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Climate Change and Coastal Zone of Bangladesh: Vulnerability, Resilience and Adaptability

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Abstract: The coastal region of Bangladesh covers about 20% of total land area and over 30% of the cultivable lands of the country. It includes highly diverse ecosystems e.g. the world's largest single tract of mangroves (the Sundarbans), beaches, coral reefs, dunes and wetlands. With its dynamic natural environments, provides a range of goods and services to the peoples of Bangladesh. It is agreed and documented that being a deltaic coastal country, Bangladesh is one of the most vulnerable countries to climate change in the world. Climate-related change in coastal zones embodies potential additional stress on systems that are already under intense and growing pressure. The country has already been facing several climate change effects such as increasing cyclones, flood frequency probabilities, erosion, inundation, rising water tables, salt water intrusion and biological effects. Coastal environments particularly at risk include mangroves, tidal deltas and low-lying coastal plains, sandy beaches, coastal wetlands, estuaries and coral reefs. These bio-geophysical possessions will have consequent effects on ecosystems and eventually affect socio-economic systems in the coastal zone. The Sundarbans, most important ecosystem of the country will be totally lost with one meter rise in sea level. There are two options to minimize the impacts named mitigation and adaptation. It is needed to be considered both mitigation and adaptation options for Bangladesh, even though the country has very limited scope for mitigation. This is why mitigation involves global efforts to execute and adaptation is more local. As a result, effective adaptation policies and mitigation measures ought to be developed and implemented to minimize climate related impacts on Bangladesh.

Key words: Bangladesh % Climate Change % Impacts % Adaptations % Vulnerability

INTRODUCTION

Bangladesh has a 711 km long coastline that consists of a vast network of river systems draining the vast flow of the Ganges-Brahmaputra-Meghna River system [1]. The coastline of Bangladesh (Fig. 1) broadly divided into three regions: the deltaic eastern region (Pacific type), the deltaic central region and the stable deltaic western region (Atlantic type) [2]. A set of connections of rivers originated from the Himalayas flow over the country that carries sediments. The river release on the Bangladesh coastline is heavily loaded with sediments consisting of suspended and bed-load, giving rise to a highly energetic estuary. A total of 35.1 million people live in the coastal zone of Bangladesh in 2001, increasing from only 8.1 million a century earlier [3]. It is anticipated that, the coastal population will be growing to about 41.8 million in 2015 and 57.9 million in 2050 [4]. As per the proposal and decisions of Bangladesh government meetings, coastal zone of Bangladesh consists of 19 districts (Bagerhat, Barguna, Barisal, Bhola, Chandpur, Chittagong, Cox's Bazar, Feni, Gopalganj, Jessore, Jhalkati, Lakshmipur, Narail, Noakhali, Patuakhali, Pirojpur, Satkhira and Shariatpur comprising 147 Upazilas) and the Exclusive Economic Zone (EEZ) [5]. Furthermore, a distinction has been made between Upazilas facing the coast or the estuary and the Upazilas located behind them. A total of 48 Upazilas are exposed to the sea and /or lower estuaries among 12 districts, are defined as the exposed coast and the remaining 99 Upazilas of the coastal districts are

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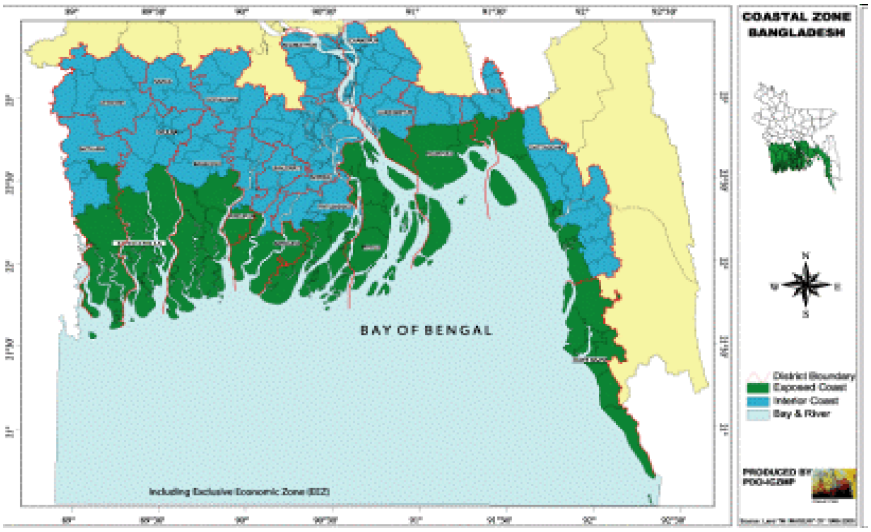

Fig. 1: Coastal zone of Bangladesh (Source: [8]).

termed interior coast [6]. The coastal saline area lies about 1.5 to 11.8 meters above the mean sea level. The estuarine islands are constantly being changed shape and position due to river erosion and new alluvial deposition [7]. These areas are subject to flooding in the monsoon season and water logging in parts of the basin areas in the dry season. The most considerable characteristic of hydrology in relation to agricultural development is the seasonal shallow flooding (up to 90 cm) which affects about 64 % of the total area.

Man made global climate change and associated sea-level rise can have major adverse penalty for coastal ecosystems. Human induced climate change is caused by the increase in CO_2 levels due to emissions from fossil fuel combustion, followed by aerosols and cement manufacture. Other factors, including land use, ozone depletion, animal agriculture and deforestation. The atmospheric concentration of carbon dioxide was about 280 ppm. Today it is about 350 ppm and rising. It was observed that, the supplementary greenhouse gases such as methane and nitrous oxide was increased similarly [9].

This study emphasizes on the vulnerabilities to climate change and the possibilities for adaptation in the coastal zone of Bangladesh.

MATERIALS AND METHODS

This paper is based on available secondary sources (published and grey literature) on the impacts of climate change on coastal zone of Bangladesh. The resources include online publications, books, governmental reports, international reports, scientific journals and news articles that focused on climate change related issues in Bangladesh. Some studies of the same field in other parts of the world were also considered for the task.

RESULTS AND DISCUSSION

Being a low-lying deltaic nation, Bangladesh is enormously vulnerable to climate change. A variety of significant researches in the past investigated the causes of vulnerability of Bangladesh due to climate change [10, 11]. For the most part of the adverse impacts of climate change for Bangladesh are due to sea level rise, cyclones, storm surge, flood, land erosion, water logging, drought, salinity intrusion, bank erosion and tidal bore leading to large scale damages to crop, employment, livelihoods and national economy [12-14]. Bangladesh has been rated as the third most vulnerable country in the world in terms of number of people affected with respect to sea level rise. By 2050, supposing a sea level rise of 27 cm, around 33 million people would be suffering from surging [15]. A 1m rise in sea level would submerge a full 18 % of the total land area in Bangladesh.

Increasing Intensity of Cyclones: It is predicted that global warming will cause an annual temperature rise of 0.4 degrees Celsius in Bangladesh and result in greater frequency and intensity of cyclonic storms. At least 70 major cyclones hit the coastal belt of Bangladesh from the past 200 years [16]. Almost 9, 00,000 people died owing to catastrophic cyclone throughout the last 35 years [16]. The Noakhali-Chittagong Coast received 40 % of the cyclones, which is the most vulnerable area for the

Table 1: Climate vulnerabilities in different areas of Bangladesh

Vulnerabilities	Vulnerable areas	Present status	Risk of aggravation
Cyclones and storm surge	Island and exposed Upazilla	Devastating but seasonal	Increasing
Land Erosion	Meghna and other estuaries, island and other coastal area	Serious localized, Seasonal	Increasing
Flood	Exposed Upazilla	Serious, Seasonal	Increasing
Drainage Congestion	Khulna, Jessore, Noakhali	Localized and year round	Increasing
Salinity intrusion	Western exposed Upazilla	Localized, seasonal	Increasing
Drought	Satkhira	Localized and seasonal	Increasing
Earthquake	Chittagong	Unpredictable	Increasing
Shortage of drinking water and arsenic contamination	All over	Serious and Year round	Increasing
Ecosystem degradation	Marine, Sundarbans	Serious and year round	Increasing
Pollution	Chittagong, Khulna	Serious and year round with cumulative	Increasing
Climate change	All over	Serious and year round with cumulative	Increasing

Source: [8].

Table 2: Major cyclone hits in Bangladesh

Date	Maximum Wind speed (km/hr)	Storm Surge height (Meter)
30 October 1960	211	4.6-6.1
30 May 1961	160	6.1-8.8
28 May 1963	203	4.2-5.2
11 May 1965	160	6.1-7.6
15 December 1965	211	4.6-6.1
1 November 1966	146	4.6-9.1
23 October 1970	163	3.0-4.9
12 November 1970	224	6.1-9.1
25 May 1985	154	3.0-4.9
29 November 1988	160	3.0-4.0
29 April 1991	225	6.0-7.5
2 May 1994	210	2.0-3.0
25 November 1995	140	2.0-3.0
19 May 1997	220	3.1-4.2
15, November, 2007	260	3.0

Source: [18].

landfall of cyclones. The Chittagong and Cox Bazar Coast received around 27 % whereas Khulna /Sundarban and Barisal- Noakhali Coast are fairly less susceptible [17]. Some notable examples of the tropical cyclones are the Bakerganj cyclone of 1876, the 12 November of 1970, the May 1985 Urir char Cyclone and the April 1991 cyclone (Table 1).

Salinity Access: The significantly diminished flow in the dry season allows salinity to penetrate far inland through Meghna estuarine river system. About 53 % of the coastal areas were affected by salinity. Salinity limits opportunities for supplemental irrigation of *Aus* crops in freshwater areas and damages the same crops by flooding during very high tides. The highlands development of saline water throughout the dry season eliminated surface water potentials for significant land areas in the south-central southwest and southeast regions. Salinity is also affecting fresh groundwater. The shallow coastal aquifers have high salinity. Therefore, supply of water wells must penetrate 250 m or more to find water of satisfactory quality. The recharge zones of these deep coastal aquifers in Jessore, Kushtia, Faridpur and Comilla areas and perchance advance north are located away from coastal zones. Activities, such as flood prevention which decrease recharge in these upland areas, will affect the energetic balance within these aquifers between the salt water interfaces, withdrawals and recharge. An environmental terrible circumstance caused by salinity intrusion is a major problem in southwestern Bangladesh. The reduced flow of the Ganges in the dry season has exacerbated the process of northward movement of the salinity front, thus frightening the environmental health of the region [19].

Water Logging and Flood: Several reports mentioned there would be stronger-than-usual backwater effect owing to sea level rise induced high oceanic stage in the coastal areas, therefore retardation of uncontrolled flow, predominantly along the convergence points of the major rivers [19]. As an end result, the risk of riverine and rainfall-induced high intensity floods with prolonged period, as in the case of flood 1998, will increase significantly. Sea level rise along the coastal belt would not only submerge low-lying areas along the coast, moreover it would also create a optimum condition for saline waters to overtop the flood protecting coastal embankments, especially when induced by strong winds [20]. With increased rainfall, both the height and timing of peak flood levels might change [9, 10]. Alam *et al*. [21] examined flood defenselessness of Bangladesh under climate change state of affairs.

Coastal Aquaculture: Stronger flow and tidal bores would raise potential for saline water to overtop coastal embankments. Outside the embankments shrimp farms create earthen mini-polders, locally known as *ghers*, to produce shrimp in imprisonment. High tides would definitely threaten these *ghers* both inside and outside embankments [22]. General rise in surface water temperature would also put shrimps into heat related strain. It is found that, if the temperature crosses a threshold of 32ºC, the post larvae would show very high rates of mortality. All at once, warmer water might appear beneficial for algal bloom- the latter having detrimental effects on growth of shrimps. Climate change can, therefore, put this profitable business into uncertainty.

Climate Change and Sundarbans: The Sundarbans is known to all worlds' largest contiguous mangrove ecosystem with a total area of over 10,000 km^2. Approximately 60% of the Sundarbans fall in Bangladesh, located on the northern limits of the Bay of Bengal and the old Ganges delta. Sundari (*Heritiera fomes*) and the Gewa (*Excoecaria agallocha*) being the dominant species along with at least 69 species of flora. 425 species of wildlife have been identified in the Sundarbans, where 300 species of birds, the remaining were including 42 species of mammals, 35 reptiles and 8 amphibian species [23, 24]. Since the viability of the Sundarbans rests on the hydrology of the Ganges and its tributaries which supply the fresh water influx, climate change is anticipated to have considerable impact on the Sundarbans. In addition to the altered hydrology, sea level rise will also have adverse impacts on the forest following two ways, one is directly through enhanced inundation and another is indirectly by enhancing saline intrusion in river systems. During the dry season the effects of climate change on the Sundarbans would be significantly more dangerous that extends from November to April. Climate models forecasting a decrease in precipitation during this period which might further reduce freshwater flows, which will promote enhanced withdrawals upstream for irrigation. Therefore of salinity penetration in the Sundarbans, majority of the meso-haline areas will be transformed into poly-haline areas, whereas oligo-haline areas would be reduced to only a small pocket along the lower-Baleswar River in the eastern part of the forest. Such a finding closely supports earlier studies [21].

The salinity regime inside the forest will considerably change as a consequence of climate change; it has been argued that increased salinity would have discernable adverse impacts on forest regeneration and succession [21]. Beneath such conditions planting canopy would become sparse and plant height would be reduced considerably. By means of such a dramatic series of anticipated changes in forest vegetation under climate change, the productivity of the forest would be severely constrained. It is demonstrated that, total merchantable wood volume per unit area of forest land decline with increasing soil and river salinity [25]. Preliminary estimates suggested that, desertion of oligo-haline areas combined with decreasing meso-haline areas would result into over 50% loss of merchantable wood from the Sundarbans [21].

Effects on Fisheries and Fishermen: Fish and fisheries have played an important role in the nutrition, culture and economy of Bangladesh from the time immemorial. Presently, about 80 % of the daily animal protein intake in the diet of the people comes from fish. It is anticipated that about 3.5 % of the GDP of Bangladesh is contributed by the fisheries sector. Within the Agriculture sector, approximately 6.9 % of the gross value added is accounted by the fisheries sector. It is estimated that about 2.0 million people are full time employed by the fisheries. There is no study in Bangladesh to calculate climate change-induced susceptibility of the fisheries sub-sector as yet, predominantly on the physiology and ecology of native species of finfish or prawn. It is very difficult to state or predict the likely effects of climate change on different fish or prawn populations without such studies and the fisheries based on them [12]. Nevertheless, it is predicted that SLR will cause a reduction in fish production by reducing the freshwater fishing area. The winter fishing area will be reduced by decreased rainfall and river runoff and increased evaporation during winter. In the coastal the pond culture area will be affected by disturbance of salt water into the ponds unless embankments are made around them. Shrimp farming in the coastal area is a lucrative business, however increasing in salinity is likely to jeopardize it as well [26]. The estimated number of households depending on fisheries-based livelihoods ranges between 140,000 and 160,000 in the coastal zone of Bangladesh. The lives of coastal fishermen have been devastated by repeated and frequent episodes of rough sea events. Many boats have capsized; many fishermen have drowned and lost their lives. Their sagacity of security has been devastated, their lives are at risk. They can no longer train the right to life and right to safe livelihood. The widows are living in awful conditions and their children can no longer exercise their right to education or a healthy family life. Individuals who survived such rough sea events are greatly in debt

and living like fugitives. The rights of all these people have been dishonored already, which has triggered migration from the coastal areas.

Effect on Coral: The coral ecosystems are found around St. Martin's Island in Bangladesh. The rocky sub-tidal seaward margin of intertidal is about 200-600 m offshore support coral community. Corals are also found in the rock pools of lower intertidal. A sum of 66 secletarian coral species, belonging to 22 genera and 10 families, has been recorded from St. Martin [27-29]. All families represent reef forming corals. The great quantity of corals and their cover is low. The coral cover varies from 2-10% of the rocky substrate [29]. Rooted in the quadrant transect survey, the compactness at some selected areas is about 1.3 colony /m^2 [28]. By shifting and overturning substrate boulders cyclonic storms and tidal surge probably cause serious damage to coral communities. Particularly sea level rise, pose significant threats to the whole region of South Asian Seas due to the effects of climate change .Therefore, global warming, the diffusion of heat into the ocean leads to the thermal expansion of the water; this effect, joined with the melting of glaciers and ice sheets, consequences in a rise in sea level. Rising of sea level will not be uniform globally but will vary with factors such as currents, winds and tides; as well as with different rates of warming, the competence of ocean circulation and regional and local atmospheric (e.g., tectonic and pressure) effects. It is anticipated that sea level would rise, on average, about 5 mm /yr, within a range of uncertainty of 2-9 mm /yr [30]. The foremost climate change factor that is becoming increasingly important for coral communities is rising ocean temperatures, which have been occupied in chronic stress and disease epidemics among corals, as well as in the occurrence of increasing numbers of mass coral bleaching episodes. Elevated water temperatures stress corals leading to "bleaching" the exclusion of colorful, symbiotic algae that corals need for reproduction survival and growth [31].

Resilience: The extent to which a coastal system is affected by sea-level rise will strongly depend on its resilience to changes. Non-climate stresses may already have unfavorably affected the coastal systems resilience and thus its ability to cope with additional pressures. Besides, at those places where the coast has been developed and protected by hard infra-structure, landward passage of coastal ecosystems such as wetlands is blocked [32].

Adaptation Against Climate Change: Adjustment to climate alteration includes all adjustments in behavior or economic structure that reduce the susceptibility of society to changes in the climate system [33]. The potential impacts of climate change in coastal zones are reduced by adaptation. Whereas, Bangladesh has no contribution to the greenhouse gas emissions that affect global climate change, it is ironic that it has to suffer so terribly from the effects of climate change those are likely to transpire in the coming decades. As a result, assessment of vulnerability for adaptation from the viewpoint of diverse disciplines which then requires an included approach. Some adaptation strategies are blowing for the coastal area that may be pursued in Bangladesh. There are 3 adaptive options: those are retreat, accommodation and protection. Retreat is not possible by considering the high population density, future population projections, and shortage of land. We must follow the 2 other options. We should also strive to get land from the sea [34]. Regardless of hazard, some suggestions for soft adaptation options were common in all hotspots in Bangladesh, whereas hard measures were often specific to particular areas. For instance, exposures of a community to floods is reduced by building embankments or storms focus on protection and were suggested by populations living in flood and cyclone prone areas; simultaneously, soft measures such as diversifying livelihood opportunities generally were seen as necessary across all hotspots and were tightly aligned with local observations of good development practice. Including Suggestions such as restricting early marriage and polygamy; empowering women and promote female education; and ensuring access to social security. For improving disaster preparedness, a notable proposal was for women to transmit disaster warning information as other women were more likely to heed female voices and take appropriate action.

The intrusion distance of surge water inside Bangladesh is heavily dependent on resistance at the land surface [35, 36]. One of the important sources of such resistance is the forest. The western coastal area of Bangladesh includes a large mangrove forest. Even though that area is almost flat, storm surges for damaging is still much less than it is in other areas that have less mangrove coverage. Therefore, immediate and useful adaptation strategies should be utilized to protect the mangrove forest from denudation and implement a massive afforestation program all along the coastal belt. In fact, Bangladesh has a couple of ongoing projects aiming at that. Stabilizing the land a forestation is

required, generate more accretion leading to more land and also increase the level of topography that will reduce inundation by sea level rise (SLR). Coastal area may also be changed by cropping practices. Varieties of new rice may be developed to withstand higher salinity and higher temperatures and be grown and harvested during the non-cyclonic period. A massive program of constructing cyclone shelters in the coastal area was undertaken in Bangladesh. These particularly built shelters will be used as shelters for human beings, animals and property during cyclonic periods and as community centers, schools and so forth during normal times. Requiring the number of shelters has been calculated on the basis of storm surge heights at the coast and the inland intrusion of surge water. The circumstances may change under the future temperature increase and SLR and in that case the number of shelters requires may have to be revised by considering the various scenarios and actions taken accordingly. By Constructing of embankments in the coastal area is another adaptation and protection measure. Penetration of surge water will obstructed by Embankments; and even if the surge overtops them, the water energy will then be greatly reduced. Involving people at the grass-root level is one of the best ways to adapt to climate change. Bangladeshi people are very enterprising and inventive. They have been living with disasters for a longtime. In Bangladesh, adapting to changing situations is a familiar habitual practice. What is important is to carry out detailed scientific studies, to make the people aware of the impending dangers and to develop, along with them, methods of adaptation.

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