Internationales Asienforum, Vol. 38 (2007), No. 3–4, pp. 375–397

Sea Level Rise
A Threat to the Coast of Bangladesh

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1. Introduction

Temperature rise in the atmosphere causes sea level rise (SRL) and affects low lying coastal areas and deltas of the world. Global mean surface air temperature has increased by between about 0.3 and 0.6°C since the late 19th century. The additional data available since 1990 and subsequent re-analyses have not significantly changed this range of estimated increase. Data show that recent years have been among the warmest since 1860 (IPCC, 2007). Sea level rise has various impacts on Bangladesh, a coastal country with a 710 km long coast on the Bay of Bengal. It has already affected Bangladesh through land erosion, salinity intrusion and loss in biodiversity and will cause further damage in the form of damage to infrastructures, crop failure, fisheries destruction, and loss of biodiversity. A sea level rise of 1 m will inundate 17.5% of the country's vast coastal area and flood plain zone. As a result, Bangladesh will fail to achieve its development goals including Millennium Development Goals.

This paper focuses on SLR and its impacts on the coastal areas of Bangladesh and its people. It also considers the potential adaptations and mitigation strategies. The study is based on the available secondary resources such as IPCC reports, books, government policy documents, international reports, and scientific journals. It utilizes both qualitative and quantitative information and data to portray the impacts of SLR on the Bangladesh coast, also suggesting some solutions how Bangladesh might adapt to the problems. Emphasis was placed on assessing the impacts rather than measuring the rate of sea level rise, or the root causes of global warming.

1.1 Causes of sea level rise

Due to various human activities, carbon dioxide (CO_2) and other greenhouse gases are accumulated in the earth's atmosphere, resulting in climate change. Rising temperature expands the ocean volume in two ways. Firstly, it melts the mass volume of ice in the polar region and secondly, it causes thermal expansion of the ocean's. Wigley and Raper (1987) comment that the relative contributions of thermal expansion and ice melting to this sea level rise are uncertain and estimates vary widely. The human factor mainly responsible for global warming and sea level rise is the burning of fossil fuels. Deforestation is another human activity, responsible for decreasing the CO_2 sink. Miller (2004) states that 75% of the human caused emissions of CO_2 since 1980 are due to fossil fuel burning and the remainder to deforestation, agriculture, and other changes in the land use. The two largest contributors to current CO_2 emissions are the world's thousands of coal-burning power and industrial plants and more than 700 million gasoline-burning motor vehicles (555 million of them cars).

1.2 World sea level rise scenario

Global sea level has risen by between 10 and 25 cm over the past 100 years and much of the rise may be related to the increase in global mean temperature (IPCC, 2007). Sea level rose by ~160 mm during the 20th century (Church et al., 2006). Another study by Church et al. (2004, 2005) found a sea level rise of 1.8±0.3 mm per year over a 51 year period (1950-2000). Church & White (2006) estimate a sea level rise from January 1870 to December 2004 of 195 mm, a 20th century rate of sea level rise of 1.7±0.3 mm per year and a significant acceleration of sea level rise of 0.013±0.006 mm per year. With this constant rate of acceleration, sea level rise from 1990 to 2100 would range from 280 to 340 mm. Tide gauge data show that global average sea level rose between 0.1 and 0.2 m during the 20th century (IPCC, 2001b).

2. Sea level rise and the Bangladesh coast

2.1 Sea level rise in Bangladesh

Bangladesh is highly vulnerable to sea level rise, as it is a densely populated low-lying coastal country of extremely gentle slope comprising broad and narrow ridges and depressions (Brammer et al., 1993). The World Bank

TABLE 1: Sea level rise in Bangladesh and its potential impacts

Year	2020	2050	2100
Sea level rise	10 cm	25 cm	1 m (high end estimate)
Land below SLR	2 % of land (2,500 km^2)	4 % of land (6,300 km^2)	17.5% of land (25,000 km^2). Patuakhali, Khulna and Barisal regions will be most affected.
Storm surge		Recurrence of the 1991 cyclone with a 10 % increase in intensity, wind speed increases from 225 to 248 km/h; storm surge goes from 7.1 to 8.6 m with 0.3 m SLR.	Storm surge goes from 7.4 to 9.1 m with 1 m SLR.
Flooding	20% increase in inundation	Increased flooding in Meghna and Ganges floodplain. Monsoonal floods caused increased agricultural yield loss.	Both inundation area and flood intensity will increase tremendously.
Agriculture	Inundation of 0.2 million metric tons of production; <1 % of current total. Agricultural production will be reduced and a number of crop varieties will be affected.	0.3 m SLR inundate 0.5 million metric tons of production, 2% of current total.	Devastating floods may cause crop failure for any year.
Ecosystem	Inundates 15% of the Sundarbans.	Inundates 40% of the Sundarbans.	The Sundarbans would be lost. Loss of the Sundarbans and other coastal wetlands would reduce breeding ground for many estuarine fish, which would reduce their population.
Salinity	Increase	Increase	Increase

Source: Adapted from World Bank, 2000

(2000) estimates a 10 cm, 25 cm resp. 1 m rise in sea level by 2020, 2050 and 2100. This rise would inundate 2%, 4% and 17.5% of the total land mass of the country (Table 1). Milliman et al. (1989; cited in Frihy, 2003) reported a sea level rise in Bangladesh of 1.0 cm per year.

Subsidence also contributes to sea level rise in Bangladesh. The Ganges and the Brahmaputra deliver approximately 1.6 billion tons of sediment annually to the face of Bangladesh (Broadus, 1993). These sediments compensate for the natural compaction and subsidence of the delta and keep its size relatively stable. Sediment replenishment is considered to balance the subsidence of the delta that results in a net sea level rise (Agrawala et al., 2003, p. 15). A study by the SAARC Meteorology Research Centre (cited in Alam, 2003) found that tidal level in Hiron Point, Char Changa and Cox's Bazar rose by 4.0 mm/year, 6.0 mm/year and 7.8 mm/year respectively, based on the tidal gauge record of the period 1977-1998 (Table 2). The rate of the tidal trend on the eastern coast is almost double that of the western coast. This difference could be due to subsidence and uplifting of land. However, Singh (2002) maintains that the difference is mainly due to land subsidence.

TABLE 2: Increase of tidal level in three coastal stations of Bangladesh coast

Tidal Station	Region	Latitude (N)	Longitude (E)	Datum (m)	Trend (mm/year)
Hiron Point	Western	$21^0$48'	$89^0$28'	3.784	4.0
Char Changa	Central	$22^0$08'	$91^0$06'	4.996	6.0
Cox's Bazar	Eastern	$21^0$26'	$91^0$59'	4.836	7.8

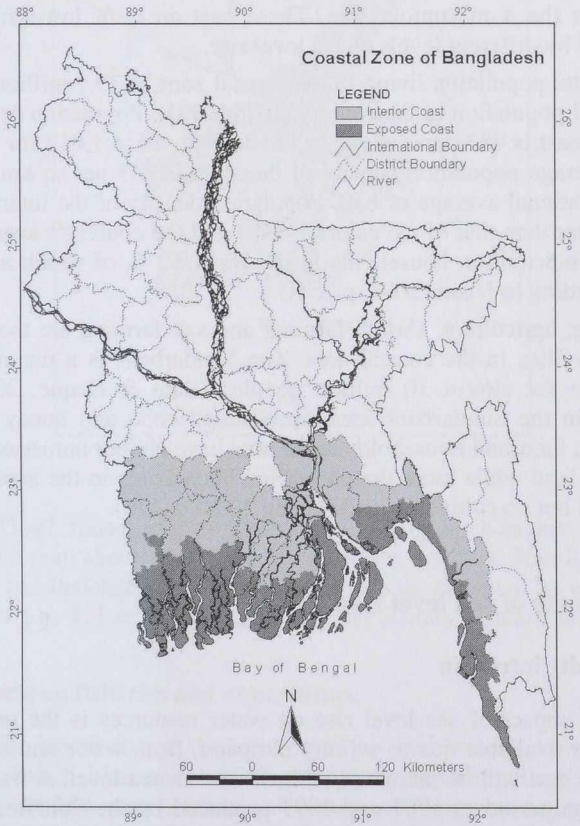
Source: Adapted from Alam, 2003, p. 9

Besides ice melting and thermal expansion, area specific land subsidence and uplifting is a contributory factor to the sea level rise in Bangladesh. To measure the exact rise in sea level on the coast of the country, sediment supply in the delta and rate of subsidence and uplifting should be studied scientifically and elaborately.

2.2 The coastal zone of Bangladesh

Bangladesh, a flood plain delta, is a land of rivers and canals. The country slopes gently from north to south, comprising about 710 km coastline. According to the Coastal Zone Policy (CZPo, 2005) of the Government of Bangladesh, 19 districts out of 64 are in the coastal zone covering a total of 147 upazillas[1] (Figure 1). Out of these 19 districts, 12 districts are contiguous with the sea or lower estuary directly.

FIGURE 1: Coastal zone of Bangladesh



[1] Upazilla is the smallest administrative unit of Bangladesh.

The coastal zone covers 47,201 sq km land area, which is 32 % of the total landmass of the country (Islam, 2004, p. xvii). Water area covers 370.4 km from the coastline (UNCLOS, 1982, Article 57), estuaries and the internal river water. The Exclusive Economic Zone (EEZ) is also treated as a coastal zone of its own.

The southern part of Bangladesh falls under the coastal zone that receives the discharge of numerous rivers, including the Ganges-Brahmaputra-Meghna (GBM) river systems, one of the most productive ecosystems of the world. Except Chittagong and Cox's Bazar, all parts of the coastal zone are plain land with extensive river networks and accreted land. Figure 2 shows the contours of the country, indicating that almost one third of the landmass lies within the 4 m contour line. These vast areas of low-lying land are threatened by different levels of sea level rise.

The total population living in the coastal zone is 35.1 million, i.e. 28 % of the total population of the country (BBS, 2003). Population density in the exposed coast is 482 persons per sq km as opposed to 1,012 for the interior coast. Average population density of the zone is 743 per sq km, compared with the national average of 839. Population density of the interior coast is much higher than that of the exterior coast and the country's average. There are about 6.8 million households in the zone, 52 % of which are absolute poor according to Islam (2004, p. xvii).

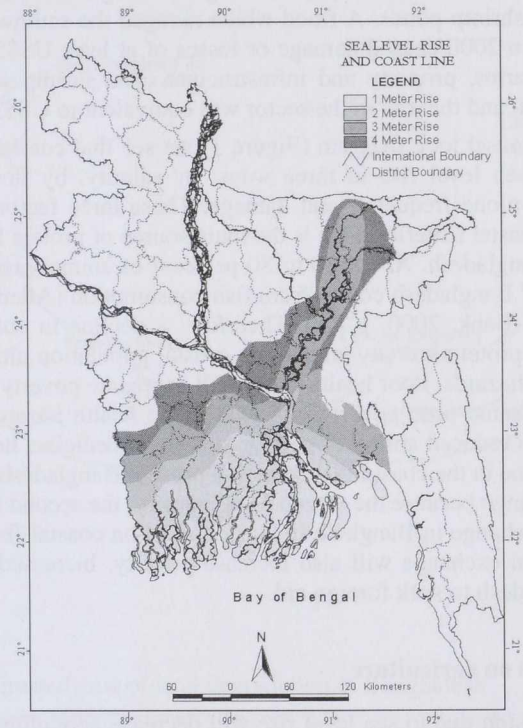
Fishing, agriculture, shrimp farming and salt farming are the main economic activities in the coastal area. The Sundarbans is a major source of subsistence for almost 10 million people (Islam & Haque, 2004). Main activities in the Sundarbans area are fishing, wood and honey collection. Almost ten thousand households in the area have neither homestead land nor cultivable land while more than a million households in the area have only homestead but no cultivable land (Islam, 2004, p. 136).

3. Impacts of sea level rise

3.1 Salinity intrusion

The main impact of sea level rise on water resources is the reduction of fresh water available due to salinity intrusion. Both water and soil salinity along the coast will be increased with the rise in sea level. A water salinity map for the period of 1967 and 1997 produced by the Soil Resources Development Institute (SRDI, 1998a) shows that the problem already exists. A comparative study of the Soil Salinity map of SRDI (1998b, 1998c) for the

FIGURE 2: Contours of Bangladesh and sea level rise



period 1973–97 shows salinity intrusion in soil is much higher than water salinity. The map shows that the soil of Jessore, Magura, Narail, Faridpur, Gopalgonj and Jhalokati had become salinized in the course of 24 years. A sea level rise of 1 m will extend the soil and water salinity area at a faster rate.

3.2 Impacts on fisheries and aquaculture

Sea level rise would change the location of the river estuary, causing a great change in fish habitat and breeding grounds. Penaid prawns breed and develop in brackish water, where salt water and fresh water mix. Sea level rise would make this interface recede changing the habitat of prawns. There are 60 shrimp hatcheries and 124 shrimp processing plants in the coastal zone (Haque, 2003). While sea level rise is helping shrimp farming by

introducing salinity in the coastal area, it is also harmful. Another conesquence of sea level rise, namely flooding, is doing harm to the sector by overflowing shrimp ponds. A flood which ravaged the southwestern part of Bangladesh in 2000 caused damage or losses of at least US$500 million to crops, fish farms, property and infrastructure. The shrimp sector was the most affected, and the loss in the sector was equivalent to US$230 million.

In the causal loop diagram (Figure 3) we see that coastal fisheries are affected by sea level rise in three ways; by salinity, by flooding and by increasing cyclone frequency and damage. These three factors collectively reduce the coastal fisheries. Fish is the main source of protein for the coastal people of Bangladesh. About 60 to 80 per cent of animal protein intake of the people of Bangladesh comes from fish consumption (Alam & Thomson, 2001; World Bank, 2000, p. 61). Therefore, a decline in coastal fisheries would cause protein scarcity among the coastal population ultimately pending to health hazards. Poor health status will aggregate poverty in the coastal area. At the same time poverty will exacerbate health hazards because of poor people's reduced ability to pay for sufficient medicine, health care and food. A decline in the coastal fisheries will prevent Bangladesh from earning foreign exchange because the frozen food industry, the second largest source of foreign exchange in Bangladesh, is dependent on coastal fisheries. Insufficient foreign exchange will also increase poverty. Increased poverty will cause Bangladesh to seek foreign aid.

3.3 Impacts on agriculture

Salinity intrusion due to sea level rise will decrease agricultural production through the unavailability of fresh water and soil degradation. A World Bank (2000) study concluded that increased salinity from a 0.3 m sea level rise will alone reduce the net production of rice by 0.5 million metric tons. Another study by the Bangladesh Agriculture Research Council (BARC) estimated that land degradation due to salinity itself causes a net loss of 4.42 million ton of wheat per year, which is equivalent to US$ 587 million (Table 3).

Sea level rise affects coastal agriculture, especially rice production in two ways. Salinity intrusion degrades soil quality which in turn reduces rice production. When the rice fields are converted into shrimp ponds, total rice production decreases accordingly. In the fiscal year (FY) 1997–98, the area of rice production decreased by one per cent compared to the FY 1993–94, while the total rice production declined by 26 per cent during the same period (Islam, 2004, p. 190).

FIGURE 3: Causal Loop Diagram (CLD) of sea level rise impacts on coastal fisheries sector

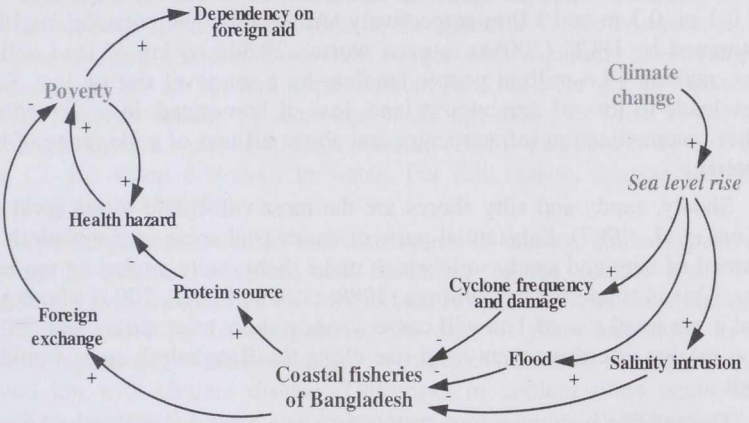


TABLE 3: Estimated cost of land degradation in Bangladesh

Nature of Land Degradation	Physical Quantity of Loss Output	Amount (m tons/yr.)	Cost (m US $/yr.)
Water Erosion	Cereal Production Loss	1.06	140.72
	Nutrient Loss	1.44	544.18
Fertility Decline	Cereal Production Loss	4.27	566.84
	Additional Agricultural Inputs	1.22	461.04
Salinity	Production Loss of Wheat	4.42	586.75
Acidification	Production Loss	0.09	11.95
Total		12.50	2311.48

Source: Adapted from BARC, 1999

3.4 Impacts on landmass and settlement

About 2,500, 8,000 and 14,000 sq km of land (corresponding to 2%, 5% and 10% of the country's total land area) will be lost due to a sea level rise of 0.1 m, 0.3 m and 1.0 m respectively (Ali, 2000). The potential land loss estimated by IPCC (2001a) is even worse—29,846 sq km of land will be lost, making 14.8 million people landless by a sea level rise of 1 m. Land loss leads to loss of agricultural land, loss of homestead, loss of road and other communication infrastructure and above all loss of wide range of biodiversity.

Shoaly, sandy and silty shores are the most vulnerable to sea level rise (Kont et al., 1997). Substantial parts of the coastal areas of Bangladesh are formed of silty and sandy soils which make them easily eroded by sea level rise. This is supported by Vellinga (1988; cited in SDNP, 2004) who argues that a sea level rise of 1 m will cause a sandy shore to erode by 100-500 m. The erosion rate due to sea level rise along the Bangladesh coast would be high.

The net-like mangrove root-system acts as a coastal stabilizer and binder (Hossain, 2001) that protects soil erosion in the coastal area. Salinity intrusion will harm the mangrove forest of the area, which will in turn alter the soil composition. Thus, sea level rise will accelerate soil erosion in the coastal area by reducing the mangrove forest.

3.5 Impacts on salt industry

About 19,670 ha area is used for salt production along the Cox's Bazar coast of the country. There are 216 salt pans, comprising some 8,153 ha in Chakaria and Cox's Bazar Sadar thana of the district and producing 175,030 metric tons of salt annually (Hossain and Lin, 2001, p. 19). This coastal industry is continuously influenced by sea water and its level. The whole process of salt production (i.e. activities in reservoir, condenser and crystallizers) is carried out close to the coastline. Moreover, the salt mills are also located there. A sea level rise of 1 m will inundate all the salt fields and ruin the sector. Salt farmers cannot move land upwards because physical properties of the soil of the present salt field will not move backwards with sea level rise.

3.6 Impacts on health

Sea level rise may increase the risk of health hazards like diarrhoea, cholera, etc. Cholera is an infectious disease of the small intestine of human beings and is common in the coastal area of Bangladesh. *Vibrio cholerae* is the microbe causing cholera. It survives longer with a salinity level ranging from 2.5 ppt[2] to 30 ppt and needs sodium ion (Na^+) for growth (Borroto, 1998). Average salinity of sea water is 35 ppt or 3.5%. Most of the salt present in the sea water is sodium chloride (NaCl) that breaks up into Na^+ and Cl^- ion when dissolved in water. For this reason, coastal area is a breeding ground for cholera.

With the increased density and distribution of salinity, cholera germs are finding favourable conditions and spreading in the coastal area. This hypothesis is also supported by Colwell and Huq (2001) who show that most major epidemics [of cholera] during the last 50 years originated in the coastal region. So, coastal water and its saline environment are closely associated ion with cholera disease. Outbreaks of cholera often occur after flooding, because the water supply becomes contaminated (Eco-health Glossary, 2007). Thus, by increasing flood risk, sea level rise increases the risk of cholera outbreak too.

3.7 Impacts on ecosystem

The Sundarban mangrove forest is the largest in the world, located in the south west of Bangladesh. The area of the Sundarbans varies each year because of soil erosion or land accretion. However, its present area covers 6,500 sq km (FAO, 2003, cited in Islam & Haque, 2004). Sea level rise will cause rise in the salinity concentration in the water and soil of the Sundarbans. Increased salinity will change the habitat pattern of the forest. Sundari, the most typical kind of tree in the Sundarbans is thought to suffer from *top dyeing disease* because of increased salinity (Kausher et al., 1993). Aquatic organisms will migrate inward, because of increased salinity too.

The Sundarbans will be completely lost with 1 m sea level rise (World Bank, 2000, p. 63). Loss of the Sundarbans means great loss of heritage, loss of biodiversity, loss of fish resources, loss of life and livelihood, indeed the loss of a very high productive ecosystem. The area of the Sundarbans inundated according to sea level rise is shown in Table 4.

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[2] PPT = Parts per thousand

TABLE 4: Fate of the Sundarbans with different sea level rise

Sea level rise	Potential impacts
10 cm	• will inundate 15% of the Sundarbans
25 cm	• will inundate 40% of the Sundarbans
45 cm	• will inundate 75% of the Sundarbans
60 cm	• will inundate the whole Sundarbans
1 metre	• will destroy the whole Sundarbans
	✓ Less valuable Goran and Gewa trees would replace species like Sundari, the main economic species in the Sundarbans.
	✓ Loss of the Sundarbans and other coastal wetlands would reduce breeding ground for many estuarine fish, which could reduce their population.

Source: Adapted from World Bank, 2000

Considering the high biodiversity value of the coastal zone, a number of important ecosystems have been declared protected areas. These include reserved forest, two national parks, one eco-park, five wildlife sanctuaries, one game reserve, one Ramsar site, three ecologically critical areas, two world heritage sites, one marine reserve and one fish sanctuary. Because of applying multiple designations to protected areas in a number of ecosystems, some sites are known under different categories of protection. With the exception of Himchari national park, Sitakunda eco-park, Chunati wildlife sanctuaries and Teknaf game reserve, all protected areas in the coastal zone will be inundated by a 1 m sea level rise.

3.8 Impacts on security

Anything that hurt human beings, directly or indirectly, is a security threat. Dalby (2002) explains that 'ecosystem people' are locally based populations who use their own labour to survive by cultivating and harvesting food and other resources from specific localities. Many of these people have been displaced from their homes in recent decades becoming 'ecological refugees'. Sea level rise will create such environmental refugees in the country, forming 'ecological marginalization' (Homer-Dixon, 1998). Barnett (2003) points out that 5.5 million people living on the Ganges delta in Bangladesh who will be forced to relocate with a 45 cm rise in sea level may seek to

move further inland, but a significant number may seek to move to neighbouring India. Previous migration of this kind has been a factor in violence in the region (Swain, 1996). Robert Kaplan (1994, cited in Elliott, 2004, p. 203) highlighted that different environmental problems including sea level rise will prompt mass migration, and in turn, provoke group conflicts. There is a long-term conflict between Bangladesh and India regarding the distribution of water of the Ganges river (Nishat & Faisal, 2000; Ronnfeldt, 1997; Swart, 1996; Swain, 1993), refugees and other issues. Sea level rise induced environmental refugees may well aggregate the conflict.

4. Response to sea level rise

The above discussion reveals that Bangladesh has to face the crucial effects of sea level rise. However, no country can overcome this problem overnight. Global communities are endeavouring to minimize the impacts of climate change and one of its ultimate results, the sea level rise.

The strategies to minimize the impacts can be identified under two broad categories, mitigation and adaptation, distinguished by Smit et al. (1999) as follows:

> Mitigation is a response to the broad issue of climate change and involves reducing or stabilizing greenhouse gas emissions or levels, in order to mitigate changes in climate. ... adaptation refers to adjustments in ecological-social-economic systems in response to actual or expected climatic stimuli, their effects or impacts.

In this context, Bangladesh needs to consider both mitigation and adaptation options, even though the country has very limited scope and capacity for mitigation, because mitigation involves global efforts to execute GHG emission reduction programmes whereas adaptation is more local. So, effective adaptation policies and programmes as well as appropriate mitigation strategies should be developed and implemented to minimize sea level rise impacts on Bangladesh.

4.1 Adaptation

Adaptation seeks to reduce the adverse effects of sea level rise on living organisms, including humans and the environment. The ability to adapt and cope is a function of wealth/income, technology, scientific and technical knowledge and skills, information, infrastructure, policy and management institutions and equity (Chatterjee & Huq, 2002). Sea level rise adaptation

can be addressed by changes in policies that lessen pressure on resources, improve management of environmental risks, and enhance adaptive capacity. However, changing policy issues are beyond the scope of this study. As most of the people of coastal areas are engaged in fishing and agriculture, the adaptation efforts should address these two sectors.

As shown in the Causal Loop Diagram (Figure 3), there are different options for coastal fisheries. Five loops may reinforce the increase of fish production. Foreign exchange earned by coastal fisheries could be invested for the development of the sector, and be used for disaster-preparedness, special weather forecasting and research.

Coastal communities should be prepared for disasters. A disaster calendar that considers disaster-intense times, disaster-prone zones and salinity will help the fisher community to have a safe production and safe harvest. A participatory community fund is another option that will enhance the fishermen's capacities.

Efficient research can find out salinity-tolerant species for the coastal fisheries sector. After selecting different species for different zones or saline environments, the fishermen should be trained in the breeding, cultivation and harvesting of the species. Research will also suggest new or advanced technology for the sector. For example, cage cultivation, which is not practised in Bangladesh, could be introduced in coastal areas of weak current flow. By cultivating salinity-tolerant species and by practising advanced fishing techniques, coastal communities can adapt to sea level rise, which is shown in the reinforcing loop R and R0 of the Causal Loop Diagram (Figure 3).

Again, money invested in fishing sector could be used for mangrove afforestation. Mangroves provide a breeding ground for shrimps, increasing the number of natural shrimp larvae (Islam & Haque, 2004; Hossain, 2001). The mortality rate of natural shrimp larvae is low. Shrimp cultivation will increase production. Increased production will increase shrimp export leading to an increase in foreign exchange earnings of the sector. The reinforcing loop is shown in R1 of the Causal Loop Diagram.

The area of Bangladesh coast that will be inundated by sea level rise should be prepared for an alternative mode of cultivation. Initiatives should be taken to reduce dependency on *Penaeus monodon* and monoculture could be replaced by polyculture. Brzeski and Newkirk (1997) reported that in Taiwan combined harvest in the polyculture pond with tiger shrimp, milkfish and mullet was higher than that of the highest producing monoculture shrimp pond. The harvest was 1.5 t/ha of shrimp and 13.75 t/ha of fish for polyculture and 10.5 t/ha of shrimp for the best monoculture pond. Indian tiger shrimp, milk fish and mullet are common species in the coastal area of

Bangladesh. The two last-named fish are also popular among the coastal people and have good commercial value. Polyculture of these species will bring good returns in terms of currency.

Adaptation should be introduced in agriculture, including crop changes and resource substitutions (IPCC, 2001a). Salinity tolerant species could be introduced in agriculture, fisheries and in the coastal forestry. By a participatory approach to coastal resource planning, inventory and zoning (Hossain and Lin, 2001), the long-term impacts of sea level rise can be estimated.

Coastal water should be monitored to detect the presence of cholera germs. If cholera germs are found in any area, necessary steps should be taken to stop the outbreak of cholera. Oral saline, which is essential for the treatment of dehydration, should be easily accessible in the coastal area and free saline should be distributed in the event of a cholera outbreak in the coastal zone. Alternative sources of fresh water should be increased as the coastal zone is threatened by water-borne cholera and diarrhoea. Water treatment facilities should be established in the area.

Adaptation to the change in the ecosystem is no easy task. As the Sundarbans are predicted to be affected most by sea level rise, attention in the form of research and development should be paid this ecosystem. Rice is the staple food of the people of Bangladesh. The decrease in rice production by the anticipated sea level rise should be compensated by introducing advanced agricultural technology and by cultivating high yield varieties in other parts of the country. Training in advanced agricultural techniques and in the use of seeds of high yield varieties of rice should be provided to the farmer. Initiatives should be taken to develop salinity tolerant species.

4.2 Mitigation

There is a renowned proverb in medical science that 'Prevention is better than cure'. Emission control is the prevention of climate change and sea level rise. Although Bangladesh emits a negligible volume of greenhouse gases, the country should take necessary steps to reduce its emissions. Control of deforestation and fossil fuel use is essential for the purpose. IPCC (2001a) indicates the main measures to reduce greenhouse gases emission: 1) Demand reduction and/or efficiency improvement, 2) substitution among fossil fuels, 3) switch to nuclear energy, 4) switch to biomass, 5) switch to other renewables, 6) CO_2 scrubbing and removal, and 7) afforestation.

The recently introduced compressed natural gas (CNG) driven vehicles that produce little hydrocarbon, carbon mono- (CO) and dioxide (CO_2) (Miller, 2004) is an exemplary step to minimize greenhouse gases emission

in Bangladesh. The country should adapt the low emission technology to other fields. Introducing biomass (e.g. biogas), using renewable resources (e.g. wind and solar energy) are other options. Bangladesh has a plan to provide all its citizens with electricity by the year 2020. To fulfill this noble vision, the country should seek possible renewable resources. Favourable natural conditions like sufficient sunshine and wind exist already.

However, solar energy is not used appropriately in Bangladesh because of its high initial cost. This should be financed by external sources as a soft loan (<5% interest). All photovoltaic materials and other necessary equipment should be exempted from import tax. Community participation on all types of photovoltaic projects should be ensured to enable community ownership. Attention should be paid to develop photovoltaic technology domestically, and local engineering and manufacturing companies should be encouraged to provide indigenously manufactured equipment of international standard.

Afforestation in the coastal zone has the potential to increase forest cover in the country, which will then act as carbon sink (Binkley et al., 2002). Mangrove plantation in the zone will be a good means of coastal protection against cyclones, storm surges and soil erosion. By protecting the soil from erosion, increased mangrove afforestation will increase the plantation survival rate in the area. Site suitability, provision for the second rotation crop, encroachment and insect infection are major problems for the mangrove plantation in the coastal zone (Iftekhar & Islam, 2004). If these specified problems are solved, the area of mangrove forest will be increased.

5. Recommendations and conclusions

Article 1.2 of the United Nations Covenant on Civil and Political Rights states that 'in no case may a people be deprived of its own means of subsistence'. Sea level rise is a great threat to the 40 million people of Bangladesh, estimated to become environmental refugees, i.e., it is a potential threat to a basic human right of a large section of the population. The Bangladesh government has the responsibility to prevent this danger.

5.1 Role of Bangladesh government in reducing the impact of sea level rise

The Ministry of Water Resources of the Government of Bangladesh formulated a Coastal Zone Policy in 2005 that pays very little attention to sea level rise (CZPo, 2005). Article 'c' of the section 4.8.3 of the policy says:

'efforts shall be made to continuously maintain sea-dykes along the coastline as first line of defense against predicted sea-level rise'. According to article 'd' of the same section, 'an institutional framework for monitoring/detecting sea level rise shall be made and a contingency plan for coping with its impact.' However, the policy does not explain how the dykes will be made. Nor does it discuss the possible environmental impacts of the proposed dykes. Policy wants an institutional framework that will monitor sea level rise and will have contingency plans for coping. But it does not mention how the contingency plan will be made. An integrated policy is, therefore, absolutely necessary.

As regards adaptation, government should take initiatives to improve irrigation efficiency, watershed management, and agricultural productivity and to promote risk management to compensate loss in agriculture. The government should develop and promote the use of hybrids and develop infrastructure for post-harvest management, marketing and agribusiness (IPCC, 2001a). Farmers of the coastal zone should be provided with free agricultural education and the support necessary for adjusting to sea level rise. It is essential to introduce salinity tolerant species in agriculture, forestry and fisheries.

The Bangladesh Rice Research Institute (BRRI) should conduct research to develop salinity-tolerant rice species whereas the Bangladesh Agricultural Research Council (BARC) could do likewise for other agricultural crops. The Department of Agricultural Extension (DAE), Ministry of Agriculture (MoA), should be involved to disseminate new species and their cultivation techniques. The Bangladesh Forest Research Institute (BFRI) could be engaged to identify salinity tolerant species of mangrove.

People affected by sea level rise could be resettled according to the cluster village method with some adjustments. As Bangladesh is the most densely populated country in the world, relocation of coastal people inland is not possible because of land unavailability. So, local level management of sea level rise impacts must get first priority. For the purpose, the coastal zone should be protected where it is environmentally viable. Where protection is not possible, attention should be paid to a better management of the area. The potential of accelerating land accretion in the coastal areas and its stabilization as well as subsequent utilization should also be explored.

Multipurpose cyclone shelters built mainly after the cyclone of 1991, were found useful in subsequent storm surges and cyclones. At present, about 15% of the coastal population benefits from cyclone shelters. To ensure the safety of the remaining 85%, 14,220 cyclone shelters are needed.

With the expected increase of Bangladesh's population, more cyclone shelters will be needed.

There are about 130 polders in the zone that were built to protect agricultural land in the 1960s. In the early decades of the polder construction, agricultural production was good in the areas. However, in a number of cases, the dynamics of the delta development process and its complex characteristics were not properly considered in designing the polder projects. As a result, severe water logging and increased salinity are being experienced in those polders and the natural delta development process is being hampered.

Lessons should be taken from other countries that have been successful in handling the problem. The Netherlands is the pioneer nation in controlling the sea and thus saving the country. Though there are differences between the two countries in terms of environment, technical knowledge and financial resources, Bangladesh can still learn from the country how to deal with SLR.

Finance is an important issue for Bangladesh to adapt with the impact of sea level rise. To increase domestic financial resources, government should raise funds from the coastal zone. Coastal fisheries, coastal agriculture, salt industries, wood collectors, honey collectors and coastal tour operators are completely dependent on the zone. These business groups should play an important role in the adaptation to sea level rise as they themselves are greatly threatened by its impact. They should pay a disaster preparedness tax that will be used to adapt with the impacts. Frozen food is the second largest foreign exchange earning sector of Bangladesh. Shrimp hatcheries, shrimp ponds and shrimp processing plants are located in the coastal zone. The shrimp industry should pay an added tax to be invested in the adaptation process.

As Bangladesh is a salt producing country, salt is very cheap, roughly US$ 0.08 per kg. The price of the salt should be raised a little and money earned by this economic instrument should be used for the adaptation of sea level rise. However, salt is an essential human commodity easily influencing public opinion. For this reason, political leaders do not want to increase the price of salt. But what will happen if salt production decreases day by day? Bangladesh will have to import salt if production cannot meet the demand which will cause a sharp rise of prices. So, to save the salt industry from the impact of sea level rise, a moderate raise in the price of salt should be accepted on moral grounds.

Sectors discussed are the most vulnerable to sea level rise impacts and they should welcome the economic instrument proposed for raising money

to enhance the adaptation capacity of Bangladesh. If Bangladesh fails to implement the adaptation measures carefully, people working in these sectors will lose their means of subsistence within a period of 100 years and thus endanger the livelihood of future generations.

5.2 Role of the international community

The 1997 Kyoto Protocol strengthened the UN Framework Convention on Climate Change (UNFCCC). In accordance with Article 3 of the Protocol, countries listed under Annex B must reduce their collective emissions of six key greenhouses gases by at least 5% compared with 1990 levels throughout the 2008-2012 period. To fulfill this requirement, the EU, Switzerland, most states of Central and Eastern Europe should decrease their emissions by 8%, the USA by 7%, Canada, Hungary, Japan and Poland by 6%. Although the USA subsequently rejected the protocol, 178 countries eventually reached a binding agreement for its implementation in Bonn in July 2001 (Carter, 2001).

Failure to reach the emission target will increase the possibility of additional global warming that will aggravate sea level rise. All countries should comply with the provisions mentioned in the Kyoto protocol. The UN agencies and other International Development Agencies should extend their cooperation to help Bangladesh address the SLR issues. All multilateral and bilateral development agencies present in Bangladesh should integrate the issues of SLR as well as climate change in their country assistance development framework.

5.3 Conclusion

It is not wise to think that the sea level will not rise, or to wait and see what will happen in the future. Instead, development and implementation of adaptation policies and appropriate mitigation strategies must be identified to respond to the issue of sea level rise. Research is needed to find practical solutions to the potential problems and to develop salinity-tolerant species for agriculture and fisheries sectors. A plan for the construction of cyclone shelter centres and necessary steps to resettle the people potentially affected by a disaster should be initiated. The coastal protection must include adequate drainage facilities. Adaptation costs should be recovered from coastal resources by using economic instruments.

Research is also required to ascertain how to save the country's wide range of biodiversity threatened by the sea level rise. Also, Clean Develop-

ment Mechanism should be widely adopted. Technical and financial support from the international community is necessary to combat the impact of sea level rise in Bangladesh. Bangladesh alone is not able to face such a large-scale problem. A global initiative to reduce the greenhouse gases emission is a basic requirement.

6. References

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Acknowledgement

Thanks to one anonymous referee and Dr. Michael Mann of Historisches Institut, FernUniversität in Hagen, Germany for their editorial support. Special thanks to Mr. Amanullah Bin Mahmood, GIS Specialist, Centre for Natural Resources Studies (CNRS), Dhaka, for providing Figure 2 and 3.