Impacts of Sea Level Rise on the Coastal Zone of Bangladesh

Masters thesis of

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ABSTRACT

Impacts of sea level rise on Bangladesh were assessed using secondary sources. The study revealed that a one meter sea level rise will affect the vast coastal area and flood plain zone of Bangladesh. Both livelihood options of coastal communities and the natural environment of the coastal zone will be affected by the anticipated sea level rise. It will also affect national and food security of the country. The Sundarbans, the most important ecosystem of the country will be totally lost with one metre rise in sea level. Mitigation and adaptation are two options to minimize the impacts. A combined effort of Bangladesh Government, Bangladesh's people and International communities is emerge need to survive.

Key words: *Sea level rise, Bangladesh, coastal zone, impacts, adaptation*

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1. Introduction

1.1 Introduction

Climate change is an important issue nowadays. Various human activities are making the world hot to hotter. The ultimate result is global warming, i.e. climate change. Rising temperature in the atmosphere causes sea level rise and affects low lying coastal areas and deltas of the world. In 1990, Intergovernmental Panel on Climate Change estimates that with a business-as-usual scenario of greenhouse gas emission, the world would be 3.3^0C warmer by the end of the next century, with a range of uncertainty of 2.2 to 4.9^0C (Warrick et al., 1993). With rise in temperature, sea level will rise because of thermal expansion and ice melt.

Sea level rise has various impacts on Bangladesh, a coastal country facing 710 km long coast to the Bay of Bengal. It already has affected Bangladesh by land erosion, salinity intrusion and loss in biodiversity. Its potential threats are coming even strongly in the future. Sea level rise will cause river bank erosion, salinity intrusion, flood, damage to infrastructures, crop failure, fisheries destruction, loss of biodiversity, etc. along this coast. A one-meter sea level rise (SLR) will affect the country's vast coastal area and flood plain zone. It will affect Millennium Development goals, causing environmental refugees. Most vulnerable sectors to one metre sea level rise are coastal resources, water resources, agriculture and the ecosystem of Bangladesh.

Adaptation and mitigation are two options for Bangladesh. Of which the first one is country specific, or even local specific, but mitigation demands collective efforts of global communities. Development of adaptation policies for different sectors will help Bangladesh to face the crucial hazards of sea level rise. Lobby in the international communities will be helpful to mitigate CO_2 emissions, which is responsible for global warming and sea level rise. Proper mitigation plan and formulating adaptation policies are emerging need to minimize sea level rise impacts on the country.

This paper reviews the one metre sea level rise impacts on the coastal zone of Bangladesh, on the basis of available secondary sources. The resources includes books, government reports, international reports, scientific journals, maps and news articles that highlighted sea level rise related issues in Bangladesh. Some studies of the same field in other parts of the globe were also considered for the task. The study tries to seek for both qualitative and quantitative impacts and also tries to find out some solutions that would help Bangladesh to adapt to the problems. In the study, emphasis was placed on assessing the impacts rather than measuring rate of sea level rise or its root cause global warming, i.e. climate change debate. The study also does not do any cost analysis that is involved in adaptation and mitigation process.

1.2 Problem identification

This paper addresses the following search collectively

- what is the rate of sea level rise in Bangladesh? Especially, when will the sea level rise up to one metre?
- what are the possible impacts of sea level rise on the coastal agriculture, fisheries, landmass and settlements, salt industries, tourism, health, ecosystem and above all on the national security?

- what should be the response to sea level rise by Bangladesh, locally and globally? Should Bangladesh prepare for the upcoming event?

The study was done on the basis of secondary sources. A field trip would enrich the study by assessing the local people's opinions about the issues and how they think about tackling the different problems of the anticipated sea level rise. This was not done because of financial constraints. Information technology in Bangladesh is still in its infant stage and most of the important data or information was not accessible via web sources.

1.3 Linking to sustainable development

The main concept of sustainable Development is to meet the present needs without compromising the needs of the future generations (WCED, 1987). To ensure the supply of the future's demand, development plan should be developed in such a way that consider the upcoming good, bad or worst scenarios. To reach that *gateway to development,* environmental hazards like sea level rise and its impacts should be face or may be *handled* carefully. Because development trains without considering environmental hazards and natural disasters may run to the other way. For example, cyclone of 29 April 1991 in Bangladesh coast caused a death toll of 138,882 lives and the economic loss of Bangladesh was US$ 1,780 million (Chowdhury, 1998). Integration of natural hazards to the development plan of Bangladesh could have reduced number of death toll and economic loss significantly.

Bangladesh is still carrying that loss by borrowing money from external sources like foreign aid or loans from the World Bank, pushing it back in terms of development. Sea level rise have various significant impacts on economy, environment and security of Bangladesh and if these impacts are not integrated in the development plans, it will fail to attain sustainability. Thus, this study can help sustainable development of Bangladesh by pointing out potential sea level rise impacts and some possible recommendations that could be coordinated with the development activities of the country.

2. The coastal zone of Bangladesh

2.1 Coastal boundary

Bangladesh, a flood plain delta, is a land of rivers and canals. The country is sloping gently from the north to the south, meeting the Bay of Bengal at the southern end. The whole coast runs parallel to the Bay of Bengal, forming 710 km long coastline (CZPo, 2005). 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) of the country. Out of these 19 districts, only 12 districts meet the sea or lower estuary directly.

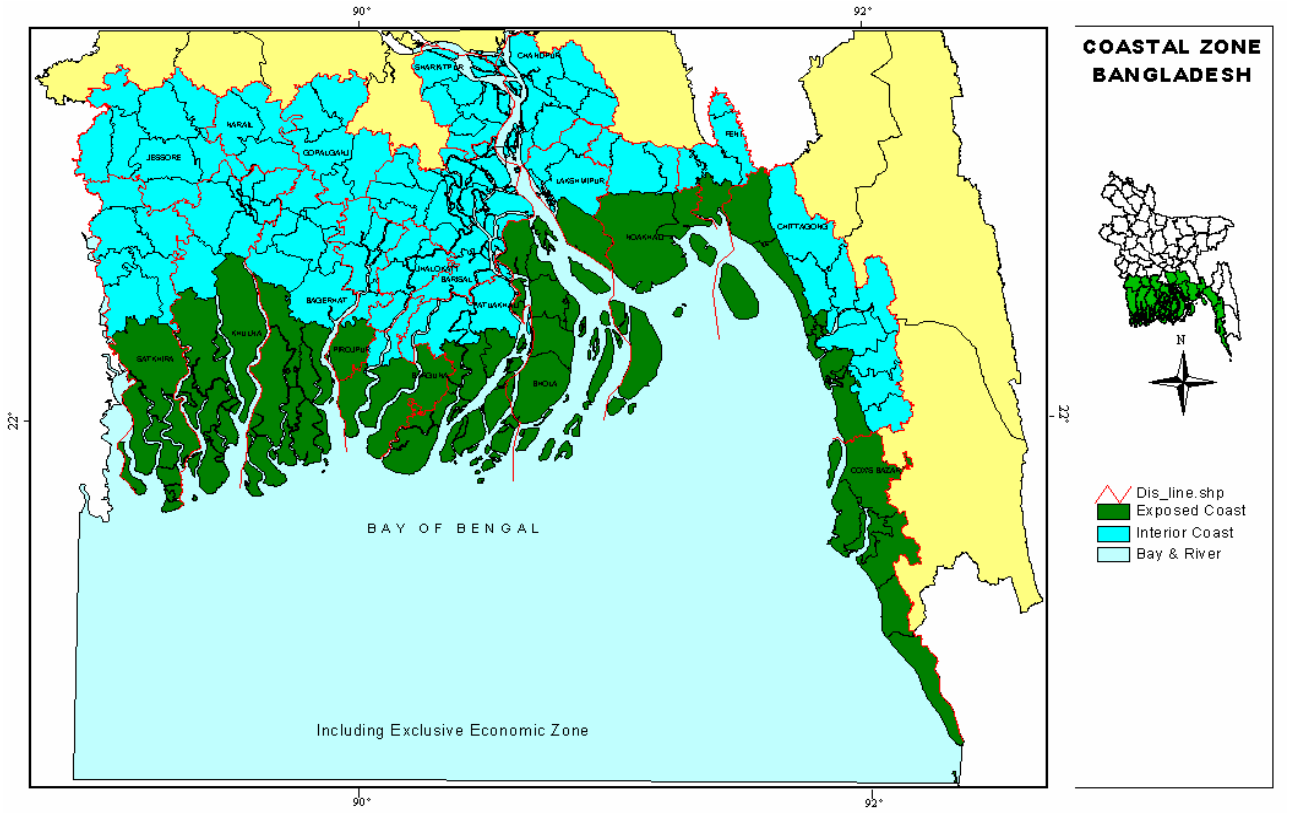


Figure-1: Coastal zone of Bangladesh (Source: Islam, 2004)

The zone is divided into exposed and interior coast according to the position of land. The upazillas that face the coast or river estuary are treated as exposed coastal zone. Total number of upazillas that fall on exposed coastal zone is 48 in 12 districts. A total of 99 upazillas that are located behind the exposed coast are treated as interior coast. The exposed coast embraces the sea directly and is subject to be affected highly by the anticipated sea level rise.

[1] Upazilla is small administrative unit of Bangladesh (sub-district).

The coastal zone covers 47,201 square kilometer land area, which is 32 percent of total landmass of the country (Islam, 2004; p.xvii). Water area covers 370.4 km (200 nautical miles) 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 coastal zone that receives discharge of numerous rivers, including Ganges-Brahmputra-Meghna (GBM) river system, creating one of the most productive ecosystems of the world. Except Chittagong-Cox's Bazar, all parts of the coastal zone are plain land with extensive river networks and accreted land, which is known in Bangladesh as char land. India is at the west of the zone whereas Myanmar is at the east of the coast. Pramanik (1983; cited in Islam, 2001; p.9) has divided the Bangladesh coastal zone into three regions namely eastern, central and western coastal region. However, the shape of the coastal zone is quite unstable and changing time to time due to erosion and accretion.

2.2 Eastern coastal zone

The eastern coastal zone starts from Bodormokam, the southern tip of mainland to the Feni river estuary. This zone is very narrow. A series of small hills are run parallel to this zone. Karnafully, Sangu and Matamuhury river falls into the Bay of Bengal in this area. The Naf river falls to the Bay of Bengal dividing Bangladesh from Myanmar. Soil characteristics of the eastern coastal zone are dominated by submerged sands and mudflats (Islam, 2001; p.9). The submerged sand of the zone has formed a long sandy beach of 145 km from Cox's Bazar towards Teknaf. Two of the country's most important sandy beaches from tourists' perspective, namely Patenga and Cox's Bazar are located in this coastal zone. Fish farming, fishing in the bay, salt production and tourism are main economic activities of the zone.

2.3 Central coastal zone

Central coastal zone extends from Feni river estuary to the eastern corner of the Sundarbans, covering Noakhali, Barisal, Bhola and Patuakhali districts. The zone receives a large volume of discharge from the Ganges-Bhrahmputra-Meghna river system, forming high volume of silty deposition. More than 70% of the sediment load of the region is silt; with an additional 10% sand (Coleman, 1969; cited in Allison et al., 2003). Because of the sediment discharge and strong current, the morphology of the zone is very dynamic and thus erosion and accretion rates in the area are very high. Numerous islands are located in the area including the country's only island district Bhola. Many islands have been formed in last few years in the area by the process of land accretion. At the same time many have been eroded or disappeared (Rahman et al. 1993; Pramanik 1988, Cited in SDNP 2004). Kuakata, an attractive sandy beach is located at the zone under Khepupara upazilla of Patuakhali district

2.4 Western coastal zone

The western coastal zone is covered by the Sundarbans mangrove forest, covering greater Khulna and part of Patuakhali district. Because of presence of mangrove forest, the zone is relatively stable in terms of soil erosion. Mangrove swamps, tidal flats, natural levees and tidal creeks are characteristics of the zone. Mangroves of the area support feeding and breeding grounds for fish and shrimps species, enriching the area in fisheries bio-diversity. The area lies at 0.9 to 2.1 metre

above mean sea level (Iftekhar & Islam, 2004). Soil characteristics of the western coastal zone are silty loams or alluvium. Islam (2003) mentioned that mangrove dominated coastal areas have developed on soil formations of recent origin consisting of alluvium washed down from the Himalayas. The zone also has tourist attraction in the Sundarbans.

2.6 Islands

About 60 islands are identified in the coastal zone to date (Islam, 2004; p.17). Most of the islands are located in the central coastal zone, because of the dynamic river flow of the Ganges-Brahmputra-Meghna river system. Hatia, Sandweep and Maishkhali are three upazilas and Bhola, an administrative district are four bigger islands in the zone. Some islands are limited to only in a small village. St. Martin is the only coral island of the country located in the Bay of Bengal, about 9.8 km (Hossain, 2001) to the southeastern side of mainland. The island has an area of 7.5 km^2 and situated under Teknaf thana of Cox's Bazar district. A total number of 177 char lands are also identified in the coastal zone (Islam, 2004; p.17).

2.7 People and livelihoods

Total population living in the coastal zone is 35.1 million that represent 28 percent of total population of the country (BBS, 2003). Population density in exposed coast is 482 persons per square kilometer whereas the value is 1,012 for the interior coast.

Average population density of the zone is 743 per sq. km., and the same value for Bangladesh average is 839 (Figure-2). Population density in interior coast is much higher than that of exterior coast and the country's average. There are about 6.8 million households in the zone of which 52 percent are absolute poor according to Islam (2004; p.xvii).

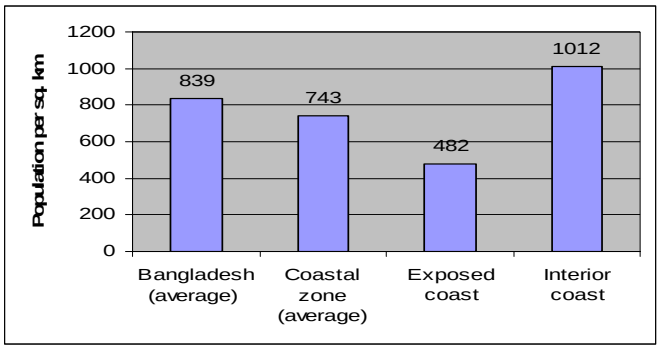


Figure-2: Population density in the coastal zone of Bangladesh

Fishing, agriculture, shrimp farming, salt farming and tourism 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 fisheries, wood collection and honey collection. Almost ten thousand households in the area have neither homestead land nor cultivable land. On the other hand, more than a million households in the area have only homestead but no cultivable land (Islam, 2004; p.136).

Per capita gross domestic product (GDP) for the coastal zone was US$277, a little bit lower than that of national average (US$278), during the fiscal year 1999-2000.

Per capita GDP is higher in Chittagong (US$428) and Khulna (US$352) district. Excluding these two districts, GDP per capita in the coastal zone falls to US$235. The lowest GDP per capita is in Feni district, having a value of US$193 (Figure-3).

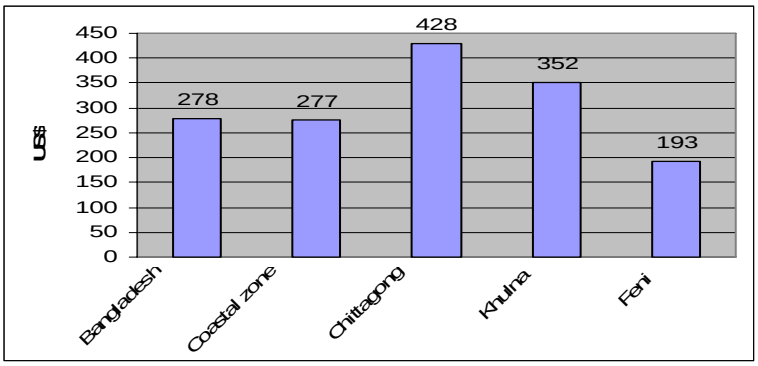


Figure-3: GDP per capita in the coastal zone

Per capita GDP is higher in Chittagong and Khulna district because of industrialization in the area. Sixteen coastal districts' GDP per capita is below the national average because of environmental hazards and natural disasters. Low GDP per capita and high population pressure reinforce each other, preventing people to get out of the poverty.

2.8 Infrastructures

There are 35,712 km of roads in the coastal zone including the rural earthen ways. But some of the remote areas of the zone are still inaccessible by road transport because of the river network. For that reason water ways are the main transportation mode in eastern and central coastal zone. Almost all small and big cities of the areas are connected with the capital Dhaka by waterways. There are also ship-breaking industries in the zone at Fauzderhat, 20 km South-west to Chittagong district, extending 16 km long sea beach (Anderson et al., 2000). The industry is the second largest ship breaking facilities in the world, supporting livelihood to about 100,000 people.

3. Sea level rise

3.1 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 expand the ocean volume in two ways. Firstly, it melts mass volume of ice of the polar region and secondly, it causes thermal expansion of water of the ocean. 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, from a small expansion effect through roughly equal roles for expansion and ice melting to a dominant expansion effect. These two factors increase volume of ocean water of the earth and rise in the sea level.

The human factor that is mainly responsible for global warming and sea level rise is 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 is the result of deforestation, agriculture, and other human 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). Emissions of CO_2 from U.S. coal burning power and industrial plants alone exceeded the combined CO_2 emissions of 146 nations, which contain 75% of the world's people (Miller, 2004). As a small nation, Bangladesh plays an ignorable role for greenhouse gas emission.

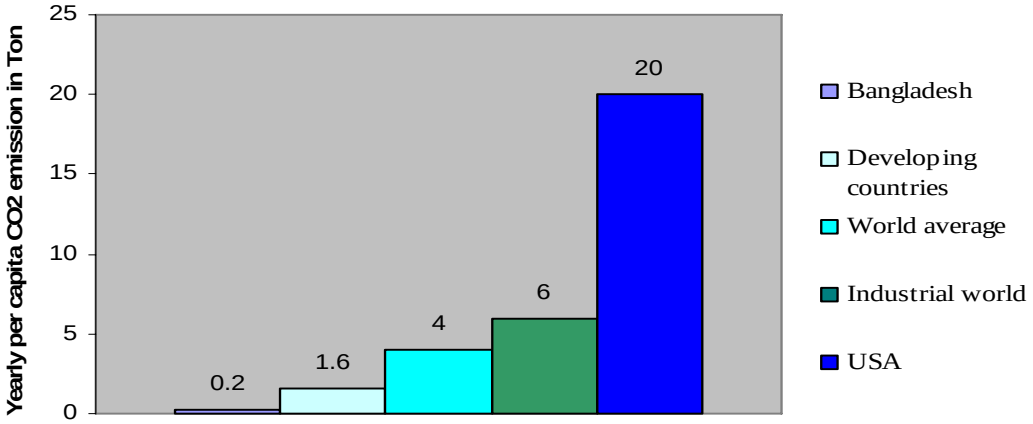


Figure-4: World wide per capita carbon dioxide emission (Data source: NAPA, 2002)

According to National Adaptation Programs of Action (NAPA, 2002) dialogue, per capita CO_2 emission in Bangladesh is 0.2 ton per year. But that figure for developing countries, world average, industrial world and United State of America (USA) is 1.6, 4.0, 6.0 and 20.0 ton respectively (Figure-4). The developing countries, representing nearly three-quarters of the world population, are responsible for less than one-quarter of the fossil-fuel carbon emissions. The OECD countries, with about 15% of the world population, account for around 44% of the total emission. One

country, the USA, is solely responsible for 23% of the total yearly fossil-fuel carbon emission to the atmosphere. In contras, Bangladesh contributes a minuscule 0.06% (Warrick at el., 1993).

Besides, ice melting, thermal expansion and also some local factors like subsidence and siltation play role in the sea level rise process.

3.2 World sea level rise scenario

In 1990, Intergovernmental Panel Climate Change (IPCC) estimated a 3.3˚C rise in the global temperature under business-as-usual conditions by 2100 with a range of uncertainty of 2.2 to 4.9˚C. Such a change in global temperature occurred naturally over past 10,000 years. IPCC's estimation of global sea level rise was 1.0 to 2.0 mm/ year over the last century. With the high increasing rate of global temperature, sea level will rise at a faster rate of 2-6 times than the present rate (Kausher, 1993). Wigley and Raper (1987) estimated that the greenhouse-gas-induced thermal expansion contribution to sea-level rise between 1880 and 1985 was 2-5 cm and for the period 1985-2025 the estimate of greenhouse-gas-induced warming was estimated to 0.6-1.0°C. The resulting concomitant oceanic thermal expansion would raise sea level by 4-8 cm. Nicholls et al. (1999) estimated that by the 2080s, sea-level rise could cause the loss of up to 22% of the world's coastal wetlands. When combined with other losses due to direct human action, up to 70% of the world's coastal wetlands could be lost by the 2080s. IPCC estimated that sea level rise would be 66 cm under business-as-usual conditions by 2100 with a range of uncertainty of 13 to 110 cm (Table-1).

Table-1: Global GW and SLR Scenario

Model Assumption	**GW Scenario by year (^{0}C)**				**SLR Scenario by year (cm)**			
	2010	***2030***	***2050***	***2100***	***2010***	***2030***	***2050***	***2100***
Low	0.3	0.7	1.2	2.2	4	8	15	31
Business-as-usual	0.5	1.1	1.7	3.3	8	18	30	66
High	0.7	1.5	2.5	4.9	13	29	48	110
Source	Bretherton et al., 1990; Cited in Warrick et al., 1993				Warrick and Oerlemans, 1990; Cited in Warrick et al., 1993			

3.3 Sea level rise in Bangladesh

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). World Bank (2000) showed 10 cm, 25cm and 1 m rise in sea level by 2020, 2050 and 2100; affecting 2%, 4% and 17.5% of total land mass respectively (Table-2). Milliman et al. (1989; cited in Frihy, 2003) reported 1.0 cm per year sea level rise in Bangladesh.

Table-2: Sea level rise (SLR) in Bangladesh and its possible impacts

Year	2020	2050	2100
Sea level rise	10cm	25cm	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	-	1991 cyclone happens again 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.	Increase flooding in Meghna and Ganges floodplain. Monsoonal floods increase yield loss.	Both inundation area and flood intensity will increase tremendously.
Agriculture	Inundate 0.2 Mmt. of production; < 1 % of current total.	0.3 m SLR inundate 0.5 Mmt. of production; 2% of current total.	Devastating flood 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

(Adapted from World Bank, 2000)

UNEP (1989) showed 1.5 m sea level rise in Bangladesh coast by 2030 (Figure-5), affecting 22,000 Sq. km (16% of total landmass) area with a population of 17 million (15% of total population) affected. Since this scenario was calculated in 1989, the expected rate of sea level rise has been modified because of uncertainty. At present expected rates, this situation will occur in about 150 years from now. However, number of potential population affected by the projection of World Bank by one metre sea level rise (17.5 million) and that of UNEP by 1.5 metre sea level rise (17 million) is similar.

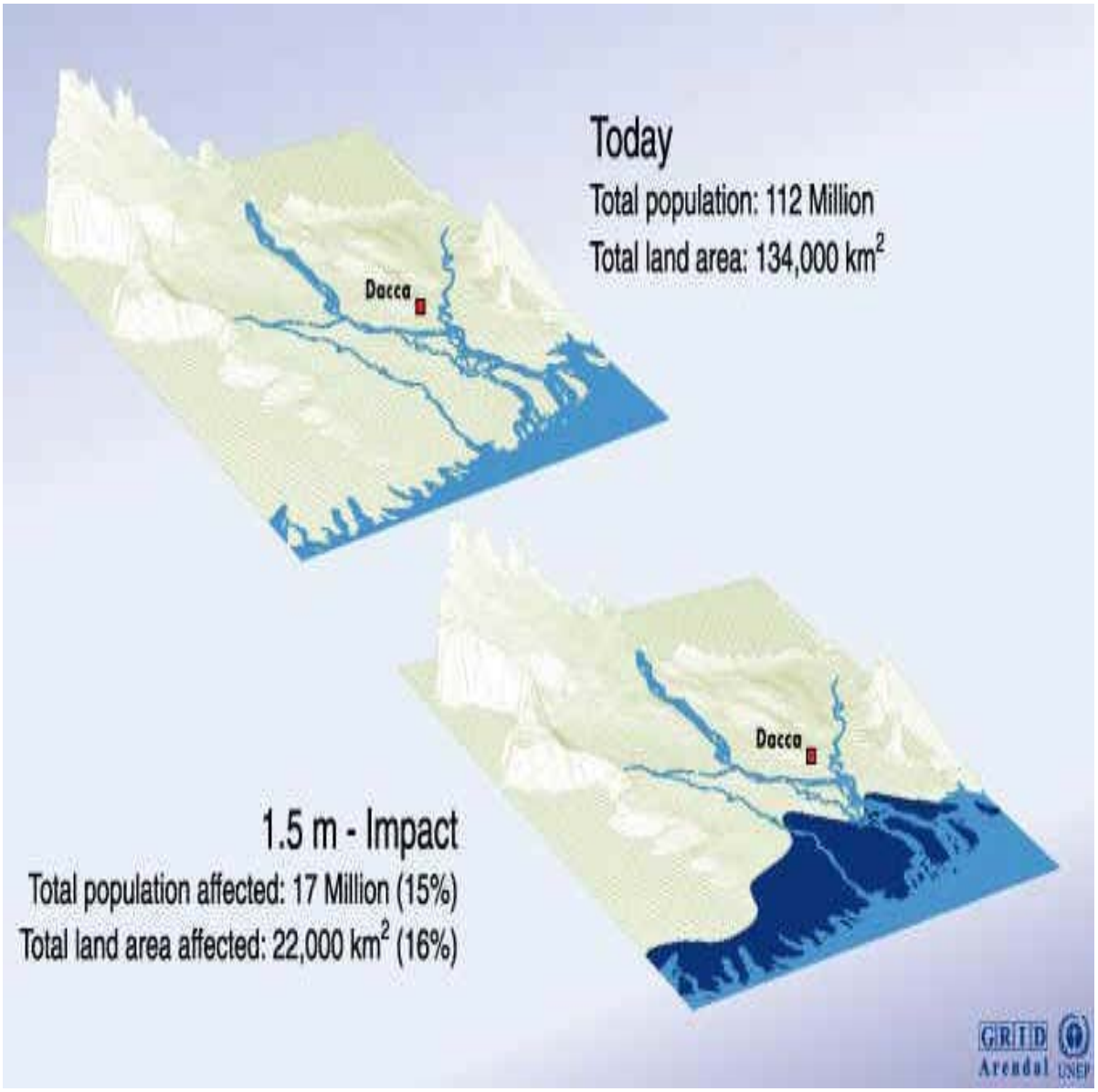


Figure-5: Impacts of 1.5 metre sea level rise on Bangladesh (Source: UNEP, 1989)

Subsidence is also a considerable factors for 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 the natural compaction and subsidence of the delta and keep its size stable, relatively. So, sediment replenishment is considered to balance subsidence of the delta that results a net sea level rise (Agrawala et al., 2003; p.15).

A study by SAARC Meteorology Research Centre (SMRC, cited in Alam, 2003) found that tidal level in Hiron Point, Char Changa and Cox's Bazar raised 4.0 mm/year, 6.0 mm/year and 7.8 mm/year respectively, observing tidal gauge record of the period 1977-1998 (Table-3). The rate of the tidal trend is almost double in the eastern coast than that of the western coast. This difference could be due to subsidence and uplifting of land. However, Sing (2002) mentioned that the difference is mainly due to land subsidence.

Table-3: 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

(Adapted from SMRC; cited in Alam, 2003, p.9)

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

4. Impacts of sea level rise on the coastal zone of Bangladesh

4.1 Salinity intrusion

The main impacts of sea level rise on water resources are fresh water availability reduction by salinity intrusion. Both water and soil salinity along the coast will be increased with the rise in sea level, destroying normal characteristics of coastal soil and water. A water salinity map for the period of 1967 and 1997 (Figure-6) produced by Soil Resources Development Institute (SRDI, 1998a) shows that the problem is already on the way. A comparative study between Soil Salinity map of SRDI (1998b, 1998c) for the period of 1973 and 1997 shows salinity intrusion in soil is much higher than water salinity (Figure-7 and 8). The map shows that soil of Jessore, Magura, Narail, Faridpur, Gopalgonj and Jhalokati was newly salinized in 24 years of time expansion. A one meter sea level rise will expand the soil and water salinity area at a faster rate.

Shrimp farmers of Bangladesh mainly cultivate Indian Tiger Shrimp (*Peneaus monodon)*. Water salinity required for maximum growth of this species is 5-25ppt (Chanratchakool, 2003). It can not be cultivated in fresh water. Salinity intrusion in the freshwater zone of the coastal area has opened the door to shrimp farmers to cultivate tiger shrimp in the area. Vast number of land area is converted to saline water field day by day. Table-4 shows shrimp farm areas in three coastal districts during the year 1975, 1987 and 2004 that indicate salinity intrusion.

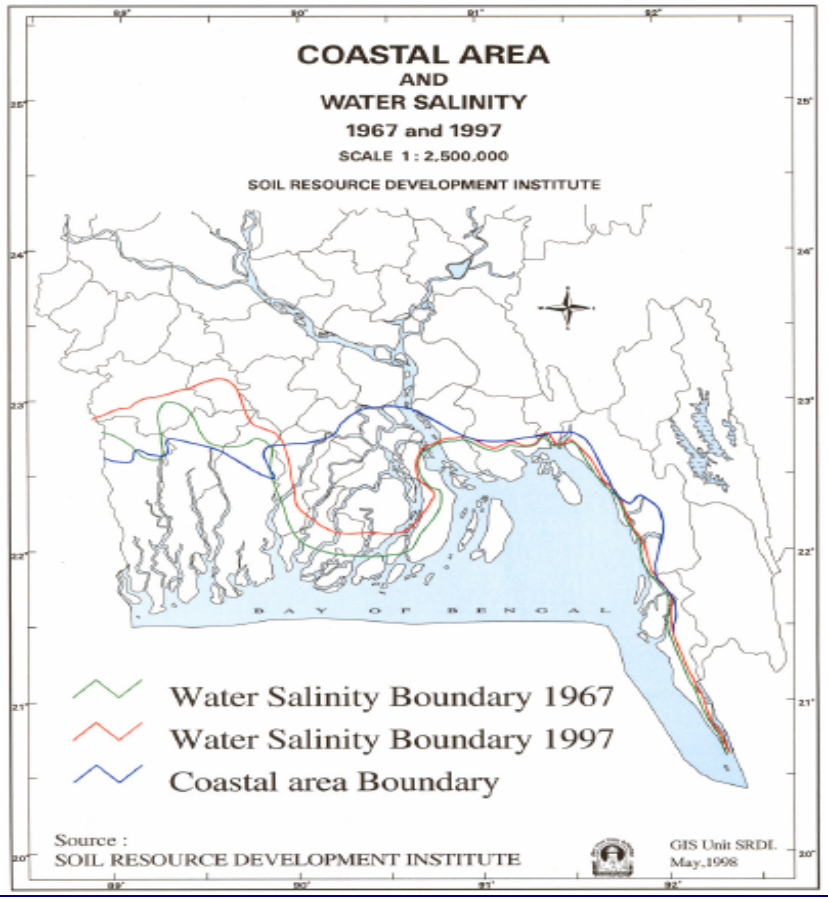


Figure 6: Water salinity map of Bangladesh (Source: SRDI, 1998a)

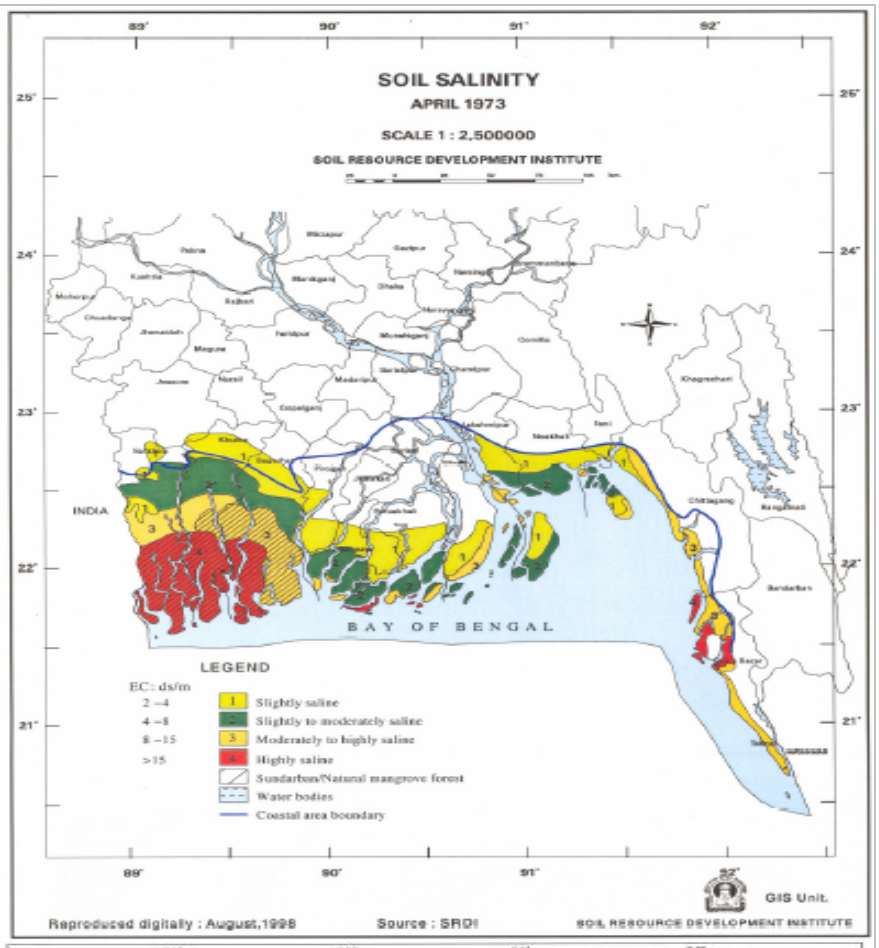


Figure-7:
Soil salinity map of Bangladesh of the year 1973 (Source: SRDI, 1998b)

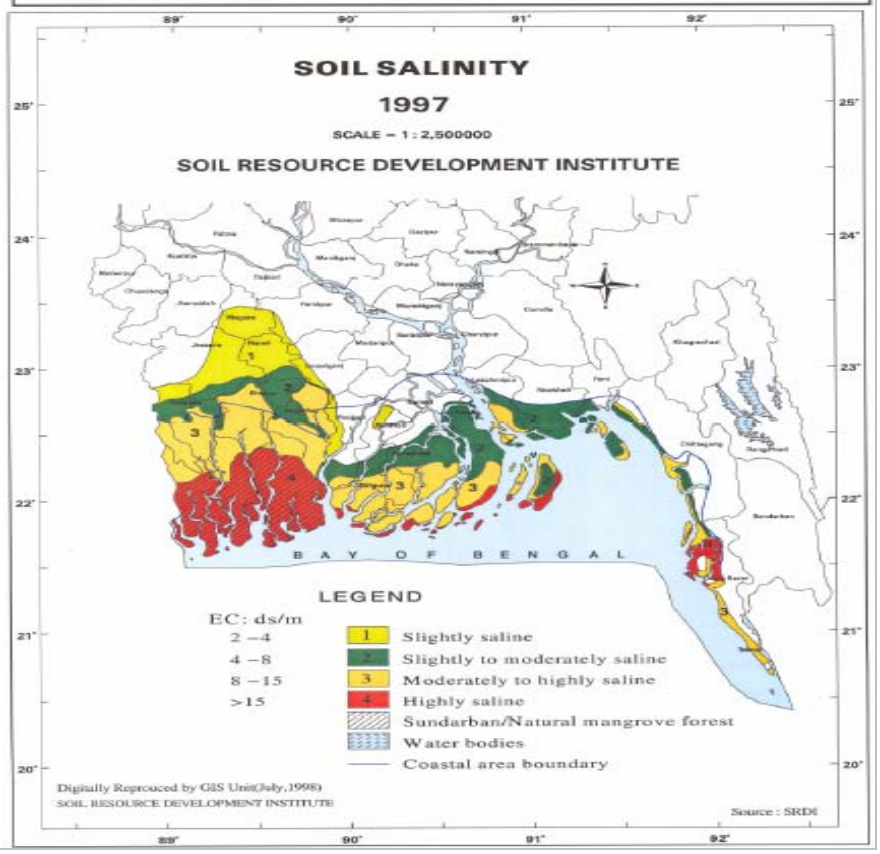


Figure-8:
Soil salinity map of Bangladesh of the year 1997 (Source: SRDI, 1998c)

Shrimp farm areas in the year 2004 were 87 fold more than that of the year 1975. It is another indicator of salinity intrusion in the coastal zone. In last thirty years time period, salinity intrusion has degraded land quality and farmers can't grow any agricultural crops in their fields. Thus farmers become zero productive land owners, in one sense landless with their existing saline land. Salinity intrusion causes loss in agriculture, loss in biodiversity, loss in fresh water and its resources.

Table-4: Shrimp farm area in Satkhira, Khulna and Bagerhat districts (Ittefaq, 2004)

Year	Shrimp farm area (hectare)
1975	1,330
1987	67,650
2004	115,900

4.2 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 ground. Penaid prawns breed and develop in brackish water, where salt water and fresh water mix. Sea level rise would turn this interface backward, changing habitat of prawn. There are 60 shrimp hatcheries and 124 shrimp processing plants in the coastal zone (Haque, 2003). The hatcheries are located at Teknaf, Ukhia and Sadar thana of Cox's Bazar district. Favourable environmental condition and brood stock availability are the main reason to set up hatcheries in the area. Some hatcheries have also started test production in Chittagong and Satkhira coast.

It is to be mentioned that all the above districts are located in the coastal zone (Figure-1). As the zone is vulnerable to sea level rise, shrimp hatcheries and shrimp fields are also vulnerable to the phenomena. However, sea level rise is helping shrimp farming by introducing salinity in the coastal area, but it is also harmful. If we consider another sea level rise phenomena, for instance flooding; it is doing massive harm to the sector by overflowing shrimp pond and let the shrimps to set free in open water. 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 sector, losing shrimp fields of equivalent US$230 million (CNN, 2000). After the flood, representative of Bangladesh Frozen Foods Exporters Association expressed that flood hits the shrimp sectors seriously (Basher, 2000). A shrimp farmer expressed "I have lost up to 400 million taka (US$7.4 million) invested in 40 shrimp projects, maybe I will never be well-off again" (Asaduzzaman, 2000). In addition, high projected magnitude of sea level rise will inundate the present shrimp ponds and will destroy this prospective foreign exchange earning sector of Bangladesh.

There are 21 government fisheries service centres in the coastal zone. These centres facilitate the fishery sector with fuel supplies, landing, whole sale, icing, inland transportation and other activities with an aim to improve the yield of the sector. These service centres are much closed to coastline or estuaries and are potential to be inundated by sea level rise. There are some areas in the coastal zone that are far from city or fisheries service centre and have no icing facilities. Fishermen of such areas dry fishes in open sunlight to avoid spoilage. Locally these dry fishes are known as 'Shutki'. Dry fishes are rich in nutrient value and a popular dish among the coastal people, especially in the southeastern coastal zone. The dry fish industry will also be affected by anticipated sea level rise.

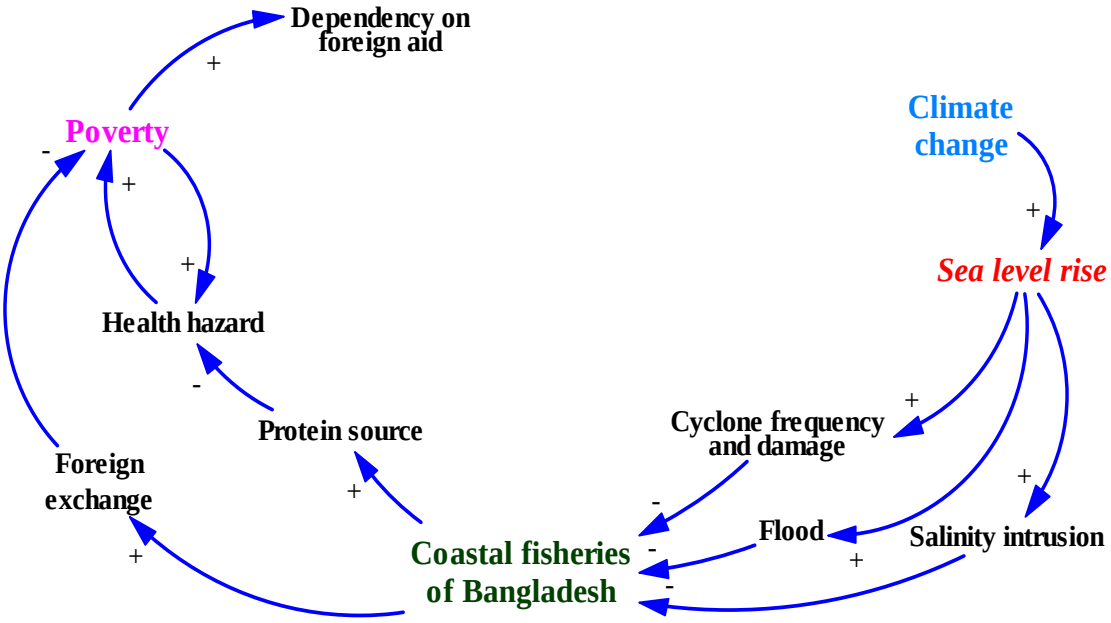


Figure-9: Causal Loop Diagram of sea level rise impacts on coastal fisheries sector

If we search the cause-impact relationships of sea level rise and coastal fisheries of Bangladesh, as described in the following causal loop diagram or CLD (Figure-9; for more about CLD, please see Haraldsson, 2004), 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 decrease the coastal fisheries. Fisheries are the main protein source for the coastal people of Bangladesh. About 60- 80 per cent of animal protein intake of the people of Bangladesh comes from fish consumption (Alam & Thomson, 2001; World Bank 2000, p.61). So, decreased coastal fisheries would cause protein scarcity among the coastal populace that ultimately causes health hazards. Poor health status will gear up poverty in the coastal area. At the same time poverty will boost up health hazards because of lacking sufficient medicine, health care and nutrition. If the coastal fisheries decrease, it will hinder Bangladesh from earning foreign exchange, as because the frozen food industry, the second largest foreign exchange earner sector of Bangladesh, is dependent on coastal fisheries. Insufficient foreign exchange earning will also increase poverty. Increased poverty will cause Bangladesh to seek foreign aid.

4.3 Impacts on agriculture

Salinity intrusion due to sea level rise will decrease agricultural production by unavailability of fresh water and soil degradation. Salinity also decreases the terminative energy and germination rate of some plants (Rashid et al., 2004; Ashraf et al., 2002). Ali (2005) investigated the loss of rice production in a village of Satkhira district and found that rice production in 2003 was 1,151 metric tons less than the year 1985, corresponding to a loss of 69 per cent. Out of the total decreased production, 77 per cent was due to conversion of rice field into shrimp pond and 23 per cent was because of yield loss (Table-5).

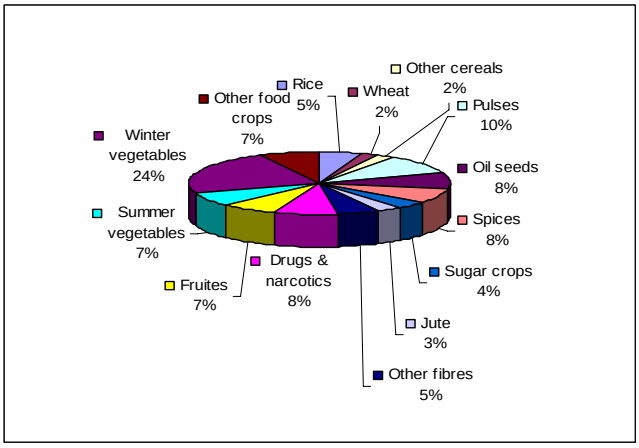
Table-5: Declining rice production because of soil degradation

		Year	1985	1990	1995	2003
Area & months under rice and shrimp farming in ha (% crop land)	HYV Aman July - Nov.		345.5 (100)	344.6 (100)	332.4 (97.0)	314 (91.9)
	HYV Boro Dec. - May		200.4 (58)	269.6 (78.2)	122.4 (32.8)	58.2 (17)
	One shrimp cycle Dec. – Jan.		36.5 (10.6)	75.0 (21.8)	210.0 (67.2)	255.8 (91.0)
	Two shrimp cycle Dec. – Nov.		0	0	20.6 (3.0)	55.0 (8.0)
Expected total rice production			1373	1689	1679	1673
Observed total rice production			1265	1260	745	522
Decline in rice production due to loss of	Area		108	221	670	890
	Yield		-	208	264	261
Total loss of rice production			**108**	**429**	**934**	**1151**

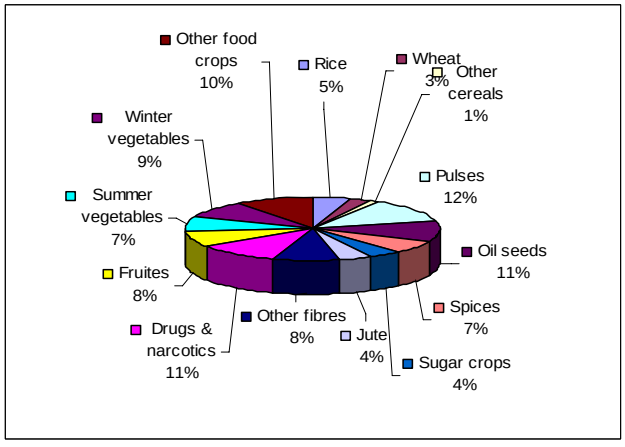
(Adapted from Ali, 2005)

Practicing shrimp cultivation in saline water has a drawback, and that is a decrease in rice production due to degraded soil quality. The decrease rate is very high and the scene is common for almost all rice fields in Khulna, Satkhira and Bagerhat districts.

A World Bank (2000) study suggests that increased salinity alone from a 0.3 metre sea level rise will cause a net reduction of 0.5 million metric tons of rice production. Sea level rise affects coastal agriculture, especially rice production in two ways. Salinity intrusion degrades soil quality that decrease or inhibit rice production. When the rice fields are converted into shrimp ponds, total rice production decreases because of decreased rice field areas. In the fiscal year (FY) 1997-1998, rice production area was decreased by one per cent compared to the FY 1993-1994, whereas the total rice production was decreased by 26 per cent during the same period (Islam, 2004, p.190). Farmers couldn't produce two rice crops[2] during the year, as one vegetation cycle was used for shrimp cultivation instead. For that reason, the decrease in production is seemingly too high compared to the decrease in area.



a). Production area (% of total production area of Bangladesh)



b). Total Production (% of total production of Bangladesh)

Figure-10: Agricultural Production in the Coastal Zone of Bangladesh

[2] In most cases farmers of Bangladesh grow rice two or three times a year, in the same rice field.

Figure-10 represents the crop-wise agricultural production in the coastal zone. It shows that rice production (16%) in the coastal are is lower comparative to production area (24%). The coastal zone is very important for pulses, oil seeds and vegetables production, which will fall gradually similarly to rice, with increase in salinity in the zone. It may be questioned why the coastal zone is still producing high volume of pulses and oil seeds. The answer is because these crops are produced in comparatively inner or landward part of the zone, where salinity is still very low. Sea level rise with adding more salinity to the water and soil of the area will decrease production of the mentioned and other crops.

Rice is the staple food of the people of Bangladesh. It was estimated earlier that farmers of the country have 10,000 rice varieties in their collection (Brammer et al., 1993). These varieties include Aus, Aman, Boro and IRRI group. Most of the varieties are in the Aman group. Sea level rise will increase flood frequency and flooding duration, affecting Aman production. Due to sea level rise, salinity of water and soil will increase, and this will damage Aman cultivable land. Because of the shortage of fresh water, Boro rice production will be decreased. IRRI and wheat production will also be affected by salinity increase. A study by BARC (1999; cited in Islam, 2004) concluded that salinization will cause a reduction of wheat production equivalent to US$ 586.75 million. Miller (2004) stated that high projected rise in sea level of about 88 cm (35 inches) would flood agricultural lowlands and deltas in parts of Bangladesh. Agricultural lands in the coastal area will be affected by salinity; soil quality will be degraded and flooding event will loss the agricultural production of the coastal land of Bangladesh. Thus sea level rise will have an impact on agricultural production, especially on food production, leading Bangladesh to fail, obtaining food security.

As Bangladesh is a dense populated country, there is no specific grazing field for cattle. Farmers get grass from their rice field. Hey is another source of fodder. Decreased rise production is decreasing fodder production resulting in fodder shortage. Ali (2005) noticed that fodder shortage is the cause for a declining livestock population from 630 in 1985 to 168 in 2003 in a small village in Satkhira district.

If we try to find out the big picture of sea level rise impacts on agriculture of Bangladesh, it shows almost similar behaviour as in the case of coastal fisheries (Figure-9). Sea level rise affects agriculture in three ways, i.e. by salinity intrusion, by flooding and by increasing cyclone frequency and its depth of damage. Combined effects of these three factors decrease agriculture production in the coastal zone. Decreased agriculture will cause decreased GDP. If agricultural production is decreased, food and cash crop production will be decreased too. Decreased food production will cause food shortage leading to health hazards or even famine. The ultimate result of reduced agricultural production is high poverty that will force Bangladesh to seek aid from other countries.

4.4 Impacts on landmass and settlement

The SLR will inflict its impacts on Bangladesh in the coastal area and through the coastal area, on the whole of Bangladesh. About 2,500, 8,000 and 14,000 km^2 of land (with a corresponding percentage of 2%, 5% and 10% with respect to the total land area of the country) will be lost due to SLR of 0.1m, 0.3m and 1.0m respectively (Ali, 2000). The potential land loss estimated by IPCC (2001) is even worse. It reports 29,846 sq. km area of land will be lost and 14.8 million people will be landless by 1-m SLR. (Figure-11 & 12) Land loss leads to loss of agricultural land, loss of

homestead, loss of road and other communication infrastructure and above of loss of wide range of biodiversity. One of the major causes of land loss is erosion.

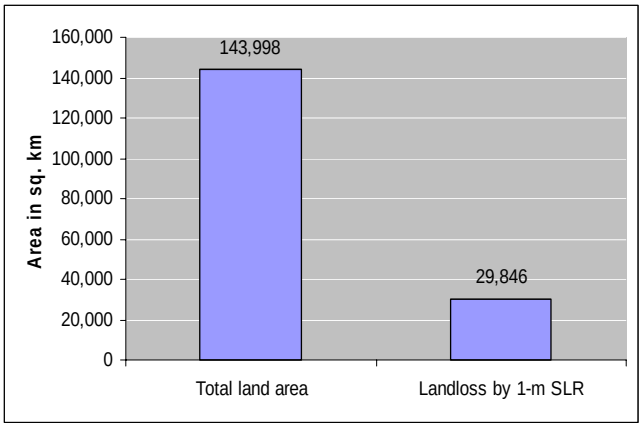


Figure-11: Total area and potential land loss by 1-m SLR (Data source; IPCC, 2001)

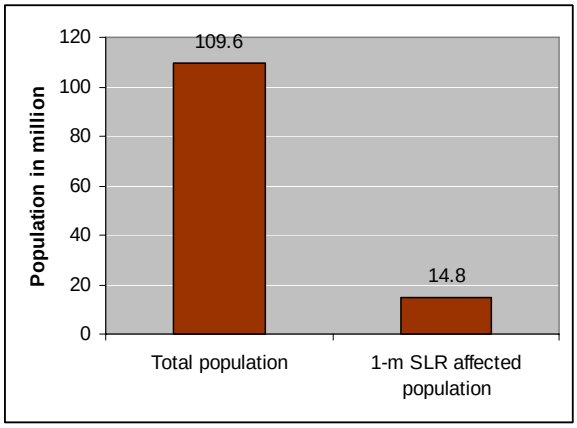


Figure 12: Total population and 1-m SLR affected population. (Data source: IPCC, 2001)

Sea level rise initiates erosion by raising water level. Raised water level wash out the loose top soil of the coast, making the coastal region steeper. Back water effect is accelerated by sea level rise that also cause erosion. Silt or other particles eroded from the surrounding areas are deposited when the lowlands of the coastal areas are filled with water. Sea level rise will play important role in erosion processes in the coastal zone.

Most vulnerable shore types to sea level rise are shoaly, sandy and silty shore (Kont et al., 1997). Coastal areas of Bangladesh are formed of silty and sandy soils which make them vulnerable to sea level rise. Sandy and silty shores are easily eroded by sea level rise. It is supported by Vellinga (1988; cited in SDNP, 2004) stating that sea level rise of 1.0 metre will cause an erosion of a sandy shore in the order of 100-500 metre. Erosion rate due to sea level rise along the Bangladesh coast is high.

The forecasted land erosion will cause displacement of coastal population. Most of the poor people do not own land. In some cases they only have a small piece of land to build a cottage to live in. Once the home is eroded, they become homeless, something like refugees in their own country. When they build a new house, it is eroded after a couple of years. Then they move to a nearby area and set up another house which is also eroded after some years. A study by Hutton and Haque (2003) observed that people even displaced ten times during the period of 1981-1993, because of river bank erosion of the Jamuna river. Thus, erosion will cause financial loss for the displace-people to build their new houses.

Sea level rise will increase morphological activities in the river, inducing increased river flow. Accelerated river flow will increase river bank erosion too (Alam 2003, p.13). Bank erosion is severe in char areas and sometimes it may wipe out chars from the map of Bangladesh. About 196 square kilometers of char area was eroded and a total of 11 chars were disappeared from Meghna river estuary area during the period of 1972-1987 (Pramanik, 1988; Cited in SDNP, 2004). Char area protects inland areas from tidal surge. It also helps accretion process along the main land. If

char areas are eroded, mainland will be affected seriously by tidal surge. When all chars disappear, the mainland will be eroded rapidly reducing land area of Bangladesh year after years.

Net-like spread root system of mangrove acts as coastal stabilizer and binder (Hossain, 2001) that protects soil erosion in the coastal area. Salinity intrusion will harm mangrove forest of the area. Decreased mangrove will result in breaking soil composition. Thus sea level rise will accelerate soil erosion in the coastal area by reducing mangrove forest.

4.5 Impacts on salt industry

Bangladesh is one of the salt producing countries of the world. Cox's Bazar coast of Bangladesh coastline is suitable for salt production. About 19,670 ha area has been used for salt production along the Cox's Bazar coast of the country. There are 216 salt pans, having an area of 8,153 ha only in Chakaria and Cox's Bazar Sadar thana of the district, producing 175,030 metric tons of salt annually (Hossain and Lin, 2001, p.19). This coastal industry is fully influenced by sea water and its level.

To produce salt, sea water is collected from nearby canal or river and stored in the reservoir. After three days brine is transferred into the condenser. Again, after three days dense brine is transferred into the crystallizer. Transferring time (i.e. 3 days) may vary upon the evaporation rate that is influenced by sunshine, wind speed and humidity. Salt crystals are supplied to salt mill owners where washing, crushing, iodine mixing and packaging is done. All the activities of salt production that are handled by salt farmers (i.e. activities in reservoir, condenser and crystallizers) are performed in the close area of the coastline. Moreover, salt mills are also located very close to the coastline. A one metre sea level rise will inundate all the salt fields and will ruin the sectors. Salt farmers can't move upwards land for the purpose because, physical properties of the soil of the present salt field will not move backwards with sea level rise. About 20 million people are directly or indirectly related in salt production (Hossain and Lin, 2001, p.20) and/ or trading in Bangladesh. Sea level rise, by inundating salt fields will force this huge number of people to be unemployed. This large population will try to find alternative profession, which is very hard or even impossible, in the case of present situation of Bangladesh.

4.6 Impacts on tourism

A significant part of Bangladesh coast is sandy beaches that attract tourists. Kuakata beach in Patuakhali district, Patenga beach in Chittagong district and Cox's Bazar beach in Cox's Bazar district are attractive tourist areas of the country. Cox's Bazar sea beach is the world's largest unbroken sandy beach having a length of 145 km (Hossain and Lin, 2001 p.21), attracting the tourists of home and abroad. Out of 18 tourist areas identified by Bangladesh Parjatan Corporation (BPC), five spots namely Chittagong, Cox's Bazar, Kuakata, Khulna and the Sundarbans are located in the coastal zone (Bangladeshonline, 2005).

Numerous tourism related infrastructures are situated in the coastal zone. Bangladesh Parjatan Corporation has seven motels in Cox's Bazar and one motel in Chittagong and Khulna district each. Besides BPC establishments, private owned hotel, motel, guest house or other mode of tourist accommodations would be around 500 in the same areas. All the tourist facilities in the coastal zone will be affected by sea level rise directly or indirectly. Tourism sector of Kuakata will suffer the most because all the facilities are very close to the coastline and the area is more vulnerable

comparative to Cox's Bazar and Chittagong. However, all the mentioned areas are highly vulnerable in terms of sea level rise related natural disaster, e.g. flood, storm surge, etc.

A study of Bangladesh Parjatan Corporation suggests that 19 per cent of foreigners visiting Bangladesh are tourists, the rest visit Bangladesh for business or other official purposes. At national level, tourism industry serves the nation with economic development. At the local level, it helps to strength local economy, culture and heritage. Sea level rise, by affecting this promising sector will affect the national economy and heritage of Bangladesh.

4.7 Impacts on health

Sea level rise may increase the risk of health hazards like diarrhea, 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 causing microbe of cholera that survive longer with salinity level ranging from 2.5 ppt[3] to 30 ppt and need 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 the reason, coastal area is breeding and nursery ground of cholera disease.

Water salinity of the coastal area of Bangladesh varies from 0 ppt to 20 ppt (Jakobsen et al., 2002). Water salinity and its distribution in the coastal area are increasing with the increase of sea level rise (Faisal & Parveen, 2004; Alam, 2003; IPCC, 2001a; World Bank, 2000). With the increased density and distribution of salinity, cholera germs are getting favourable habitat and spreading in the coastal area. This hypothesis is also supported by Colwell and Huq (2001) that states, most major epidemics [of Cholera] that have occurred during the last 50 years originated in coastal region. So, coastal water and its saline environment have close association with cholera disease. Outbreaks of cholera often occur after flooding, because the water supply becomes contaminated (Eco-health Glossary, 2005). Thus, sea level rise, by increasing flood risk, increase the risk of cholera outbreak too.

Increased stress on the fresh water zone by saline sea water will decrease fresh water availability in the coastal zone (IPCC, 2001a). Increased unavailability of fresh water will force people to drink contaminated water leading to cholera, diarrhea and other water born diseases. Again, increased salinity in the coastal zone will decrease food production in the area, causing malnutrition for the coastal people. So, sea level rise will accelerate water born diseases and malnutrition in the coastal area. However, the degree of probability of cholera and the depth of malnutrition is a matter of further research.

4.8 Impacts on ecosystem

The Sundarbans will be completely lost with 1 metre sea level rise (World Bank, 2000, p.63). Loss of the Sundarbans means great loss of heritage, loss of biodiversity, loss of fisheries resources, loss of life and livelihood and after all loss of very high productive ecosystem. Area of the Sundarbans, inundated by different scale of sea level rise is shown in the Table-6.

[3] PPT = Parts per thousand

Table-6: Fate of the Sundarbans with different sea level rise (SLR)

Climate change event	Potential impacts

Sea level rise	• 10 cm SLR will inundate 15% of the Sundarbans
	• 25 cm SLR will inundate 40% of the Sundarbans
	• 45 cm SLR will inundate 75% of the Sundarbans
	• 60 cm SLR will inundate the whole Sundarbans
	• 1 metre SLR will destroy the whole Sundarbans
	  • Species like Sundari, main economic species in the Sundarbans, would be replaced by less valuable Goran and Gewa.
	  • Human habitation possible prevents inland migration.
	  • Loss of the Sundarbans and other coastal wetlands would reduce breeding ground for many estuarine fish, which could reduce their population.
	Sea level rise would result in saline water moving further into the delta. This would reduce the habitat for fresh water fish, although it could increase the habitat for estuarine fish.

(Adapted from World Bank, 2000)

The Sundarbans mangrove forest is the world's biggest unique chunk of mangrove forest, located at the south of the tropic of cancer, the southwest part of Bangladesh, covering part of Khulna, Satkhira and Bagerhat district (Iftekhar & Islam, 2004). The area of the Sundarbans varies each year because of soil erosion or land accretion. However, its present area in Bangladesh part is 6,500 square kilometer (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 dominating trees of the Sundarbans is thought to suffer from *Top dyeing disease* because of increased salinity (Kausher, 1993). Aquatic organisms will migrate inward, because of increased salinity too.

The Sundarbans is very rich in biodiversity. It is the hotspot for vast amount of flora and faunas. It is the last habitat of Royal Bengal Tiger. A study conducted in 1993 revealed that the Sundarbans is home to about 362 Royal Bengal Tigers[4]. The site is home to a number of unique and globally or nationally endangered species of plants like rare Sundri, Gewa, Passur, animals like endangered Royal Bengal Tiger, vulnerable Pallas, Fishing Eagle and Masked Fin foot, and critically endangered River Terrapin, all listed in the IUCN Red Book, rare species of shark and very rich avifauna. At this transitional zone between freshwater supplied by rivers and saline water pushed by high tides from open sea, many fish species such as *Peneaus monodon*, *Macrobrachium rosenbergii, Lates calcarifer*, *Metapeneaus monoceros* and *Pangaisus pangaisus* depend for spawning and juvenile feeding on the Sundarbans aquatic habitat (Rabbiosi, 2003).

The Sundarbans is also a habitat of some important species like- Wild boar, Spotted deer, Barking deer, Rhesus macaque, Jungle cat, Leopard cat, Otter, Squirrels and the Indian porcupine. The forest also supports habitat to marine turtles, crocodiles, frogs, and fresh water dolphins. With the

[4] BSS (Bangladesh Sangbad Sangstha), please see http://www.earthisland.org/map/ltfrn_90.htm#asia, accessed on 30 September 2005.

loss of the Sundarbans, habitat of these species would also be lost. It is not known yet, if these valuable species could survive any where else.

Environmentally protected areas are declared with a view to save the natural habitat and to save the biotic flora and fauna of the area. Considering the high biodiversity value of the coastal zone, some parts of the zone is declared as protected areas. The protected areas include reserved forest, two national parks, one eco-park, five wildlife sanctuaries, one game reserve, one Ramsar site, three Ecological Critical Areas, two world heritage sites, one marine reserve and one fish sanctuaries (Table-7).

Table-7: Protected areas in the coastal zone of Bangladesh

Type	Name	Area (ha)	Location	Will 1-m SLR affect?
Reserved Forest	-	885,043	Bagerhat, Barguna, Bhola, Chittagong, Cox's Bazar, Feni, Khulna, Lakshmipur, Noakhali, Patuakhali, Satkhira	Yes
National Park	Himchari	1,729	Cox's Bazar	No
	Nijhum Dweep	4,232	Hatiya, Noakhali	Yes
Eco-park	Sitakunda	808	Chittagong	No
Wildlife Sanctuaries	Sundarban East	31,227	Bagerhat	Yes
	Sundarban South	36,970	Khulna	Yes
	Sundarban West	71,502	Satkhira	Yes
	Char Kukri Mukri	2,017	Bhola	Yes
	Chunati	7,761	Chittagong	No
Game Reserve	Teknaf	11,615	Cox's Bazar	No
Ramsar Site	The Sundarbans	601,700	Bagerhat, Satkhira, Khulna	Yes
Environmental Critical Areas	Sonadia	4,916	Cox's Bazar	Yes
	Teknaf beach	10,465	Cox's Bazar	Yes
	St. Martin Island	590	Cox's Bazar	Yes
World Heritage Site	Wildlife Sanctuaries of the Sundarbans		Bagerhat, Satkhira, Khulna	Yes
	Shaat Gombuz Mosque	0.16	Bagerhat	Yes
Marine Reserve		69,800	Bay of Bengal	Yes
Fish Sanctuaries		15,614	Barisal, Bagerhat, Bhola, Patuakhali, Narail, Khulna, Jessore, Lakshmipur, Feni	Yes

(Adapted from Islam, 2004 p.75)

About 7 species of fishes, 2 species of amphibians, 7 species of reptiles, 8 species of birds and 8 species of mammals are threatened animal species living in these protected areas (Islam, 2004 p.74). Excluding Himchari national park, Sitakunda eco-park, Chunati wildlife sanctuaries and Teknaf game reserve- all the protected areas in the coastal zone will be inundated by one metre sea level rise, destroying the area and its valuable wild and threatened animal species.

Sea level rise will decrease availability of light for corals, affecting photosynthesis process. Decreased rates of photosynthesis will decrease the growth of corals, causing destruction of St. Martin's island, the only highly productive coral island of the country.

4.9 Impacts on security

Security is a secure condition or feeling. It is a broad issue that indicates safe status of the state and its citizen. Barnett (2003) mentioned 'security in a general sense is the condition of being protected from or not exposed to danger'. And it is the assurance of free enjoyment as Soroos (1997; cited in Barnett, 2003) defined 'the assurance people have that they will continue to enjoy those things that are most important to their survival and well-being'. Let us assume that opposition to the above mentioned two definitions of security is 'security threat'. What is 'not exposed to danger' or 'most important to survival and well-being'? Well, not exposed to danger is free from all sorts of hurt, that could be human generated or natural. Any thing or occurrence that hurt human being, directly or indirectly is a security threat. Sea level rise, by reducing fresh water availability, reducing fisheries and agricultural production, eroding coastal land, losing biodiversity and by causing health hazards creates a danger situation for the people of Bangladesh. Again, 'most important to survival and well-being' is the basic needs of human being.

Table-8: Impacts of sea level rise on the basic needs of the people of Bangladesh

Basic needs	How sea level rise affects it
Food	Rise in sea level would flood agricultural lowlands and deltas in parts of Bangladesh (Miller, 2004; Bennett et al., 1991) that will decrease food production, causing shortage of food. Only salinity intrusion due to sea level rise will reduce 0.2 million metric ton of rice production (WB, 2000).
Cloths	Sea level rise will increase poverty. Increased poverty will decrease cloths buying capacity of the people of Bangladesh
Housing	In Bangladesh, 29,846 sq. km. area of land will be lost and 14.8 million people will be landless by sea level rise (IPCC, 2001a), losing their house.
Health	Sea level rise by extending coastal area and by increasing salinity in the area will increase the risk of cholera. It will accelerate flood intensity facilitating transmission of diarrheal disease (World Bank, 2000).
Education	Sea level rise will cause destruction of infrastructure including educational institutes. Besides, students of flood, or other sea level rise affected family will leave school/ college, in search of work to support their family.

Food, clothing, housing, health and education are the basic needs of the people of Bangladesh. Table-8 explains how sea level rise affects the basic needs of large number of people of the country. Affecting basic needs, sea level rise becomes a threat to food security and other well-being securities.

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 ecological or environmental refugees in the country, forming 'ecological marginalization' (Homer-Dixon, 1998). Barnett (2003) states, 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 inland within Bangladesh, but a significant number may seek to move

to neighbouring India and Pakistan-and previous migration of this kind has been a factor in violence in the region (Swain, 1996).

A study of Earth Policy Institute (2004) shows the problem more seriously, that about 40 million people of Bangladesh out of 144 million will become environmental refugees due to 1-m sea level rise (Figure-13).

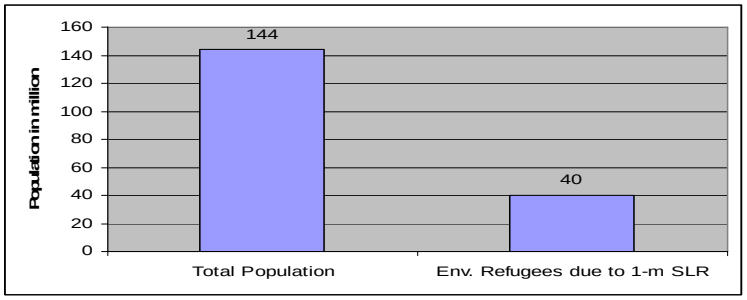


Figure-13: Environmental refugees by 1-m SLR

(Data source: Earth Policy Institute, 2004)

Robert Kaplan (1994; Cited in Elliott, 2004, p.203) highlighted that different environmental problem including sea level rise will prompt mass migration, and in turn, incite 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 trigger the conflict. Nowadays 'Push back' is common news in Bangladeshi newspapers that means pushing Bengali speaker from India to Bangladesh by Indian Border Security Force (BSF). Environmental refugees created by sea level rise will cause even worse situation that may trigger conflict between the two countries. Thus, sea level rise might be a threat to national security of Bangladesh.

5. Possible response to sea level rise

From the long discussion in the previous chapter, it is clear that Bangladesh has to face the crucial effects of sea level rise. But Bangladesh or even any country in the world cannot overcome this problem overnight. So, global communities are paying their attention to minimize the impacts of climate change and one of its ultimate results, sea level rise. The output to minimize the impacts is either mitigation or adaptation. Let us distinguish between mitigation and adaptation as Smit et al. (1999) did regarding climate change-

> *'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 that context, Bangladesh needs to consider both mitigation and adaptation options, even though the country has very limited scope for mitigation. This is because mitigation involves global efforts to execute and adaptation is more local. So, effective adaptation policies and mitigation measures should be developed and implemented to minimize sea level rise impacts on Bangladesh.

5.1 Adaptation

Adaptation seeks to reduce the adverse effects of sea level rise on living organisms, including human 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. As most of the population of the coastal communities of Bangladesh is fishermen and farmers, the adaptation options should be emphasized on these two sectors to overcome the problems of the anticipated issues. However, changing policy issues are beyond the scope of this study.

If we can implement different adaptation options of coastal fisheries, as shown in the following Causal Loop Diagram (Figure-14), we find that five loops may reinforce to increase the fisheries production. Foreign exchange earned by coastal fisheries could be invested for the development of coastal fisheries sector. The investment could be used for disaster preparedness activities, special weather forecasting and research.

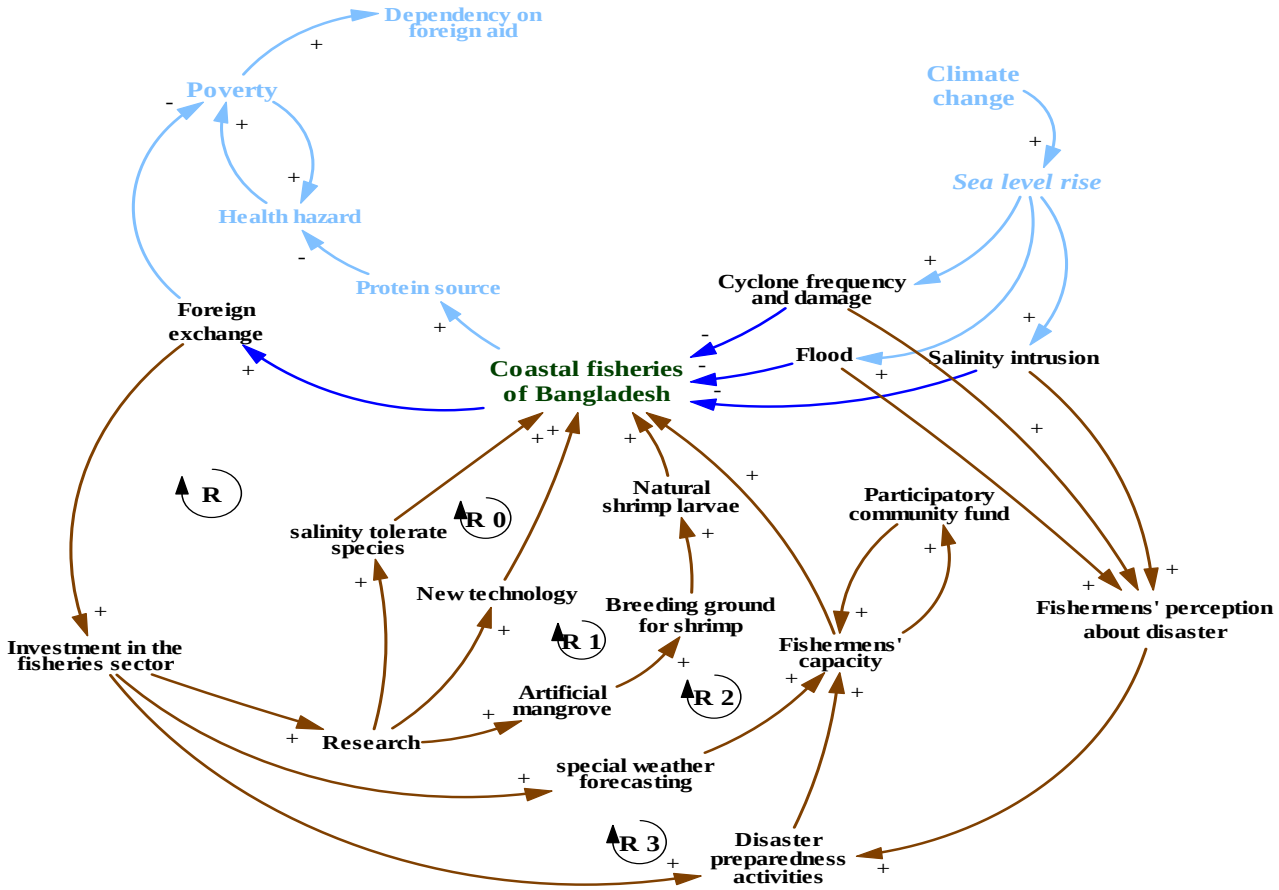


Figure-14: CLD for the adaptation options of coastal fisheries with sea level rise

The fishermen invest their year long savings, which are under threat to be destroyed by sea level rise induced disasters like flood. Coastal communities should be prepared to face these adverse situations by having disaster preparedness activities. Disaster preparedness activities include pre and post disaster activities, not only the duty during the disaster event. Though, it is difficult to have a plan for any disaster before it has happened, it should be done ahead. The fishermen should be updated about the disaster and their duties to minimize the potential loss by the event. A disaster calendar should be prepared for the community, so that they can have a safe plan for fish farming. For example, most of the cyclones in the coastal zone occur in October and May; coastal district Noakhali is mostly heated by cyclone, which is almost the country's one-third; salinity is high in Khulna, Satkhira and Patuakhali districts could be considered in the proposed disaster calendar. Following the disaster calendar, fishermen can avoid the specified time period and the specific coastal district for fishing and fish farming. A disaster calendar that considers disaster intense time, disaster prone zone and salinity will help the fisher community to have a safe production and also safe harvest.

Weather forecasts in Bangladesh *Betar* (Radio) and Bangladesh Television, whose target groups are mostly illiterate coastal farmers and fishermen, are developed and delivered by educated people in highly educated language. These fisher and farmer communities don't know what El-Nino is or what *Nimnochaap* (Depression) is. Weather forecasting should be in easy language, so that the target groups can understand it easily and completely and can react with the direction of the forecast. People of different coastal zone have different dialects. Local radio stations should

broadcast weather forecast in local dialect. Besides forecasting, local radio station should broadcast special programmes that communicate coastal communities about different issues of sea level rise.

Participatory community fund is another option that will enhance the fishermen's capacities. The concept of micro-savings could be used for the participatory community fund in the area. In the savings method, the fishermen should be motivated to form a small group of 20-25 members and each group member will save a small amount of money (for example, US¢20). Individual's weekly savings will be collected and deposited into the group's bank account. A small committee of five members, elected or selected will take decisions of the group and a member who is comparatively educated among the members and accepted by the members will handle bank activities. The savings will be used in case of harvest failure or in case of other natural disaster that affect their fish farms. In case of no environmental hazard or natural disaster, the fund could be used to form a cooperative that will bring more financial gain to the poor fishermen. Adapting with disaster and having financial solvency, the coastal community will gain resiliency, which is shown in R2 and R3 reinforcing loops in the CLD (Figure-14).

Efficient research can find out salinity tolerant species for the coastal fisheries sector. Species selection should be done for low, moderate and high saline environment. After selecting different species for different zones or saline environments, the fishermen should be trained about breeding, cultivation and harvesting of the species. Research will also point out new or advanced technology for the sector. For example, cage cultivation, which is not practiced in Bangladesh, could be introduced in coastal areas of weak current flow. By cultivating salinity tolerate species and by practicing advanced fisheries techniques, coastal communities can adapt with sea level rise, which is shown in the reinforcing loop of R and R0 of the CLD (Figure-14).

Again, money invested in fisheries sector could be used for artificial mangrove aforestation. Mangroves provide breeding ground for shrimp, increasing the number of natural shrimp larvae (Islam & Haque, 2004; Hossain, 2001). Mortality rate of natural shrimp larvae is low. Shrimp cultivation with low mortality rate will increase production. Increased production will increase shrimp export and subsequently foreign exchange earnings of the sector will be increased too. The reinforcing loop is shown in R1 of the CLD (Figure-14).

The area of Bangladesh coast that will be inundated by sea level rise should be prepared for alternative mode of cultivation. The fishermen, who are involved in capture fisheries in the coastal zone, are the most vulnerable group. Water salinity of their ponds will be higher than the expected salinity level required for fisheries cultivation, because of sea level rise. Coastal capture fisheries are mainly a monoculture that only depends on tiger shrimp (*Peneaus monodon*). Initiatives should be taken to reduce dependency on *P. monodon* and monoculture could be altered by practicing polyculture. Brzeski and Newkirk (1997) reported that in Taiwan, combined harvest in the polyculture pond with tiger shrimp, milkfish (*Chanos chanos*) and mullet (*Mugil cephalus*) 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 latest two fishes are also popular among coastal people and have good commercial value. Polyculture of these species will bring good returns in terms of currency. A study by Salam et al. (2003) found 43% land suitable for brackish water crab and shrimp culture in southwestern part of Bangladesh while additional 5% and 49% areas were moderately and marginally suitable for the purpose. In the interior coastal area where salinity come close to zero could be used for fresh water prawn culture followed by brackish water shrimp and crab culture. Thus, polyculture will ensure

highest financial returns and optimum use of land in the land scarce coastal area, as it shows higher harvest comparative to monoculture and ensures cultivation throughout the year.

P. monodon is very sensitive to salinity and its required salinity for maximum growth is 15-25ppt (Chanratchakool, 2003). Indian White Shrimp (*P. indicus*) and Western White Shrimp (*P. vannamei*) are more flexible in terms of salinity tolerance. Indian white shrimp can tolerate salinity up to 42 ppt and Western White Shrimp can tolerate a wide range of salinity starting from 0.5 ppt to 45 ppt. These two prospective shrimp species could be introduced in the shrimp sector of Bangladesh. There is a world debate about the introduction of exotic species in Bangladesh, and also globally. The fisheries sector of Bangladesh has in fact enriched with exotic species during the 50s. For example, Tilapia (*Oreochromis mossambicus*), the first exotic fish species in Bangladesh was introduced in 1954 from Thailand. Silver carp (*Hypopthalmicthys molitrix*) was introduced in the year 1967 in 1969 and Thai Pangas (*Pangasius sutchi*) was imported from Thailand in 1989 (Ali, undated). Tilapia, carp and Thai pangas are among the main species that are available in Bangladesh market. However, introduction of exotic species should be initiated with the necessary impacts assessment on Bangladesh environment, especially the impacts on the fisheries sector of Bangladesh.

The vast submerged area in the coastal zone could be used for cage and pen culture. A cage is a net-built pocket submerged in water where fish could be cultivated. Cage culture is suitable in the coastal areas with relatively weak water current. Swann et al. (1994) mentioned that 800-1000 fish could be stocked in a cage having a small volume of 3.6 cubic metre. So, the culture permits high stocking density that helps to have a high yield of fisheries in the land scarce coastal areas. However cage culture is relatively expensive at the initial stage. But, when the infrastructure is developed once, it will be cheaper than the commercial fisheries method as it is easy to observe, treatment, feed supply, harvest and relocate.

Adaptation should be introduced in agriculture, including crop changes and resource substitutions (IPCC, 2001b). Salinity tolerant species could be introduced in agriculture, fisheries and in the coastal forestry. A participatory approach to coastal resource planning, inventory and zoning (Hossain and Lin, 2001) can consider the long term impacts of sea level rise. A study by Rashid et al. (2004) showed that *Al. lebbek* could survive in varies salinity range. These type of salinity tolerate species should be developed or find out to extent plantation in the coastal areas. The species *Heritiera fomes, Sonnerata apetala and Avicennia officinalis* are suitable for mangrove aforestation in the coastal zone of Bangladesh.

It is reported that some farmers in Gournadi upazilla of Barisal district is practicing floating agriculture in their lowlands, submerged by water (Mian, 2005). In the method, dried hyacinth is piled on a floating structure and seedlings are grown on it. This method of soil less agriculture should be developed and disseminated throughout the whole coastal zone so that the farmers of the area can practice some selective agriculture, even if their agricultural lands are submerged.

Pearl culture may be another option to be introduced in the zone. By practicing these cultivations, people can maintain their domestic demand and earn money by selling surplus products, which could be used to adapt with other sea level rise impacts. Some sea foods (e.g. crab, oyster, etc.) are not treated as food in Bangladesh, even though they have high nutrient value. People should be motivated to consume sea food. Alternative raw materials should be sought for coastal resources dependant industries. Tourism and other coastal infrastructure should be built, considering sea level rise. A community based adaptation policy should be developed. For the job, an extensive study

should be done to formulate a good adaptation policy, by national and international level sea level rise experts and a strategy should be developed to handle the upcoming catastrophe.

If we try to find out the cause impact relationship of sea level rise and agriculture, it has a shape almost similar in case of the relationship between the coastal fisheries and the sea level rise (Figure-14). Coastal agriculture is also affected by sea level rise induced hazards, e.g. salinity intrusion, flood and cyclone frequency and damage. In case of agriculture, it doesn't have any mentionable contribution to earn foreign exchange, but it has significant contribution to the GDP of Bangladesh. If GDP is high enough for extra allocation of money for research, it will help to find out salinity tolerate species for agriculture and also new agricultural techniques like floating agriculture. Finding salinity tolerant species and new agricultural techniques, the farmer of the coastal areas can adapt with the adverse situation of sea level rise.

Mangrove afforestation will protect soil erosion because its roots help to compact soil. Decomposition of dead leaves of mangrove will add organic matter to the soil, turning coastal land fertile. Newly accreted land in the riverside or coastal areas comes under the jurisdiction of Department of Forest of Bangladesh government for 20 years and the department plants and nurses new trees in the land to protect the areas from erosion. Bangladesh is a land scarce country and surrounding people start to settle there in 5-6 years (Iftekhar & Islam, 2004). Human settlements should be prohibited in the new lands for the designated 20 years time expansion. The forest department should have a special team to protect the areas from this type of illegal settlement. People should be motivated in such a way that they understand about the benefits they will get, when the land gets maturity.

People engaged in the salt industries should be provided information regarding possible impacts of sea level rise on the sector. Lands that are used as salt-bed should be protected by polders. The areas where polder construction is not possible, the salt farmers of those areas should be motivated to alter their professions and one of the choose livelihood practice might be fish farming suitable for that environment. Existing salt mills that are very close to the coastline should be relocated towards landward parts of the country.

Tourism in the coastal area should be developed under the principle of eco-tourism. Tourism infrastructure should be protected by polder and where polder construction is not feasible from environment point of view, it should be relocated. Further tourism infrastructures should be constructed with full consideration of sea level rise.

Coastal water should be monitored to detect the presence of germs of cholera disease. There is a government health complex in every upazilla in Bangladesh. The coastal health complexes can do this job regularly or at least weekly. One doctor in the coastal health complex should have expertise in cholera issue. 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 accessable in the coastal area and free saline should be distributed in cholera outbreak portion of coastal zone. Coastal people should be trained how to make oral saline at home, simply using salt, sugar and clean water.

Options of fresh water availability should be increased as coastal zone is threatened by water born cholera and diarrhea disease. Water treatment facilities should be introduced in the area. As Bangladesh is densely populated country, people's dwellings are here and there, almost everywhere, scattered. So, central water treatment plant will not be economically feasible, because it will need long and extensive water pipe network. For the job, household level water treatment plant should be developed; one of the options may be filtration, using indigenous knowledge. Filtration process is

very easy to develop and people can make it using sand, charcoal and soil made pitcher that are available in Bangladesh. An ideal filtration method should be developed and non government organization and community based organization network in the rural area could be used to motivate the people and disseminate the water treatment model.

Adaptation to the change in ecosystem is very hard task and sometime impossible, even. As the Sundarbans is predicted to be affected most by sea level rise, attention should be paid on this ecosystem mostly. *Sundari* is the dominating tree species that covers 62.4% of the Sundarbans (Iftekhar & Islam, 2004). If this species is lost, it will cause imbalance in the ecosystem, as organisms and their environment are interconnected with each other. Massive loss of the *Sundari* tree species by *top dying disease* is believed, due to salinity increase in the water and soil of the ecosystem. Diagnosis of the *top dying disease* should be done properly and possible scientific solutions should be sought. If any new salinity tolerate species is found, it should be planted in a specific area as pilot project and its plantation could be extended in other area, only when it proofs feasibility from environmental, financial and social point of view. The salinity tolerate species could be planted in proposed mangrove plantation programme.

Animal species of the Sundarbans should be transferred to new mangrove plantation areas also. The Sundarbans is the last habitat of the Royal Bengal Tiger and only 362 is reported to be in Bangladesh part, also having almost equal number in the Indian territory of the forest. Special attention should be paid on this species, to protect its extinction. Safe zone should be created in the forest for the specified tiger where all human activities will be prohibited including activities of the forest department, so that it can have safe breeding to increase the number of the species. It is important to note that the Sundarbans forest couldn't be protected by polders as this tidal mangrove ecosystem needs the interface between land and sea.

The protected areas that are under potential threats of sea level rise should be studied extensively to point out the problems of the areas from environmental point of view and to find out the solutions. It is reported that protected areas, like other parts of the coastal zone are over exploited by local communities. The communities should be motivated to stop over exploitation and at the same time forest authority should take legal action against any anti regulation exploitation.

Rice is the staple food of the people of Bangladesh. Rice production decreased by the anticipated sea level rise should be making up by introducing advanced agricultural technology and by cultivating high yield varieties in other parts of the country. Training about advanced agricultural techniques and seeds of high yield varieties of rice should be provided to the farmer. Initiatives should be taken to develop salinity tolerate species. Resource mapping in all parts of the zone should be done using participatory approach, where local people will have access to identify their resources, to analyze the problems in using resources and their solutions.

People should be motivated and trained to do area specific business, suitable for their areas. Coastal poor people should be provided with small scale soft loan of less than 5% interest rate to operate those area specific livelihood activities. It should be remind that the poor in Bangladesh can hardly reach to government financial institute. So, they are deprived from the financial help from the government. Hutton and Haque (2003) found that only 7% riverbank erosion affected people accessed any form of official assistance. So, money should be provided to the poor by non government organizations or community based organizations. Earnings by small scale businesses will be invested in the same field that will create flow of money. Increased flow of money will increase production and supply (Martinussen, 2004; p.67), expanding the business and subsequent profit of the poor.

5.2 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. Though, Bangladesh emits a negligible volume of greenhouse gasses (Figure-4), the country should take necessary steps even to cut down its emissions. Control of deforestation and fossil fuel use is essential for the purpose. IPCC (2001a) indicates the main greenhouse gas emission reduction measures which are: i). Demand reduction and/or efficiency improvement, ii), Substitution among fossil fuels, iii), Switch to nuclear energy, iv). Switch to biomass, v). Switch to other renewables, vi). CO_2 scrubbing and removal, and vii). Afforestation. Bangladesh should follow its level best, the above mentioned seven measures.

To reduce demand, Bangladesh needs to control its excess population growth. World Commission on Environment and Development (WCED, 1987) expresses in *Our Common Future* that, 'Excessive population growth diffuses the fruits of development over increasing numbers instead of improving living standards in many developing countries'. So, population control should be given the first priority in Bangladesh, where population density is the highest in the world. The recently introduced Compressed Natural Gas (CNG) driven vehicle that produce low hydrocarbon, carbon monoxide (CO) and CO_2 (Miller, 2004) is an exemplary step of Bangladesh to minimize greenhouse gas emission. Approximately US$ 1.22 worth of CNG will be enough for a sedan car to run 100 km, whereas for octane users, the same car will run for a maximum of 30 km at the same cost at the prevailing fuel rate in Dhaka (Anon, undated). As CNG is more than three times efficient (in terms of cost) than octane, people will use this low emission natural gas if favourable environments could be ensured. Necessary steps to popularize the CNG fuel include sufficient refueling stations, availability of conversion device that is used to convert a vehicle from octane fueled to CNG fueled and availability of spare parts of the device and necessary training to create technical personnel in the fields. The country should adapt this low emission technology to other fields. Introducing biomass (e.g. biogas), using renewable resources (e.g. windmill, solar photovoltaic) is also need to adopt.

Bangladesh has a plan to bring all its citizens under national electricity grid by the year 2020. To fulfill this noble vision, the country should seek possible renewable resources. Favourable natural conditions like sufficient sunshine and wind-speed exist for promotion of renewable energy in the country. In Bangladesh, average absorbable solar radiation is 0.193 kW/ m^2 (Islam & Huda, 1999). Bangladesh has an area of about 143,998 square kilometer. This means that Bangladesh receives a constant supply of 28 TW[5] energy from the sun, which is nearly 200 kW per capita for a population of 140 million. The annual per capita consumption of electricity in Bangladesh is estimated as 112 kW, which is available only for 18% of the population (Samrina, 2004). Comparative to the present electricity consumption, solar energy availability is a huge amount of energy. A World Bank survey reports that 500,000 households of Bangladesh may be potential market for solar home system (Sarkar et al., 2003). So, Bangladesh has a potential for solar energy.

However, solar energy is not used appropriately in Bangladesh because of its high initial cost. This cost should be provided from external sources as soft loan (<5% interest). Import tax on all solar photovoltaic (PV) materials and other necessary equipments should be exempt. Community

[5] TW = Trillion watt

participation on all types of PV project should be ensured, so that community ownership is developed. The organizations or institutes, experienced in PV handling should be involved in the system. Attention should be paid to develop PV technology domestically. Local engineering and manufacturing companies should be encouraged to provide indigenously manufactured equipment of international standard to renewable energy project sponsors. Mass communication should be conducted to popularize PV within the rural communities, as the cost of PV system will decrease proportionally with the increase of consumers. It is possible to envisage a virtuous circle of market growth, expanded production, and further economies of scale that will shortly allow PVs to compete in their own right against conventional electricity supply technologies in grid-connected applications (Jackson & Oliver, 2000). Favourable conditions for foreign investors should be created to create joint venture.

Aforestation in the coastal zone has potentiality to increase forest cover in the country. Coastal plantations initiated by the forest department of Bangladesh government during the period of 1960-2001 succeeded for a net of 61% of plantation (Table-9). About 39% of plantation didn't survive due to erosion mainly, which is a phenomenon of sea level rise in the coastal zone.

Table-9: Coastal plantation during 1961-2001

Division	Total Plantation (km^2)	Plantation Failed			Net Plantation
		Eroded	Encroached	Total	
Noakhali	595	24	17	41	59
Bhola	302	39	7	46	54
Patuakhali	220	10	1	11	89
Chittagong	368	31	15	46	54
Total	1485	27	12	39	61

(Adapted from Iftekhar & Islam, 2004)

An extensive afforestation programme in the coastal zone will increase the forest cover and act as carbon sink (Binkley et al., 2002). Mangrove plantation in the zone will be 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, area of mangrove forest will be increased in the coastal zone. Hossain and Lin (2001) identified 1,929 ha and 1,895 ha land suitable and moderately suitable respectively for mangrove afforestation in Chakoria and Cox's Bazar Sadar upazilla of Cox's Bazar district. A similar feasibility study could be done to find out the land suitability for mangrove afforestation in the whole coastal zone of Bangladesh.

6. Discussion and Conclusion

Article 1.2 of the United Nations Covenant on Civil and Political Rights states, '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, who are projected to be environmental refugees. It is threatening potentially to the basic human right to the large number of population. So, Bangladesh government has to save this big population from the danger.

6.1 Role of Bangladesh government to reduce sea level rise impacts

Ministry of Water Resources of the Government of the People's Republic of Bangladesh has formulated a Coastal Zone Policy in 2005 that pays very little attention about sea level rise (CZPo, 2005). Article'c' of the section 4.8.3 of the policy expresses 'efforts shall be made to continuously maintain sea-dykes along the coastline as first line of defense against predicted sea-level rise'. Article'd' of the same section tells, 'an institutional framework for monitoring/detecting sea level rise shall be made and a contingency plans for coping with its impact.' However, the policy doesn't explain how the dykes will be made. It doesn't discuss the possible environmental impacts of the proposed dykes too. The policy wants an institutional framework that will monitor sea level rise and will have contingency plans for coping. But it doesn't say how the contingency plan will be made. It doesn't tell anything about mitigation plan of the problem. The coastal zone policy is the most important document that should consider sea level rise issues elaborately. Government should have an integrated policy to save its large number of population that is going to be affected by the anticipated rise in the sea level.

For adaptation, the government should take initiatives to improve irrigation efficiency, runoff management, and agricultural productivity and to promote risk management to compensate loss in agriculture. Government should develop and promote the use of hybrids and to develop infrastructure for post harvest management, marketing and agribusiness (IPCC, 2001a). IRRC (2003) concluded, *BRRI Hybrid Dhan-1* variety showed 0.5 to 1.0 t/ ha yielded over that of other rice varieties, produced in Bangladesh. Farmers of the coastal zone should be provided free agricultural education and necessary support for its modification to adjust with sea level rise situation. It is essential to introduce salinity tolerant species in agriculture, forestry and fisheries.

Bangladesh Rice Research Institute (BRRI) can conduct research to develop salinity tolerate species whereas Bangladesh Agricultural Research Council (BARC) could be engaged to develop salinity tolerate species of other agricultural crops. Department of Agricultural Extension (DAE) of Ministry of Agriculture (MoA) could be involved to disseminate new species and its cultural techniques. Bangladesh Forest Research Institute (BFRI) could be engaged to develop salinity tolerate species of wood plant species like mangrove. Mass media communication could be used to disseminate new ideas about SLR. Bangladesh betar (radio) and Bangladesh Television can play the role.

After the devastating flood in 1988, the government resettled the flood affected people in *cluster village*. In the concept of cluster village, a group of flood affected people, whose land were eroded

by the flood were settled in a government land and houses for them were build in government cost with water and sanitary facilities. But the initiative was failure because of wrong site selection, political biasness and inadequate income sources. Sea level rise affected people could be resettled in cluster village method with some adjustments. In some cases, the settlement was done on government land, in densely populated areas where existing communities didn't welcome them warmly. There were conflicts between existing communities and the settlers for resources, employment and also cultural gap. So, the settlement didn't sustain.

The settlement was planned with the creation of job opportunities for the settlers, which was inadequate. The settlers left the village and moved the nearby towns for searching jobs and engaged themselves as rickshaw puller, cart puller, daily laborer. In some cases, they find nothing to do but begging. For the lacking of job opportunities, they shared the work of pre-existing communities leading to conflicts between settlers and the communities. There were misunderstanding in the settlers and the communities because of cultural gaps too. The selection of the settlers was done by government officials with recommendation from political leaders in power and was reported to select in biasness. Deserving people were not considered accordingly in the selection process. Those who were settled were in the mental unrest to be displaced with the change of government.

To overcome the mentioned problems of cluster village, site of the village should be selected from matured government land. Accreted land or government abundant land could be used for the purpose. It should be taken into account that new village have a safe distance that should be one kilometre minimum from existing population settings. Besides housing and sanitation facilities, there should be sufficient agricultural land, open water for fisheries or other means of subsistence. The houses and the land should be registered against the settler families.

To raise the income of the settlers, they should be facilitated with micro-finance programmes, to create job opportunities in the village. An NGO that has wide experience in micro-credit should be involved with the process. Grameen bank is the world wide pioneer organization to operate micro-finance programme and could be involved to facilitate the settler with finance, trading for small scale production or business, create market of the products, monitor their business and initiate necessary solutions of any new problem addressed. Seed money for the micro-finance programme should come from government and handled by the NGO. After the targeted time period, the NGO will recover the money from the settler. When the settler will enter into the micro finance activities, there will be flow of money that will create job opportunities for the settlers.

As Bangladesh is the densely populated country in the world, relocation of coastal people to the landward part is not possible because of land unavailability. So, local level management of sea level rise impacts is the first priority. For the purpose, coastal zone should be protected where it is environmentally viable. Where protection is not possible, attention should be put for a better management of the area.

Multipurpose cyclone shelter centre, which were build mainly after the cyclone of 1991 were found useful in flood and in small intense cyclone of 1991 onward. At present, about 15% of the coastal population is under the coverage of cyclone shelter centre. To ensure the safety of the rest 85% people, 14,220 cyclone shelter centres are needed. With the increase in population, more cyclone shelter centres will be needed.

There are 28,564 educational institutes in the coastal zone including primary, junior and secondary high schools and most of them are either one-storied building or a tin-shed house. On the basis of their location in the disaster prone area, half of the schools should be upgraded to three-storied buildings which are strong enough to tolerate strong wind of cyclone. Disaster affected coastal people will take shelter in these schools in the event of cyclone to safe their lives. The people will leave the shelter centres as soon as the cyclone is over. There are about 190 man-made highlands in the zone, locally known as *killas* where live stocks are kept safely during disaster. Number of killas should be increased according to the proportion of livestock. Existing cyclone shelter centres and killas are not well connected with road communication and they are in remote areas in some cases. People or livestock find problems to arrive to the centres in case of emergencies. Necessary roads should be constructed to have an easy access to the shelter centres.

There are 123 polders in the zone that were built to protect agricultural land in 60s. At the early decades of the polder construction, there were good agricultural production in the areas, which were declining because of water logging and salinity increase inside the polders. There were not sufficient numbers of sluice gate to facilitate drainage of water, logged in the polders. Malfunctioning of sluice gates was also responsible for water logging (Rasid & Haider, 2003). Decrease in soil fertility is another cause of less agricultural production. Alexander et al. (1997) found that soil fertility inside the polders were less than that of outside the polders.

For the normal functioning of sluice gates, necessary sluice gates should be constructed on the existing polders to facilitate drainage systems. The areas that are not protected by dykes in the central and eastern coastal zone should be protected by dyke construction with adequate drainage facilities and necessary Environmental Impacts Assessment (EIA). However, the western coastal zone couldn't be protected by dyke construction because of the presence of the Sundarbans mangrove forest that requires an interface between land and sea. Introduction of salinity tolerate species for agriculture, fisheries and forest resources is the best adaptation option for the coastal zone.

Lessons should be taken from other countries in the world that have shown great success to handle the problem. The Netherlands is the pioneer nation to control the sea and thus saved the country. Though there are differences between the two countries in terms of environmental settings, technical knowledge and financial resources, Bangladesh can take lessons from the country to handle the upcoming misfortune carefully.

Finance is an important issue for Bangladesh to adapt with sea level rise impacts. To increase domestic financial resources for adaptation purposes, government should raise funds from the coastal zone sources. 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 important role for the adaptation to sea level rise as these sectors are in great threat by the impacts. These business groups should pay a disaster preparedness tax that will be used to adapt with the impacts.

Frozen food is the second largest foreign exchange earners 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 that will be invested in adaptation process. The rate of the tax should be determined with consultation from ministry of fisheries, export promotion bureau and the

stakeholders of frozen food sector. If the businessmen of the sector react with the new tax impose, they should be motivated and convinced by explaining the possible threats of sea level rise on the sector. The businessmen should realize the accidental loss of the sector that was described in the section 4.2 of the paper. Government provide license to coastal fishermen to fish in the coastal zone, timber businessmen to collect wood from the Sundarbans and honey collectors to collect honey from the same forest, for a period of one year. A fixed amount of license fee should be saved and used for the adaptation of sea level rise.

As Bangladesh is salt producing country, price of salt is very cheap here, which is roughly to an amount of US¢0.08 per kilogram. The price of the salt should be raised a little bit and money saved by this economic instrument should be used for the adaptation of sea level rise. However, salt is an everyday essential food material and has high influence on public opinion. For the reason, political leaders don't want to increase the price of salt. But, what will happen, if salt production decreases day by day? Bangladesh has to import salt when the production will be less than the demand and the price will go many folds higher than the present rate. So, to save the salt industry from sea level rise impacts, a lower raise in the price of salt should be accepted morally. Ministry of Industry can collect the money from salt sector.

Two main important tourist attraction of Bangladesh are the Sundarbans and the Cox's Bazar sea beach. Most of the tourist infrastructures are located in Cox's Bazar. The projected sea level rise will destroy the Sundarbans completely and affect Cox's Bazar partly. The tourism sector should contribute to adaptation cost as their existence is under threat by it. Tourism service organizations or unit should pay a specific tax for the job. The tax could be collected from the organizations that are getting new license or renewing them. Tax could be collected monthly where possible. For example, tourist motel owner can pay tax against the number of guest they entertain, monthly. Bangladesh Parjatan Corporation could collect the tax of tourism sector. The department of forest of Bangladesh government provide license to wood collectors and honey collectors of the Sundarbans, seasonally. A certain portion of the license fee should be used for sea level rise adaptation.

The discussed sectors are the most vulnerable to sea level rise impacts and they should welcome the proposed economic instrument for raising money to enhance the adaptation capacity of Bangladesh. If Bangladesh fails to implement the adaptation measures carefully, the people engaged in the mentioned sectors will loss their means of subsistence within a short period of 100 years and thus will keep their future generations in danger.

For mitigation, government should take initiatives to stop deforestation and control the use of fossil fuel to reduce greenhouse gas emission and to rehabilitate degraded forests and watershed (IPCC, 2001a). A study (Anon, 1999; cited in Iftekhar & Islam, 2004) reports that Bangladesh has 18% of the land designated as forest but the actual coverage is less than 7%, and these remnants are further disappearing at a rate of 90 km^2 per year. The country should arrest its deforestation and take measures for plantation to maximize carbon dioxide sink. However, the government of Bangladesh claimed that the country had 9% forest cover in 1990 and was upgraded to 10.2% by the year 2000 (GoB & UN, 2005). As part of indicator *proportion of land area covered by forest* of target 9 of goal 7 of the Millennium development Goals, Bangladesh should have 20% forest cover by 2015. The country should put strong efforts into achieving the specified target.

The government of Bangladesh can take initiative to form a forum with the countries of common field of interest that are highly vulnerable to SLR and raise world voice for global justice again greenhouse gas emissions. The forum will work independently and with international organizations (e.g. IPCC, UNEP) to formulate a policy to press USA and high emitting countries for mitigation target and implement it. The government should lobby to international community for implementing Kyoto Protocol of UNFCCC (1997) and for necessary support of technical and financial issues.

6.2 Role of the international community

The 1997 Kyoto Protocol strengthens the UN Framework Convention on Climate Change agreed at Rio in 1992 by committing developed countries to reduce their collective emissions of six key greenhouses gases by at least 5% below 1990 levels throughout the 2008-2012 periods. The EU, Switzerland, most central/ east European states need to decrease 8%; the USA needs to decrease 7%; Canada, Hungry, Japan and Poland need to decrease 6%, of their emission, to reach the target. Although the USA subsequently rejected the protocol, 178 countries eventually reached a binding agreement for its implementation at Bonn in July 2001 (Carter, 2001).

Global carbon dioxide emission was reduced only 1.7% from 1990 to 1998 (UN, 2005). Section 1, Article 3 of Kyoto Protocol set the emission target as '… … reducing their [Annex B countries] overall emissions of such gases [CO_2 and other GHGs] by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012'. It is too early to comment about the emission cut of greenhouse gases. But CO_2 emission reduction of 1.7% is too small figure comparatively to the target.

Failure to reach the CO_2 emission target will increase the possibility of global warming that will affect positively on sea level rise. All the countries, including the USA should follow the Kyoto protocol to solve the global climate change problems, as well as sea level rise problems of Bangladesh. The UN agencies and other International Development Agencies should help the country to meet the challenges of sea level rise impacts. Most of the international development organization including ADB, UNDP, SIDA, CIDA, CARE (International), USAID, World Bank, JICA, Oxfam (GB) are operating various development activities in the country. The organizations should integrate the sea level rise impacts on Bangladesh in their development activities in the country.

Besides international organizations, developed countries should step forward to mitigate sea level rise impacts and to formulate and implicate adaptation policies for the nation, as Bangladesh is not responsible to create the problems. The GHG emitter countries are responsible for the problem in fact. It is their moral responsibility to be attentive to solve the problems. Bangladesh deserves cooperation from developed countries to meet SLR impact cost. If Bangladesh totally stops the emissions all at a sudden, the problem will remain in the same degree. Cooperation from international development organizations and developed countries should be financial, as well as technical. The entire scientific communities should come forward to face this challenge, providing

technical knowledge and support to minimize foresee impacts of sea level rise and thus save Bangladesh and its great population of almost 140 million.

6.3 Conclusion

Sea level rise impacts are really high for Bangladesh, though the country plays very little role in green house gas emissions, leading to climate change and sea level rise. By affecting different livelihood activities and important ecosystem of the country, sea level rise imposes a grave threat to the existence of Bangladesh. Therefore, Bangladesh government need to pay keen attention to the issue and should develop strategy to combat sea level rise impacts and thus safe its citizen.

It will not be wise to think that sea level will not rise at all, or to wait to see what happen in future. So, development and implementation of adaptation policies and taking initiatives for mitigation measures are the right ways to respond to sea level rise impacts. It deserves research to find the solutions of the potential problems, in practice and to develop salinity tolerant species for agriculture and fisheries sectors. Cyclone shelter centres construction plan and necessary steps to resettle the potential disaster affected people should be initiated. The coastal protection activities should be done with sufficient drainage facilities. Adaptation cost should be recovered from coastal resources using economic instruments. Research also needs to find out the way to save the country's wide range of biodiversity, threatened by the upcoming event.

If Bangladesh stops its total CO_2 emissions at once, the problem will remain at the same extent, because it is an outcome of excess GHG emitting countries. Helps of the international communities are necessary for technical and financial supports to combat the impacts of sea level rise on the country. Helps of technical experts and international development organizations are also essential. Bangladesh is not self-sufficient to face such a large scale problem, either. So, global initiative should be taken to save the country, as it is a global problem, to a greater extent.

7. References

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