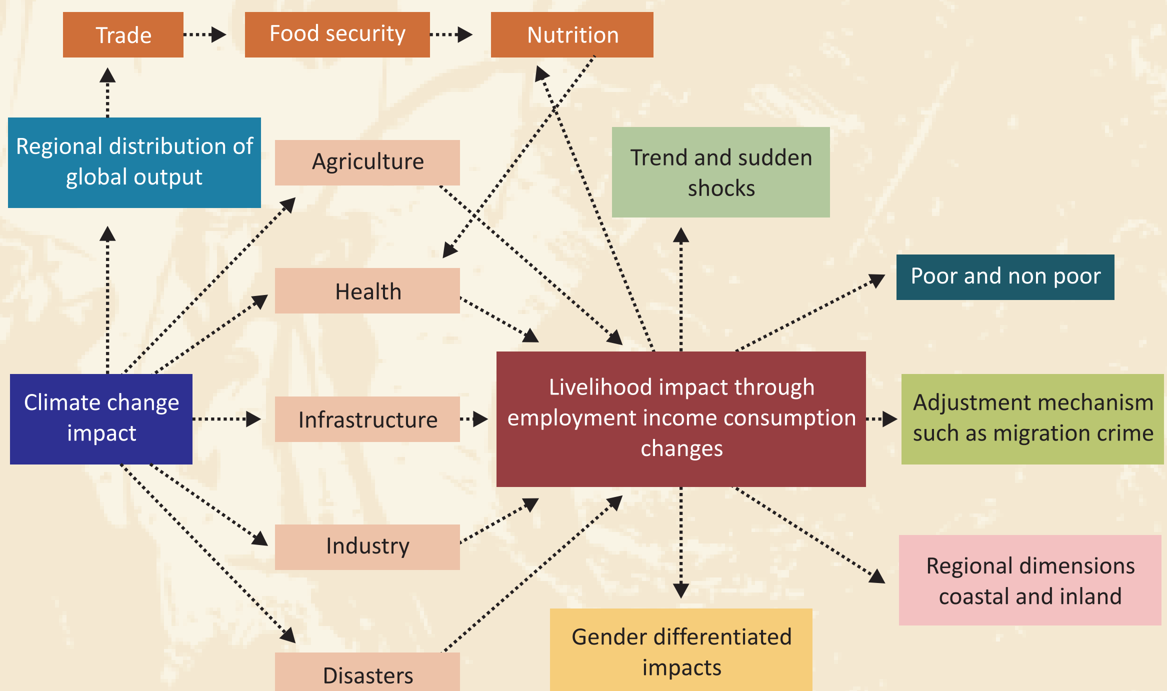
The years 2007 and 2008 saw unprecedented rise in prices of food and agricultural commodities the world over and drew the attention of policy-makers in all countries to the necessity of keeping the issues of agricultural growth and production as well the utilization of the output of the sector in constant view lest humanity is not deprived of the access to food, the most basic need of all. Consequently, while reexamining the role of agriculture in the general scheme of development, particularly in developing countries including those in Asia, one is struck by the enormous changes that have taken place in the sector and the economic, social and institutional frameworks within which it has to operate.

In fact, the uneasiness with the present state of agriculture deepens when one finds that agriculture had been contributing less and less to total GDP over time while the changes in level of income and structural changes in population call for diversification away from cereals to high-value crops and non-crop food production. Such changes also in turn demand better marketing services as well as new technology of production. Other new challenges are also rising in the horizon.

All the time, the total population had been rising which put pressure on the land available for cultivation to get increasingly more and more out of a dwindling and also somewhat degraded land base. At the same time, the changing demographic structure with very large number of young entrants to the labour force every year mean that comparatively only a few can be accommodated in agriculture and thus needs to find employment elsewhere. The question comes how this is going to affect organization of production in agriculture particularly with women becoming de facto household heads as men move to cities or outside the country in search of jobs.

The imperatives of a growing population and the increasing demands for food and other agricultural goods mean that the yield of land has to rise continuously. This had happened earlier but the rate of innovation may have reached a plateau. Renewed emphasis is needed on technology generation, innovation, and adaptation of the existing off-the-shelf technology (e.g., biotechnology, GM products) to local conditions. At the same time as much of the population will no longer be in agriculture, the output has to be marketed to cater to the demands of the non-agricultural population (urban as well as rural non-farm households).

Agriculture is a natural resource particularly land and water-intensive activity. Resource degradation in various forms is therefore expected to put pressure on it now and in future. Climate change, particularly, has become the latest in the long list of environmental woes as well as a great developmental challenge in general and for agriculture now and in particular in future years.



(Source: Asaduzzaman, et al., 2005)

Figure 10.1: Pathways of livelihood, gender and food security impacts

Figure 10.1 illustrates the generic links of climate change impacts with livelihood issues. Climate change is expected to have several impacts. Of these, we specifically pick out those which are likely to be of major importance in Bangladesh. These are agriculture, industry, infrastructure, disaster and health. Agriculture is defined to include crop cultivation, fisheries, livestock and forestry. Two aspects on which impact analysis have been specifically attempted but not shown here include water resources and bio-diversity. Both of these are cross-cutting issues and some times lead to and sometimes interact with the other impacts.

Let us first begin with climate change. While we are not going into the details of what constitutes climate change and what are their specific manifestations in Bangladesh, suffice it to say that the following four important aspects are likely to be observed in the context of Bangladesh. These are a rise in mean temperature as well as its variability both within a season and between seasons, changes in the precipitation regimes in terms of total and annual as well as seasonal variability (and consequently run-offs), carbon-enrichment of atmosphere and sea level rise.

Given the above components of climate change, agriculture is likely to be affected in several ways. The outcome of such changes is that *(i) yields of crops may decline; (b) the yields may be more variable; (c) because of species migration, natural vegetation and consequently suitability of specific locations for crops may change*. For livestock, heat stress may lower productivity in terms of draught as well as for other biological output. Changes in natural vegetation may lead to problems with fodder availability and consequently of livestock output. Changes in surface water availability and wet land regimes will create problems with fisheries habitat, particularly in shallow water due to temperature rise. The problems are likely to be more location-specific. Migration of natural vegetation is likely to create specific changes in forestry. Particularly mangroves will be affected due to sea level rise. On the whole, the changes in agriculture may lead to a fall in domestic production of food, fodder and fibre. What all these mean is that with a falling output, employment and incomes of people may fall lowering their consumption. Lower consumption will mean lower nutrition level on the whole and thus a rise in nutritional and income poverty.

The damage to the crop sector can be better analyzed against the backdrop of the performance of this sector in recent years. Agriculture as a whole contributed 46% of GDP in the late 1970s. This had fallen to just about 31% by the turn of the century and now stands at around just about a fifth of the total GDP. Manufacturing contributes around 17% while the rest is provided by services, Of course, that does not mean that agriculture has not grown at all, but that it has done so at rates much lower than for manufacturing and services. Over the last one decade agriculture as a whole has grown at less than 3.5% per annum on average while the over-all GDP has grown at 5.5% (Table 10.2) and has over the last few years risen at rates often surpassing 6%.

Table 10.2: Average annual rates of growth (%) of sectors and sub-sectors (1997/98- 2007/08)

Sector/subsector	Rate of growth
Agriculture	3.4
Crops	3.1
Livestock	4.6
Forestry	4.7
Fisheries	3.0
Mining	7.3
Industry	6.9
Services	5.9
GDP	5.5

Source: Author's estimates based on official data

Non-agricultural sectors such as manufacturing and services have grown at much faster rates. Given this, one observes also a kind of volatility in the growth rates of agriculture as evident from Figure 10.2. Note that the over-all fluctuation is more or less influenced by those in the rates of growth in the crop agriculture. And as we shall see crop agriculture in Bangladesh still to a large extent means rice cultivation.

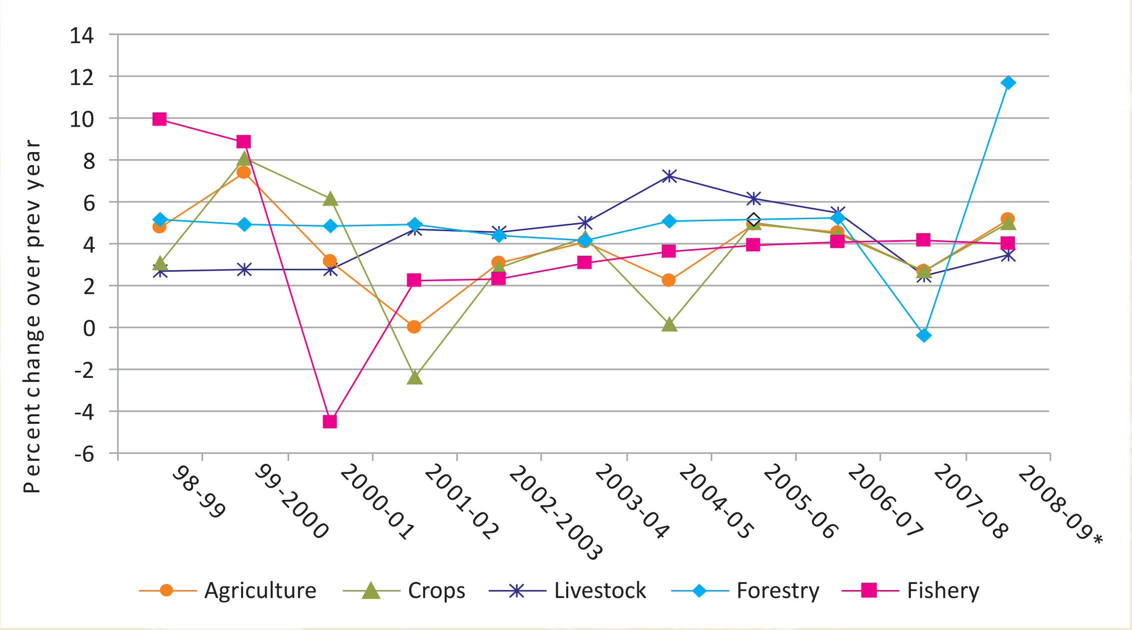


Figure 10.2: Year to year fluctuations in the rates of growth in agriculture and sub-sectoral GDP

10.3.2 PREDOMINANCE OF RICE CULTIVATION

Rice contributed nearly 75% of the gross cropped area of the country in recent years and thus whatever happens to rice determines to a large extent whatever happens to agriculture. While this provides a kind of sense of focus, this may also be the Achilles' heel of agriculture as will be clearer as we go along.

Rice production has several characteristics. First, over time dry period rice (*boro*), grown over the months of February-May under irrigated conditions, is now the most important in teems of output (Figure 10.3). *Aman* rice grown during mainly rainy season and partly rain-free months from July/August to December/January is the second most important in terms of contribution to output. But it often suffers from damages due to onset of floods as well as storms in coastal areas and moisture stress at times of flowering. *Aus* rice is basically wet rice and suffers from flood in most years and its place has been increasingly taken over by *boro*.

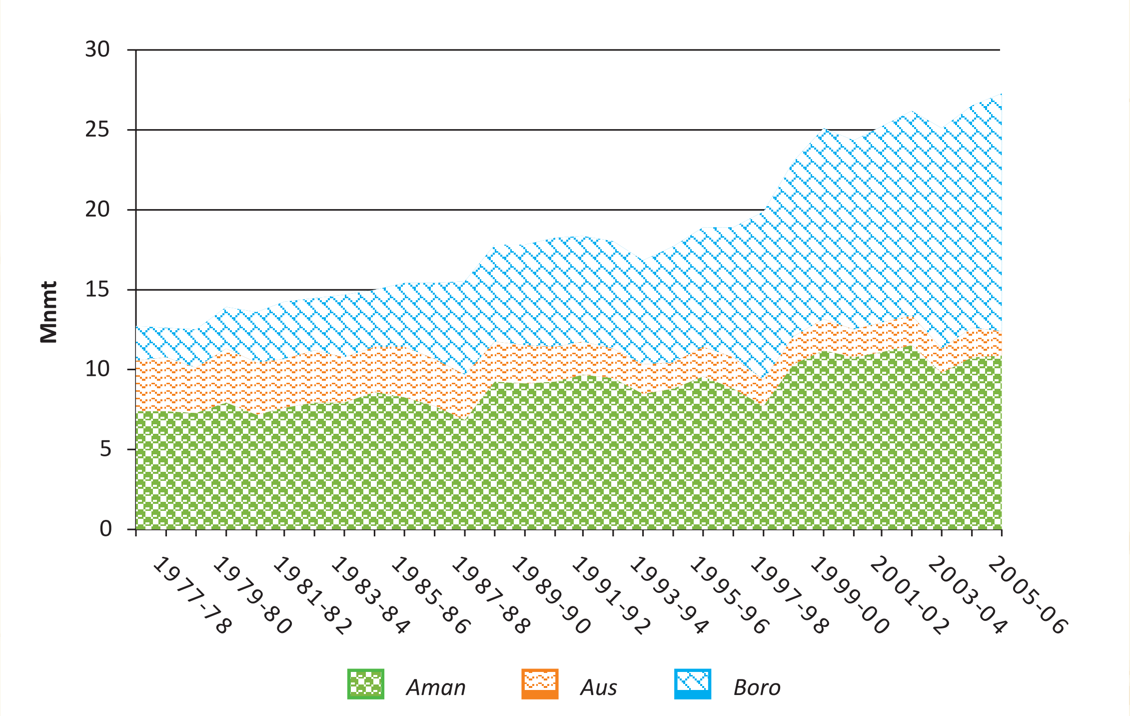


Figure 10.3: Rice output by season

The outputs of all kinds of rice is rather volatile, but most importantly it is so in case of *aman*. This is critical because the frontier for expansion of *boro* acreage has been largely reached and more now needs to be coaxed out of *aman* by stabilization of its output by lessening the damage to the crop due to flood as well as drought which also mean rising salinity in the coastal areas.

The rising output in case of rice has been possible due to a very large switch over to high-yielding varieties (HYV) of rice sensitive to application of fertiliser and water management (basically irrigation). During 1977/78 to 2006/07, the total change in area under rice had been only 0.1% while yield has changed by 2.6% raising the total rate of output change to 2.7%. The pace of yield change has been faster during the more recent period of 1992/93 to 2006/07 when area change had been 0.5% and yield change had been 3.14%. This raised the rate of output growth to an annual average of 3.6%.

The yield changes had taken place due to switchover to HYVs. As a result much of rice output is now due to cultivation of such varieties. In 2007/08, the total rice output had been 28.9 mn metric tons. Of this, 22.8 mn metric tons or 79% was due to HYVs and 3.5 mn m tons (or 12%) due to hybrid rice. Thus, local varieties accounted for just about 9% of total output. The implication of this is that many of the traditional varieties may have vanished and their germplasm lost for ever unless preserved by agricultural research centres. This bodes ill for future development of varieties with appropriate and desirable genetic qualities. At this stage we need to discuss also the other types of technological change that had been taking place in Bangladesh agriculture.

The relationship between population and agriculture may be conceptualised in several ways. First, from the demand side as population increases, everything else remaining the same, the demand for agricultural commodities particularly food increases. Hence an increasing population means the demand for agricultural commodities and food will in general rise and may have to be provided from domestic production as far as possible.

On the supply side, population provides the labour necessary for agricultural operations. Hence the change in its structure (spatial, sex-wise and age-based) and demographic dynamics such as migration may have implications for supply of labour to agricultural operations. Thirdly, as population increases while land resources may be getting scarce or degraded will have implications for technological change as more and more may have to be coaxed from the same amount and quality of land. Each of these may call for changes in organization and technological characteristics of agricultural production. We would now like to see how population characteristics may have changed to call for a serious examination of these issues in Bangladesh.

Climate Change is now more a development rather than an environmental problem. This is going to exacerbate all other general and agriculture related environmental problem related to water availability, quality, timing, and various types of disasters which will also have adverse impact on agriculture.

In one word, food security will be under grave threat while there may be substantial loss of livelihood jeopardizing the whole development effort. It has been estimated that just adapting to climate change impacts at the present level of development efforts will require US$ 5.5 billion per year including US$ 1 billion under public management and US$ 4 billion under private management the rest being due to development efforts by NGOs. Mitigation would need another US$ 4 billion per year (US$ 2 billion each under public and private management). While such level of resources are difficult to find, these indicate the cost of climate change in the economy.

For agriculture, up to 50% of projects with 60% investment will need to be revised to include adaptive measures to climate change. A related sector is water where practically all projects and whole investment have to be rethought for adaptation. And this is only at the government level.

Farmers will be the ones who will have to do the adaptation. The costs that they will face are unknown but an idea can be had from the adaptation cost estimate for the private sector as whole.

Usually the government of Bangladesh responds to a crisis through supplying of food for immediate relief efforts during and after the stress event (especially in cases of extreme weather events), coordinating food aid commitments as well as delivering and launching a post-hazard agricultural /employment rehabilitation program. As part of the relief efforts, the indicators are to be observed:

- Extent of post hazard food grain distribution;
- Extent of imported food grain through public and private channel;
- Food Aid availability.

The price of essential food grains must be monitored both at national and local level and the design of safety net programs should be reorganized accordingly. Both the availability of food (market release of food) and price accessibility in terms of entitlement are very important indicators to be monitored, locally and nationally.

- Number of VGF card distributed, extent and effectiveness of open market sale (OMS) program;
- Number of employment created (seasonally, just after the event, or it can be observed periodically for several seasons, depending on the nature of loss);
- Access to institutional credit (agriculture credit/SME credit).

A few words about the food gap *(total food grain requirements not met by net domestic food grain production)* may be in order here. With an eventual shortfall of production, depending on the extent and nature of the event, the projected food gap usually rise during and after a stress event, which might be complemented by timely import of food grains, sufficient market release coupled with entitlement (price of the food grain and availability of employment).

It may be emphasized here that the arithmetic at the aggregate level of food grain requirement, production and imports does not necessarily ensure food security at micro level. Even in a normal year, this poses considerable problems in a country where almost half of the people living below the poverty line. In a stress /hazardous year, this brings an additional dimension and assumed critical significance since the number of those who were regularly exposed to the risk of starvation and therefore, became extremely vulnerable to malnutrition and even death increase many fold. In agrarian societies if crops are lost, there may often be no time for replanting which may create famine-like conditions unless adequate measures are taken to prevent them. In any case, it may be quite some time before normal economic activities may resume. In the mean time substantial losses in production and consequently in employment and income may occur affecting growth adversely.

The second round (mainly macroeconomic) adverse impacts of disasters are no less important than the first round indirect impacts. As production, employment and incomes are lost by households and firms, this immediately leads to a loss of national income unless offset by increased economic activities elsewhere within the economy. This may also affect growth adversely because of possible higher level of indebtedness of households and firms with consequent lower capacity to invest unless insurance, credit and other similar facilities are available to absorb the losses or shocks and impacts.

The crop calendar of Bangladesh indicates that the timing of the floods coincided with the sowing season of *aman*, the major rice crop, accounting for about 50% of total domestic production, the harvesting of *aus* and also of jute.

The unprecedented flood in 1998 caused heavy damage to potential food grain production. According to the final estimate of BBS, total *aman* production was estimated to be 7.4 million tons thereby registering a decline by 12.6% in 1998/99 as compared to the previous year. This decline in production was attributed to both lower acreage (decline by 11.1%) and yield rate (declined by 1.7%) in 1998/99 as compared to 1997/98. Shortage of seedlings due to damages of seed-belts by flood impeded normal transplantation of *aman* in different parts of the country and as a result, farmers were unable to bring lands under normal *aman* cultivation in most of the flood affected regions. Moreover, at the time of harvest, *aman* plants in different areas were attacked by insects which reduced yields in the affected regions. These estimates were collected from the results of cluster reports, farmers' interviews covering all rural thanas of the country by BBS (BBS, 1999).

The shortfall in food grain production due to crop damage was estimated to be about 8.0% of the GDP originating from the crop sector, which was equivalent to about 5.5 percent of agricultural GDP and roughly 1.5% of total GDP in Bangladesh. This only captured the direct impact of crop damage in the economy. If, however, the sectoral linkages were taken into account, then the multiplier effects of crop damage could amount to a loss of about 15% of GDP originating in the crop sector, which was equivalent to more than 10% of agricultural GDP and roughly 3% of total GDP in the country (an estimation from Centre for Policy Dialogue in 2000).

The direct loss in agricultural employment due to crop damage from 1998 flood was estimated to be 0.51 million person year, of which 0.31 million man years constituted hired labor and the remainder (0.20 million person year) was contributed by family labor of the farm households in Bangladesh (Centre for Policy Dialogue, 2000, estimated using the relevant coefficient with appropriate adjustment from the sectoral lobor coefficient Matrix of I-O table for Bangladesh, 1993/94).The total loss, incorporating the indirect effects through sectoral linkages was much greater.

It may be emphasized that the government policy based on the realization that government imports and food aid alone would not be sufficient to make up for the projected loss in a severe flood year have a policy effect. Following the *aman* rice production shortfall in a flood year, government should encourage private sector imports of rice through removal of tariff on imports and ensuring the free movement of these imports as official trade, through the land routes. This will lead to keep prices in Bangladesh approximately equal to import parity level.

To address the food gap and accordingly set the tone of policy, the estimation of crop loss and the projection of future crop yields are crucial. One important point to be noted here is that, BBS comes up with a preliminary estimate, it usually takes several months before the BBS comes out with its final estimates of the actual harvest. For example, *aman* is harvested in December-January in a year (December in the preceding year) and it is only the first week of May that BBS can publish its final estimate of *aman* production. This however should not prevent us from making a few observations regarding the factors influencing the prospects of *boro* production in the successive year of flood.

- Observing the potential *boro* production is very important after a flood year. How much this production is attributed to acreage and how much to yield should atleast be tried to generate (a rapid appraisal survey by DAE can contribute to the process). The farmers must have made every effort to increase the acreage and production of *boro* rice in order to make up for the loss of *aman* production due to flood. Any attempt to put any definite estimate in place will largely remain a matter of conjecture. We should await the final estimate from BBS based on more scientific methods of investigation and using a large sample or for that matter from any other organization who can venture to come out with a definitive estimate of the crop production, based on a comprehensive survey.
- The sale of fertilizers (in terms of nutrient content) should be monitored, especially with respect to its sale in the preceding year. Although this does not mean a corresponding increase in output (a part of fertilizer is used in wheat and potato which are fertilizer-intensive), this atleast enquire whether the increases in fertilizer use match the trend in *boro* acreage of that year.
- The amount of areas irrigated in that year in *boro* season (published in Economic survey)and the type of irrigation are to be monitored to give incentives and proper policy support to irrigation.
- A large proportion of *boro* crop (more than 50%) is marketed. However, no significant impact on rice prices is expected following an expected harvest of *boro* rice. Still the gap between nominal and real wages portrays an important exhibit of entitlement of the community. This wage gap can be observed locally through primary data generation by the local concerned authority.

- The disbursement of agricultural credit should have been monitored as compared to the corresponding period of the previous year. *Boro*, being a cash-intensive crop, has certainly benefitted from the accelerated credit disbursement.

10.3.3 EXPERIENCE FROM THE PAST: THE GREAT BENGAL FAMINE OF 1943

The official famine enquiry commission reporting on the Bengal famine of 1943 put its death toll at 'about 1.5 million', which appeared to be an under-estimation even to some members of the Commission. In 1943, the overall decline of rice production was about 13% of expected average year production. This was largely the result of a cyclone in October, followed by torrential rain in some parts of Bengal and a subsequent fungus disease.

Further, the Japanese occupation of Burma in 1942 affected rice imports eventually impacting the supply to Bengal. The Bengal famine was essentially a rural phenomenon. Urban areas, substantially insulated from rising food prices by subsidized distribution schemes, saw it mainly in the form of an influx of rural destitutions. A dramatic decline in the exchange rate against labor emerges from Table 10.3. The exchange entitlement approach tends to predict a lower impact of the famine on peasants and share croppers than on agricultural labors and sellers of certain commodities and services (fishermen, craftsmen, barbers, etc., who suffered sharp deterioration of exchange entitlement).

Table 10.3: Indices of exchange rates between agriculture, labour and food grains in Bengal, 1939-44

Year	Wage Index	Food Grain Price Index	Index of Exchange Rate
1940	100	100	100
1941	110	109	101
1942	115	160	72
1943	125	385	32
First Half of 1943	130	385	34

In understanding the significance of the wage price data in Figure 10.4, it is worth bearing in mind that agricultural laborers tend to earn a great part of their income in the peak seasons of plantingand harvesting of the main crop; and even if wages have kept pace with the current rice prices, there would have been distress owing to the failure of the peak wages to anticipate the rise of food prices following the peak.

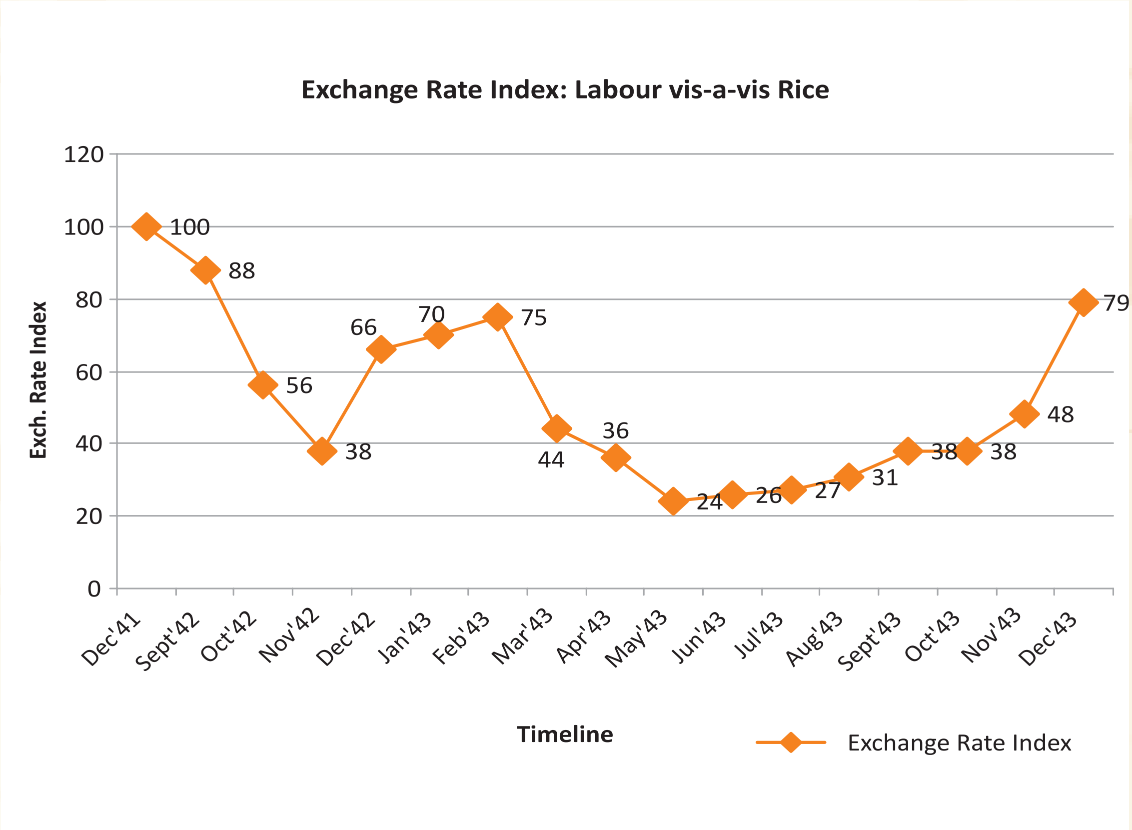


Figure 10.4: Monthly wages of agricultural, male, unskilled labour and the price of Rice and indices of Exchange Rates: Birbhum District, 1943

10.3.4 IMPACT OF HYDRO-METEROLOGICAL DISASTERS

FLASH FLOOD

Flash flood, a quick on setting event, occurring any time before the first week of May can cause real havoc to the standing *boro* crop. Owing to the submergible dikes in the north eastern part of Bangladesh, coupled with the current practice of *boro* cultivation, the timing of flash flood seems to be the most important determinant of losses. The estimated potential production loss can lead to seasonal food insecurity in these affected areas. Loss of asset erosion, migration trends, entitlement to food are the important indicators to monitor the aftermath of flash flood hazard in north eastern part of Bangladesh. A set of indicators are to be generated through primary rapid appraisal within the locality, the mechanism of generating data can be managed both by local level governance authority (Ups, Districts), CBOs or NGOs. But the capacity building to carry on the task in time must be initiated through regular institutional mechanism (for example: through MoEF/CDMP), so that any dependency on any donor or funding institution can be minimized which is important for the long term sustainability of this observation data set.

DROUGHT

Drought in Bangladesh exhibits its impact through phonological and meteorological category. Ground water irrigation in dry season for *boro* is the common practice to overcome the water stress, naturally this process is capital intensive and any deficit in timely input financing can create a loss to *boro* production. Usually drought in Bangladesh appears to be a slow on setting phenomenon, a close monitoring regarding input supply, availability of inputs in time are very important.

Especially, if the drought occurs after a climatic hazard (for example flood), the extent of subsequent stresses must be monitored closely, and if needed the policy decisions regarding input subsidies, facilitation of institutional credits for the farmers is absolutely vital. Import data of fertilizer and their time, distribution of fertilizer and their spatial and temporal data, Information regarding irrigation and its cost must be monitored. It is of utmost importance to monitor the meteorological drought in monsoon. Not each spell of such drought causes the same extent of crop loss, or other losses. If the meteorological drought prevails in April, there is a higher chance for lower *boro* crop yield. If it occurs in June, it might be insignificant in terms of food security. But as it can hinder the production of broad cast *aman*, biomass energy security can encounter a major threat.

In an increasingly encouraging scenario of jute production during last two years, and keeping the increasing thrust in demand for jute products in international market, the meteorological drought in June can be a potential threat for jute yield. If this drought condition prevails in July (especially from mid July) the potential loss in seedling production leading to loss in potential crop yield or compensating the loss by higher investments is expected. If this scenario couples with heavy shower from the third week of August, a major crop loss might be expected. *Boro* production in north western region of Bangladesh, though depending on high input investment, appears to be almost certain.

If a certain proportion of *boro* production is lost, a close monitoring of foodgrain availability, food price, employment opportunity in successive lean season (Ashwin and Kartik, the *monga* season) is absolutely vital for the areas which have experienced potential *boro* production loss. Policy towards enhancing social safety net programs can revolve in lean seasons in these areas to safeguard the livelihoods of the community and to combat potential famine situation.

SALINITY INGRESS

Salinity being getting severe in the south west belt of Bangladesh, climate change is considered as one of the driving factors for the increase of salinity intrusion. It has been reported that salinity affected areas in the coastal Bangladesh have increased from 0.83 million hectares in 2001 (Karim and Iqbal, 2001). CEGIS, (2006) reported that the 5 ppt isohaline line would show a northward shift by about 90km inland due to sea level rise by 2070s.

A long term monitoring mechanism should be built in to monitor the extent of intrusion and severity of salinity. For that matter, salinity in soil, ground water and surface water should be measured in a regular periodic interval; specifically the dry season salinity must be monitored very closely and in a long term basis. The higher rate of capillary rise of salinity is expected with increasing evapotranspiration due to increases temperature in winter, under climate change. Reverse osmosis process during dry season causes potential crop loss. Salinity ingress directly affects the yield of the most preferred crops generally observed in the coastal zone (Karim, *et al.*, 1990).

Due to increased salinity, a vast tract along the coastal zone is left fallow during the dry season in apprehension of severe crop loss. The most adverse effect of salinity ingress is observed in Shatkhira district. While the wealthy investors have thronged and forced a rapid transformation of crop lands into saline shrimp enclosures, the poor farmers have lost their agriculture-based livelihoods, forced to transfer their crop lands to the new *gher* owners and eventually become destitutes. Only a small proportion of these farmers are found in their locality while a large majority have migrated out from their villages (Ahmed and Neelormi, 2007).

Salinity induced disruption in agricultural activities and loss of agricultural livelihoods can be registered at Union Parishad with the help of District Agriculture Extension Officers/ Block supervisors. It will enable to monitor the changes in livelihoods in that locality and long term monitoring will enable the policy makers to correctly address the problem. Coordination with agriculture research system, feeding them with the salinity information, will create an enabling condition to come up with new saline tolerant varieties for not only rice but for other suitable crops as well. It is pertinent to add here that, shifting to shrimp cultivation might result in cash earnings from export, but in terms of employment and entitlement, agriculture stands as the major livelihood option in this region.

STORM SURGE AND ROUGH SEA EVENT

Cyclone and its effects are localized in nature. Losses in crops are observed only parts of the cyclone zone. The formation of cyclones is common in the northern Bay of Bengal, though cyclones hitting the coastal landmass of the country are indeed few. The high velocity winds associated with cyclones are highly damaging for infrastructure, however much less damaging to standing crops. The most damaging is the storm surge, which simply mauls standing crops (Haider, *et al.*, 1992).

Since *aus* is becoming unsuitable for profitable crop calendar, despite the risk of salinization along the coastal zone farmers cultivate *boro* in the dry season, which can safely avoid cyclonic risks. Even then cyclone can reduce crop production by affecting *aman*, if it occurs during the October-November (post-monsoon) time frame. The country experienced severe cyclones in 1970 (November), 1991 (late April), 1997 (May), and 2007 (November). However, the implications on food production were negligible in1997, slight in 1991, and significant in the two events of 1970 and 2007.

Storm surge which are associated with cyclonic activities and/ or unusually high tide when the occurrence of peak spring tides coincide with full moon, generally inundates areas that are otherwise protected by coastal embankment (or polders). Since the recession of saline water from a coastal embankment takes a few days, the crop lands become salty that destroys standing crops and triggers loss of livelihoods of farming communities. Cyclonic storm surges are also quite common that destroy weak dwelling structure of the poor households, drown people and livestock alike and inflict misery to the cyclone battered people. In the later cases, reconstruction of livelihood activities takes long time while people try to collect food from whatever sources. Under such frustrating living conditions, people generally decide to move out from their ancestral homesteads.

Rough sea events have been quite common in recent years in coastal Bangladesh. However, both the intensity and frequency of occurrence of rough sea events have been increased significantly in recent decades, due primarily to gradual warming up of the sea and subsequent rise in sea surface temperature (Ahmed and Neelormi, 2007). The sea- going fisher folks along the coastal reaches are the worst victims of rough sea events, since their fishing-based livelihoods generally come to a halt if weather signal number three or above is declared by the nearby port authority. Not only that they require to abandon fishing-trips half way and thereby forced to incur certain income losses, due to increase in frequency of occurrence of rough sea events they can not go out for fishing as many times as they used to do until a few years back. The economic implications of which are highly significant for the poor coastal fishermen.

An estimated quarter million fisher-folks in Chakaria, Maheshkhali, Laxmipur Sadar, Char Fassion, Kalapatra, and Patharghata, sub-districts (out of about 0.35 million fishers' household) have already encountered tremendous economic losses due to repeated and almost regular occurrence of rough sea events. They are highly entangled in debt and are also forced out of the reach of access to institutional credit- a decisive factor that has led to loss of their livelihoods. While many of them are contemplating to permanently out-migrate, many have already tried to take naval routs to out-migrate to far away maritime countries. Newspaper reports suggest that a large number of frustrated fisher folks have died while trying to out-migrate, while the living ones are rescued and sent to jail by the naval police of India, Myanmer, Srilanka. According to popular newspaper reports, about 20,000 fisher-folks are now in different jails of these neighboring countries.

WATER LOGGING

Water logging, in recent years, is appeared to be a major disastrous phenomenon, especially in the south west belt of Bangladesh. Most alarmingly new areas are going under water logging. A combination of gradual natural shifting of the Ganges, and its principal distributaries towards the east, establishment of coastal embankment system that induced increased sediment deposition on the river beds by making floodplains unavailable, salinity intrusion due to diversion of the Ganges flow during the dry season since the commissioning of the Farakka dam in India, and lack of operation and maintenance of sluice gates of coastal embankments have aggravated choking up the intricate river network in the southwestern region of the country to give rise to rapid waterlogging over the past three decades. In recent years, waterlogging has become a major cause of the livelihoods.

Water logging in the south western region has gradually been spreading from Jessor district (along the river Kobadak) to a large area covering four districts: Jessor, Khulna, Shatkhira and to a lesser extent, Narail. In Noakhali district, however, water logging has been caused by permanent choking up of revulets and Noakhali River, owing to human induced rapid upliftment of land from shallow sea by erecting two earthen cross dams.

No land based production is possible in some of the areas where almost seven months a year is water logged. Successive occurrence of water logging is causing severe food insecurity arising from employment insecurity, social destitution, and severe health hazard. A close monitoring of employment and income related information in water logged areas (depending on the severity) in a monthly basis is required. Loss of livelihoods, migration trends, information on infant and child mortality rates, and rate of enrollment in school should be explored within an entitlement framework.

When land based productive system under waterlogged condition remains inaccessible for crop production, farmers loose their livelihoods, and there by loose their subsistence. The male earing members of the households first tend to out migrate to semi-urban areas in search of temporary employment, leaving behind their families. Initially they send remittance to their families back home (Ahmed, 2008). However, with any adverse shock in market price of commodities they can not remit any more, which leads to further economic hardship for the spouse and dependents. The left behind households thus become female managed households, where the lead women shoulder extra burden of kids and elderly of the family, along with other household stuff responsibilities.

Waterlogging not only enhances forced out migration/displacement, it aggravates extreme economic hardship, it inflicts upon health care debacles and other social problems (Ahmed, 2008). Mairampur and Keshabpur sub-districts of Jessor bear the evidence of gradual increase in the number of female managed households and the subsequent high occurrence of out- migration. In contrast, the extent of forced displacement in Noakhali region is quite less due to the fact that the seasonal water logging leaves room to ensure atleast one crop during the dry season.

EROSION

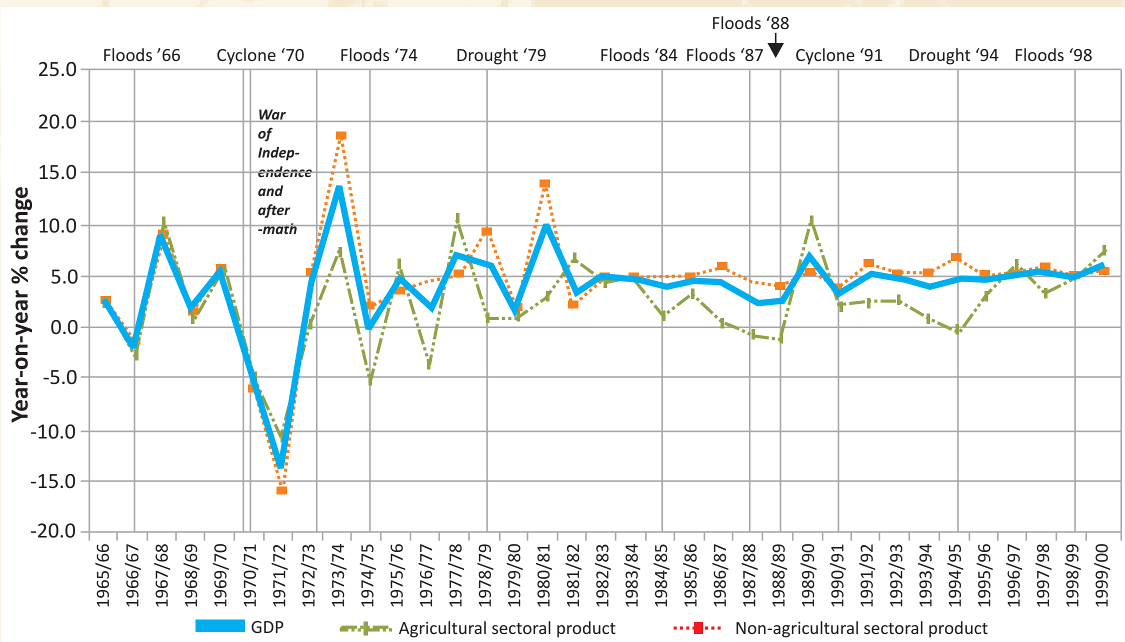
Riverbank erosion has been regarded as the most common cause of failed livelihoods in Bnagladesh, which triggers forced displacement. Riverbank erosion ends up with nothing left behind. The meandering rivers along with the GBM system poses up to 200,000 people homeless every year. However, otherwise stable coastal islands have been facing invigorated wave actions, fuelled by warming induced increase in SST along the Bay of Bengal, which has been eroding sea facing islands rather quickly.

EXTREME WEATHER EVENTS AND DISASTER

The immediate effect of a disaster is loss of lives, loss of livestock and loss of dwellings and other assets.

When the dead are buried, the misery of living is experienced by others left behind in the aftermath of disasters. Health, sanitation, food, shelter all have to be managed for people who can not immediately begin to build their lives again unless helped adequately by external agents, be they the Government, the donors or the civil society organisations. Apart from this, the other indirect effects on the economy are rather telling as evident from Figure 10.5 below. Whenever a major disaster has struck, the whole economy suffered. Agriculture suffered probably more than non-agricultural sectors. Yet, as Islam has found, even in such a situation floods cause much of the damage indirectly though the sectoral linkage effects. River floods as he has analysed caused damages 21% of which was direct (machineries, stocks etc), and 26% immediate indirect effects. More than one-half of the adverse impacts were, however due to backward and forward linkages and their multiplier effects elsewhere within the economy.

Historically major food insecurity both household as well as at macro-levels has been caused by natural hazards. During a relatively normal hydrological year, there might have been pockets where micro-scale food insecurity prevails in certain season. However, this incidence has not been considered serious enough to cause a national scale food scarcity. The district Gaibandha and Jamalpur generally receives three flood peaks and because of the late peakin most years farmers can not grow HYV *aman*. Therefore, those households having low lying crop lands generally cultivate broadcast *aman* or a low-yeilding variety called gainja. These areas are generally stricken by extreme poverty and quite regularly face food insecurity.



(Source: Benson and Clay, 2004)

Figure 10.5: Relationship between disasters, and sectoral and national GDP

10.4 MONITORING INDICATORS AND MECHANISM

10.4.1 MONITORING DATA

Summary of Data Sources for analysis of vulnerability and monitoring poverty indicators in a specific location (apart from existing institutional arrangement fot data crunching) is given below:

Data Source	Scope	Purpose
Quantitative household Survey	A number of Households selected from representative villages/unit. Income and economic activities, limited questions on historical climate event.	Analysis of poverty, resource dependency and distribution of income.
Qualitative household Survey	Selected households subject identified from historical climate impact questions from previous survey. Qualitative survey on details of historical impacts, present collective action and perceptions to risk.	Analysis of institutional adaptation and perceptions of institutional changes.
Local level Officials: Interviews	Officials from lowest tier of the governance (Union Parishad, UP), district level officers. Qualitative survey of historical impacts, present level of protection, organization and funding.	Analysis of institutional adaptation and the wider political economy.
Secondary district level Data	Historical qualitative/quantitative data on major livelihoods (agriculture, fisheries, etc.) and the structure of economic activity at local level.	Analysis resource dependency and the role of changing livelihoods in past and present income distribution.

10.4.2 INDICATORS TO BE MONITORED

Spatial setting of indicators will depend on the hot spots, indicated by the hydro-geophysical team. *Temporal setting* will be Monthly (M), Fortnightly (F), Seasonal (S) and Yearly (Y). Part of benchmarking may be using 2008 agriculture census by BBS. In the following table, monitoring indicators and their frequency of data collection is given:

Monitoring indicator	Data collection frequency
Yield of crop	S
Acreage of crop	S
Projection of potential yield	S,Y
Projection of potential loss (due to drought, flood, salinity, water logging, storm surges)	S,Y
Stock of Food (especially rice and wheat) both on public and private arrangements	F
Import of foodgrains through public (food directorate) and private channels (opening of LC)	M,S
Amount of Food aid (Grants and Gratis)	S,Y
Carry over amount of rice and wheat	M
Market release of selected food items Public stock Public release	 M M
Daily landing of marine fisheries	D
Usage of fertilizer	M,S
Production of fertilizers by type	M,S
Import of fertilizer	M,S
Energy use for Irrigation (diesel and electrified pumps, separately)	M,S
Acreage covered under irrigation (under diesel and electrified, separately)	S
Irrigation information by type and season	S
Ownership information on irrigation materials	Y
Rise in industrial cost due to lack of fresh cooling water	S,Y
Income erosion due to infrastructure losses	S,Y
Price of selected essential food items	F,M

Monitoring indicator	Data collection frequency
Wage gap (difference between nominal and real wage)	F,M
Consumer Price Index (Food and non food)	F,M
Information on labor force (with seasonal variation) *Employment data, macro level (sectoral lobor coefficient Matrix of I-O table for Bangladesh)* employment (gender segregated) *unemployment*	 M M M
Number of fishing trip by the sea going fishermen number of days encountering signal number three or above	event based, by M
Access to open resource (wet land, khas land, forest) Number of lease of open resources (with specific economic characteristic of lease holder) Number of permits issued to access forest resources Data of forest product landed at different points	Y
Information on assets (economic classification in terms of asset, landholdings, income, livestock) with gender segregation	S, Y
Number of livestock	Y
Number of VGF cards distributed	S, Y
Disbursement of agriculture credit	M, S
Number of female managed/headed household	Y
Trends in migration (gender segregated) *Number of seasonal out migrant* *Number of permanent out migrants* *Number of migrants coming seasonally* *Number of migrants coming permanently*	M, S
Asset Erosion *Distress sale of land* *Distress sale of livestock*	M, S
Damage to/ loss of infrastructure	M, S
Implication of loss of livelihood (qualitaive)	Y
Access to shelters (cyclone, flood shelter)	Y

Monitoring indicator	Data collection frequency
Investment on reconstruction of infrastructure	Y
Loss of lives (gender segregation) due to disaster- during and post disaster	Event based (Y)
Information on safety net programs	M, S
Access to safe Drinking water *Time spent to collect water* *Time spent to collect biomass* *Time spent to collect fodder*	S, Y
Actors collecting drinking water	Y
Quality/source of drinking water (by type)	S, Y
Out break of water borne/vector borne diseases (gender segregation)	M, S
Incidence of specific health hazard at specific location (Civil surgeon office, interview from local quake doctors) (gender segregation)	F, M
Hospital seat available at local level	Y
Doctors available at local level	Y
Sanitation situation number of latrines per household (with specification of type of latrine)	S, Y
Infant mortality rate	Y
Loss of employment due to ailment by seasonal water/vector borne diseases (Rapid appraisal)	S
Nutrition erosion (gender segregation)	
Crime rate (looting of fishing trawler, for example)	

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