SEA LEVEL RISE IN THE BAY OF BENGAL: ITS IMPACTS AND ADAPTATIONS IN BANGLADESH

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1.0 INTRODUCTION

Bangladesh is a South Asian developing country of low deltaic plain located between 20º34/ to 26º38/ North latitude and 88º01/ to 92º42/ East longitude. Geologically it is a part of the Bengal Basin filled by sediments washed down from the highlands on three sides of it, especially from the Himalayas where the slopes are steeper and the rocks less consolidated. It is bordered on the west, north and east by India, on the southeast by Myanmar and on the south by the Bay of Bengal. The whole country consists of low and flat land formed mainly by the Ganges and the Brahmaputra River systems except for the hilly regions in the north-eastern and south -eastern parts. The key features of Bangladesh are as follows:

- Total Area: 147,570 km² (Land: 81%; Forest: 13.4%, Water body: 5.6%)
- Land Area: 119,624 km² (Floodplain: 80%; Hill: 12%; Terrace: 8%)
- Population: 130 million (Average density: 880 persons/sq. km in 2003)
- Area of coastal zone: 47,201 km² (32% of land area of Bangladesh)
- Population in coastal zone: 35.1 million (27% of total population)
- Length of the coast: 710 km

Coastal Zone: The demarcation of coastal zone in Bangladesh is based on three basic natural systems of processes and events that govern opportunities and vulnerabilities in the coastal zones. The criteria are: tidal fluctuations, salinity intrusion, and cyclone and storm surge risk. It consists of 19 administrative districts of which 12 districts demonstrate all three criteria and are defined as Exposed Coast. The remaining seven districts, where one or two of the criteria are observed, are defined as Interior Coast as shown in Fig.1. The country has three distinct coastal regions, namely:

(i) Western Coastal Zone:

- The entire area is the floodplain of the Ganges river
- It is also called as Ganges Tidal Plain
- The famous world largest natural mangrove forest (6017 km²), the Sundarbans, is located in this area
- Average land elevation is below 1.5 m MSL
- Erosion is comparatively small. But the area suffers seriously from salinity and tidal flooding

(ii) Central Coastal Zone

- This area is the floodplain of Ganges and Meghna rivers
- It is the most active coastal zone in Bangladesh
- This area suffers from continuous erosion and accretion
- The most dynamic Meghna estuary is located in this region

(iii) Eastern Coastal Zone:

- This area possesses higher land elevation and is covered by hilly region
- It is the most stable part of country's coastal zones
- The world longest natural beach (120 km) is located in this region

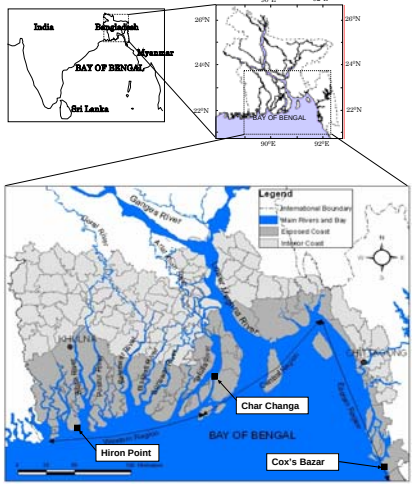

Fig. 1: The coastal zones of Bangladesh

2.0 Sea Level Rise in the Bay of Bengal

Based on measured data of mean sea level, it is confirmed that sea-level has been rising in the Bay of Bengal. Even though, the length of measured data is very small, the data however, fairly shows increasing trend of SLR which is in consistent with global trend. The sea-level in the coast of Bangladesh is influenced by three main factors (Warrick, et al., 1996).

- The level of the sea surface itself
- Rates of sediment supply to the coast and its distribution and deposition
- Long term deltaic subsidence (or uplift) from tectonic and isostatic forces.

The SAARC Meteorological Research Council (SMRC) carried out a study on relative sea level rise in the Bangladesh coast based on the measured water level for 22 years (1977 to 1998) at three gauge stations. The study revealed that the rate of sea level rise during the last 22 years is many fold higher than the mean rate of global sea level rise, which shown the important effect of the regional tectonic subsidence.

Table 1 Trend of SLR along the coast of Bangladesh [Source: SMRC, No. 3]

Station Name	Region	Latitude (N)	Longitude (E)	Trend (mm/year)
Hiron Point	Western	21º48/	89º28/	4.0
Char Changa	Central	22º08/	91º06/	6.0
Cox's Bazar	Eastern	21º26/	91º59/	7.8

The sea-level in the Bay of Bengal is also influenced by regional hydrological conditions significantly. For example in 1998, both the Ganges basin and Brahmaputra basin receives huge rainfall simultaneously which caused flood in Bangladesh for a prolonged period. It causes higher water level for more than 2.5 lunar months along the coast of Bangladesh. As a result, sea-level along the coast rises significantly. This abnormal rise of water level has been confirmed by several tide gauges of BIWTA and Port authorities. Table 2 shows the measured MSL with computed MSL. It gives an estimate of SLR due to flooding.

Table 2 The impacts of flood on SLR along the coast of Bangladesh

Station Name	Region	MSL in 1998 (m)		SLR due to Flood (m)
		Observed	Tide table	
Hiron Point	Western	1.842	1.700	**0.142**
Khepurara	Western	2.332	2.060	**0.272**
Char Changa	Central	2.248	2.037	**0.211**
Sandwip	Central	3.377	3.243	**0.134**
Cox's Bazar	Eastern	2.028	1.997	0.031

Source: Proudman Oceanographic Laboratory, UK [http://www.pol.ac.uk/psmsl/]

3.0 Impacts of and Adaptation to Sea Level Rise

3.1 Tidal Inundation

The average elevation of coastal lands in Bangladesh is below 1.5 m MSL. It is predicted in several studies that the sea-level in the Bay of Bengal may rise in the range of 0.3 to 1.5 by the year 2050 (DOE, 1993). In the coastal front there will be stronger-than-usual backwater effect due to sea level rise induced high oceanic stage, resulting into retardation of discharge flow, particularly around the confluence points of the major rivers. Consequently, the risk of floods of high intensity and duration, similar to that occurred in 1998, will be exacerbated. Under climate change scenario about 18 per cent of current lowly flooded areas will be susceptible to higher levels of flooding while about 12 to 16 per cent new areas will be at risk of varied degrees of inundation. As per NAPA recommendations, SLRs in the coast of Bangladesh are 14 cm, 32 cm and 88 cm for the year 2030, 2050 and 2100. In a recent study, IWM (2006) predicted that flooding of coastal lands may increase by 21% by the year 2001 while it is 10.3% for the year 2050 with respect to ordinary flooding condition when approximately 50% lands go under flood.

ADAPTATIONS

Rehabilitation of Coastal Embankment: The major adaptation measures against flooding in the coastal region of Bangladesh is the construction of earthen embankments along the rivers as well as parallel to coastline. The embankments are designed primarily to prevent flooding during high astronomical tides and are found useful during cyclone-generated storm surge too. Even if, the effectiveness of embankments is being questioned in several occasions, the Government of Bangladesh is currently implementing coastal embankment rehabilitation project considering its primary benefits to agricultural productions as well as flood protection. In most cases, heights are being increased under current rehabilitation works to coop with SLR (IWM, 2002). The embankments are being strengthening by planting trees along its sloping faces. A typical view of coastal embankment with plantation along it faces is shown in

Figure 2: Earthern Embankment along the Coast, Chittagong

3.2 Tropical Cyclones and Storm Surges

Bangladesh is already the worst sufferer of cyclonic events in the world. It is expected that the country will suffer from even more disastrous cyclonic storm surges in the foreseeable future due to CC and SLR.

- An analysis of all the cyclones that formed in the Bay of Bengal during the period 1877-1997 showed no corresponding increase in cyclone frequency in the Bay of Bengal.
- A model analysis shows that storm surge height will decrease by 3% for SLR of 0.3 m while it decreases by 7% for SLR of 1.0 m considering historic cyclone of 1991 as base condition. However, for the combined effect of sea surface temperature increasing and SLR always increases storm surge height (Ali, 1999).

Karim and Mimura (2005) assessed the coastal flooding due to cyclonic storm surge under CC and SLR. It was confirmed that both depth of flooding and area of flooding are significantly large under SLR.

ADAPTATAIONS

Construction of New Cyclone Shelters: An important and widely acceptable flood management option in Bangladesh is the construction of shelters commonly known as 'Cyclone-Shelter' which have been built since 1960s (Fig. 3).

Increasing Embankment Heights: Embankments obstruct the penetration of surge wave to the land and even if the surge overtops them, the wave energy reduces to a considerable extent.

Coastal Afforestation: In the recent years, plantations in the coastal area as well as along the embankments are being extensively conducted to enhance flood mitigation measures in the coastal zone by the Forest Department. An example of coastal plantation is shown in Fig. 4.

Fig. 3: Cyclone shelter in the west coastal zone

Fig. 4: Afforestation along the coast, Chittagong

3.3 Coastal Morphological Dynamics

The major factors of coastal erosion in Bangladesh include i) Strong tidal action and storm surges, ii) High wind waves and current during monsoon, and iii) High river discharge (central coastal zone). There are no accurate measurements on coastal erosion due to SLR. However, many researchers estimated the potential impacts of SLR on erosions. For example, Islam et al. (1999) predicted that average recession of the eastern coastline of Bangladesh would be about 87 times the SLR. If that is true then the land loss is:

- 6.26 sq. km for SLR of 0.1 m
- 18.79 sq. km for SLR of 0.3 m
- 62.64 sq. km for SLR of 1.0 m

ADAPTATIONS

Mangrove Greenbelt: The Government of Bangladesh is now executing the Green Belt Project in the coastal areas. This is a participatory reforestation program aimed at reduction of natural disasters as well coastal erosion. Afforestation is environment friendly and it helps to stabilize the land and also raise the ground level that will reduce inundation depth. The status of forest cover as of 2003 is shown in Fig. 5.

Bank Protection Works: In addition to soft measures, there are several hard measures including seawall and revetment to protect the coast from erosion. This kind of measures, however, are still few in the coastal areas as it takes huge investment and long-term maintenance. A typical view of revetment type bank protection works can be seen in Fig. 6.

Fig. 5: Present status of forest cover in the coastal zone as of 2003 [Source: Forest Department]

Fig. 6: Bank protection works, Chittagong

3.4 Saltwater Intrusion

As the coastal zones of Bangladesh is very low-lying, sea water may intrude much longer distance through inlands for any increase in sea-level. The SLR will also bring more coastal lands under regular inundation. This coupled with reduced flows through upstream rivers during winter will accelerate salt water intrusion to further inlands. Coastal waters will become more saline and soil salinity will increase. As a result, agriculture and fishery sectors will be severely affected by increased water and soil salinity.

ADAPTATIONS

Increased Surface Water Flow: The major initiatives to reduce salinity impacts are the increasing surface water flows from upstream, and protection of agricultural lands by constructing dikes. The Gorai River Restoration Project is an example of increasing surface water flows through deviating water from the Ganges River towards the southwest. Effectiveness of such measures is high, but feasibility is low because of high cost. Possibilities for increased local storage of fresh surface and groundwater in the area itself are low as well.

Changing Cropping Pattern: To reduce the impacts of salinity and to increase the income farmers in the coastal areas are doing fish-cum-rice (local variety) farming. Recently, they are growing forage (food for cattle) crops that are salinity tolerant (Fig. 7)

Homestead Vegetable Cultivation: In the coastal zones, people are now producing vegetable at homestead. Figure 8 shows an example of hanging vegetable production under Reducing Vulnerability to Climate Change (RVCC) project in the south west coastal area.

Fig. 7 Forage crops cultivation in saline prone area [Source: RVCC project]

Fig. 8 Homestead vegetable cultivation in saline prone area [Source: RVCC project]

3.5 Water Logging/Back Water Effect

The problem of water logging was first started during 1960 after the construction of coastal polders (dikes) with sluice gates controlling river flows and to protect low-lying agricultural lands from tidal inundation and saline water intrusion. After the construction of polders, the silt was deposited on the river beds, resulting in the silting up of rivers. Eventually, the exit points of the sluice gates became blocked, and subsequently, the empoldered areas became permanently water logged. By 1990, the water logging had extended to more than 1500 km² of prime agricultural lands in the Ganges tidal plain. It is expected that SLR will further exacerbate the water logging as it increases water level in the river.

ADAPTATIONS

Small-Scale Fish Farming: In the recent years, cage aquaculture has emerged as a strategy for fish culture in the southwest coastal zone especially in the open water bodies such as small-river, canal or wetlands. In this technique, fish are cultured in cages (Fig. 9) until they are mature enough for harvesting, while allowing them to grow in their natural environment. There is a positive social impact as it establishes rights of local people to access common water bodies.

- It allows productive use of water logged areas
- It can protect local beneficiaries from individualization of resources

Floating Garden: In the waterlogged area, the farmers are now growing different kinds of vegetable in the floating nets. Figure 10 shows an example of floating garden in the south-west coastal region. Floating gardens are a good option for beneficiaries to cope with increasing water logging.

Fig. 9 Small scale aquaculture in the water logged area [Source: RVCC project, Khulna]

Fig. 10 Floating garden for agricultural production [Source: RVCC project, Khulna]

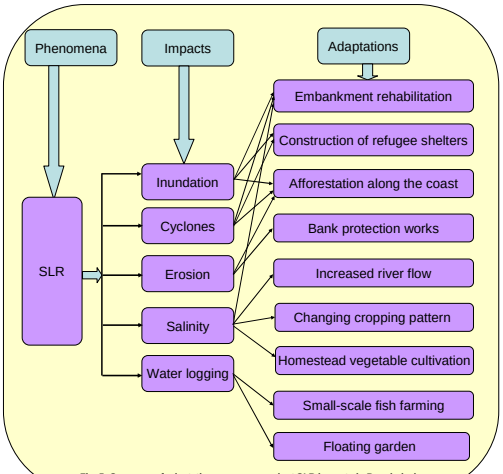

Fig. 5: Summary of adaptation measures against SLR impacts in Bangladesh

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