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FEASIBLE AND SUSTAINABLE COASTAL PROTECTION AND ADAPTATION STRATEGIES FOR COASTAL AREAS OF BANGLADESH

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ABSTRACT
Bangladesh has about a 710 km long coastline with the Bay of Bengal at the southernmost part of the country. Due to the dynamic characteristics of the Meghna estuary, geographic location and climatic conditions, the coastal regions of Bangladesh are subjected to a number of challenges every year including coastal erosion, sedimentation, salinity intrusion, tropical cyclone, storm surge, tidal bores etc. This study focuses on formulating a combination of protection and adaptation strategies to mitigate and counteract the current as well as future aggravated coastal challenges due to climate change impacts. The protection strategies include structural interventions such as coastal embankments, hydraulic structures such as regulators, sluice gates, breakwaters, afforestation and bank protection works and soft adaptation measures such as rainwater harvesting, cyclone shelters, etc. The effectiveness of the existing natural protection such as hilly elevated terrain in the southeast coast, mangrove forest in the west, natural forests in the islands at the estuary as well as of the artificial measures such as coastal polders, hydraulic structures, bank protection works, etc. are assessed in this context. The results of this study will be helpful for the policy makers to adopt suitable strategies to counteract the coastal hazards and thus reduce risk to human life, livelihood, agriculture, ecosystem and biodiversity.

Keywords: Coastal Challenges; Coastal Protection; Adaptation; Structural & Non-Structural Measures.

INTRODUCTION
The coastal zone of Bangladesh encompasses a total area of 47,201 km^2, including 19 districts & 47 upazillas(WARPO, 2006) and the exclusive economic zone in the Bay (Islam, 2004). It is home of multiple vulnerabilities. This coastal zone of the country is prone to multiple natural calamities yearly such as floods, tidal bores, cyclones, salinity intrusion, etc. Statistical analysis reveals that Bangladesh is affected by a major cyclone once every 16 years. Some major cyclones in the recent past include: the cyclone of May, 1991, hitting the southeastern coast and causing deaths of about 136,000 people; Cyclone Sidr of November 15, 2007 attacking the southwestern coast of Khulna division and the Sundarbans. Catastrophic cyclonces caused deaths of nearly 900,000 people during the last 35 years. (Islam, 2004). The frequent natural disasters, salinity intrusion and potential of sea-level rise expose the coastal belt of Bangladesh to multiple challenges and threats to human life, livelihood and economy. Besides some natural protective barriers, the coastline of Bangladesh is also protected by about 139 coastal polders, constructed by EPWAPDA (currently known as BWDB) from 1960 to 1970 (Prosoil Foundation Consultant, 2016). The main objective of the coastal polders was to prevent the low-lying land from periodic inundation of saline water during high tides. These polders protect an area of about

1.2 million hectares of coastal land (BWDB 2013). These coastal embankments play an important role in shaping and controlling the coastal morphology of Bangladesh, such as lowering the tidal range by as much as 30 percent, checking the saline water intrusion during high tides, and controlling coastal erosion. But these polders also initiated unintended consequences such as drainage congestion within the polders, siltation of natural drainage channels, reduction in upstream and overbank storage, etc. Due to morphological, land and sea-level changes in the following 50 years, and increased intensity and frequency of the storm surges, effectiveness of many of the polders along with their hydraulic structures is now in question. However, rehabilitation and reconstruction of many coastal polders and their hydraulic structures are currently ongoing under various projects (CEIP-I & CEIP-II). The objective of the study is to assess and identify the problems and limitations of existing protective measures, recommend solutions to problems associated with existing measures and recommend additional measures to mitigate vulnerability to coastal challenges.

METHODOLOGY

This study is mainly based on analyses of secondary data, published papers, reports of various organizationson coastal management issues of Bangladesh. The resources, threats, challenges and management activities of the coast were analyzed. Secondary data of storm surge, tsunami, sea level rise, erosion, salinity intrusion on coastal zone were used for analysis.

ANALYSIS

Coastal Challenges

Coastal zone of Bangladesh has been delineated based on the tidal fluctuations, salinity and storm surge risk [Fig. 1].

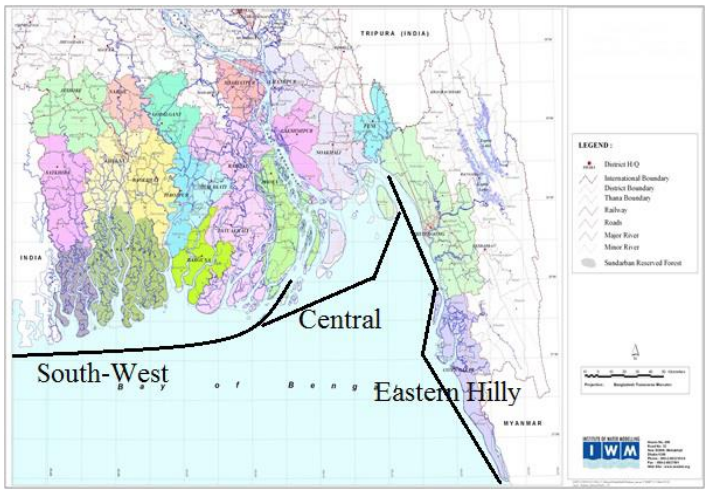

Fig.1: Coastal Zones of Bangladesh (Hasan, 2014)

Around one-third of country's total land area belongs to the coastal zone. The country has been divided into three distinct coastal regions, namely the western, central and eastern regions (Hasan, 2014). The western zone consists of flat and low salt marshes and numerous rivers and channels crisscross this region. The central region is the most active one and undergoes continuous accretion and erosion. The eastern region is protected by hilly uplands and comparatively stable. Sundarbans, the largest mangrove forest, acts as the only natural protection across a significant part of the south-west coastal zone. But the other parts of the coastal area lacks any significant natural protective barrier to dissipate the cyclone energy. The main resources of Coastal zone in Bangladesh are: Mangrove forest, Fish resource, Shrimp culture, Salt farming, Natural gas (2 offshore gas fields out of 22 in country's total), Shipping & water transport (2 sea ports), Ship breaking industry, tourism and recreation. The coastal land use distribution is shown in Fig. 2.

Major coastal problems in Bangladesh are salinity intrusion, storm surge, erosion, drainage congestion etc. In the last fifty years more than 70 coastal cyclones hit Bangladesh and more than 900000 people have died. It has been observed that about 17 percent of the 508 cyclones originated in the Bay of

Bengal hit Bangladesh. (Ahamed et al, 2012). The number of storm surges and its associated death are presented in Fig. 3 and Fig.4 (Rahman & Das, 2016).

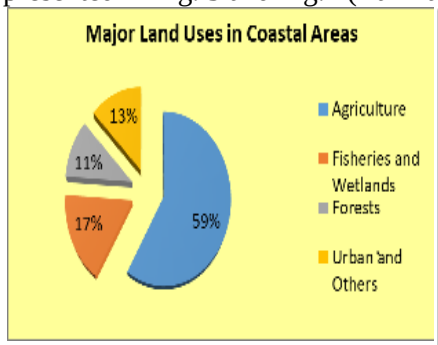

Fig.2: Major land use in Coastal Zone

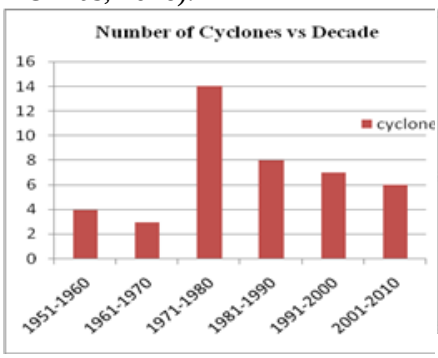

Fig.3: Number of Cyclones in Bangladesh

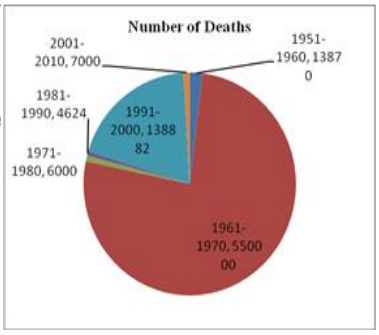

Fig. 4: Number of Deaths from Cyclones

Potential sea level rise induced by global climate change places Bangladesh at a very vulnerable situation. World According to a study conducted by World Bank (2000), the sea level rise was predicted as 10 cm, 25 cm and 1m by the years 2020, 2050 and 2100 respectively, affecting about 2%, 4% and 17.5% of total land area of Bangladesh. Rate of sea level rise was estimated as 1 cm per year according to IPCC 2005.

Various studies (Hasan 2016, Brammer 2014, Sarwar & Woodroffe 2013) conducted on coastal erosion-accretion phenomenon along the Bangladesh coastline based on analysis of satellite imagery reveal the changing landmass along the Bangladesh coastline. However, these studies produce varying results regarding the total eroded or accreted area. But they agree in the facts that, the western coast consisting of Satkhira, Bagerhat, Patuakhali,Barguna etc. are subjected to net erosion, whereas the central coast consisting of Noakhali, Feni etc. are subjected to net accretion due to coastal deposition at the Meghna estuary.

Salinity intrusion is a common problem for all the coastal districts of Bangladesh. However, high amount of fresh river water discharge from the Ganges-Brahmaputra-Meghna basin pushes back the saline seawater in the central coastal region. But during the dry season, in low flow conditions, salinity intrusion towards the land poses a major threat to drinking and irrigation water availability. The freshwater flow is drastically reduced in the dry season due to upstream water diversion and withdrawal from the major river systems. For example, the minimum discharge of the Ganges river decreases by as much as 82% is found during the dry months. (Rahman et al., 2011). As a result, the salinity increases drastically. Salinity intrusion affects the agriculture, natural fish-breeding centres and fresh water supply to the urban and rural areas of coastal zone. Salinity concentration distribution in different parts of the coastal zone is shown in Fig. 5.

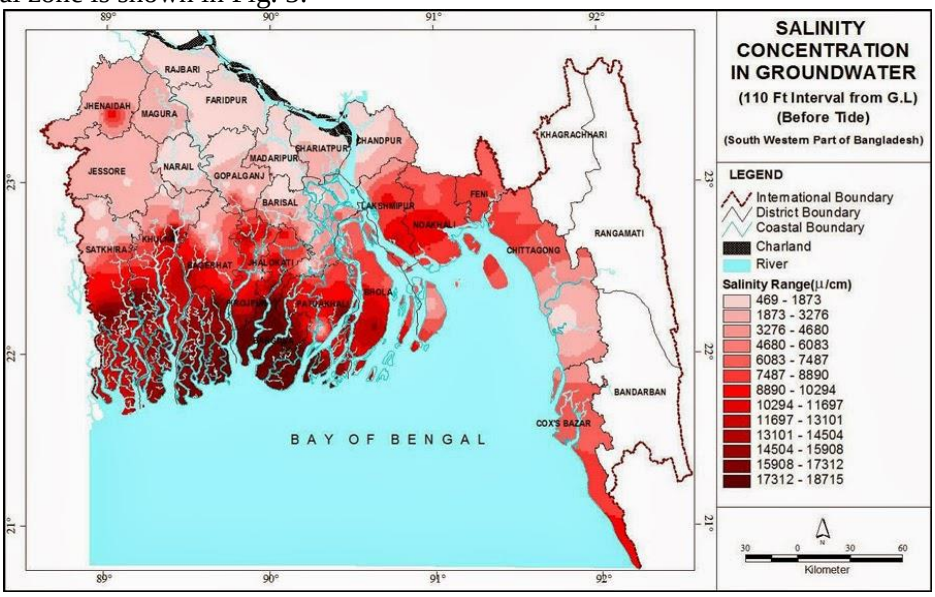

Fig. 5: Salinity Concentration Map in Groundwater in Coastal Areas of Bangladesh
(Source: Hossain & Hasan, 2017)

Coastal Protection and Adaptation Measures

The Storm Warning Center (SWC) of Bangladesh Meteorological Department (BMD) is the responsible authority to provide forecast and early warning of tropical cyclones and storm surges. Various levels of cyclone intensities are indicated by 2 distant signal modules ranging from 1 to 2 and 8 near signal modules ranging from 3 to 10 for sea ports with. The intensity of the cyclones increase from 1 through 10. Two techniques are employed by BMD for tropical cyclone forecasting: (a) Storm Track Prediction (STP), and (b) Steering and Persistence (STEEPER). But neither of these technologies is effective enough to produce fairly accurate forecasts with greater than 12 hours of lead time. For the vulnerable communities, numerous cyclone shelters are constructed to protect against cyclone and associated storm surge. Many schools, community centers and public structures in the coastal areas are designated to be used as cyclone shelters when needed. To protect the coastal community, 775 multi-purpose shelters and 1369 elevated earth mounds for livestock have been proposed to be constructed over the next 15 years in the National Water Management Plan (NWMP). One of the most successful and state of the art initiatives include the Cyclone Preparedness Programme (CPP) undertaken in joint collaboration of Ministry of Food and Disaster Management and the Bangladesh Red Crescent Society. Under this programme, a dedicated team of community volunteers were trained up in coastal and offshore island villages. Eleven coastal districts are covered under the cyclone preparedness programme. Volunteers play a crucial role in the various phases of cyclone disaster management such as: dissemination of cyclone warnings, evacuation, rescue, first aid, emergency relief and usage of radio communication equipment. They are the first line of an early warning system to their communities. As an operational wing of the government's disaster management bureau, the CPP provides scheduled daily weather reports via an extensive high frequency (HF) radio transmitting system operated by volunteers throughout the coastal region of Bangladesh. In addition, government has constructed about 2,400 cyclone and flood shelters along its coastal belt. There is still a requirement to construct a further 1,500 shelters to serve 3.56 million people residing in the high risk coasts. To promote community participation in the construction and maintenance of cyclone shelters, a complimentary disaster preparedness programme has been initiated by the government. Presently, Bangladesh is working on developing a Tsunami Preparedness Programme as an extension to the Cyclone Preparedness Programme.

Coastal afforestation is one of the most useful soft-structural measures. Forests and tree roots provide a protective cover of vegetation that anchors soils, slows and soaks up water runoff. Studies show that coastal forests like mangroves and cypress stands shield the coastlines by reducing wave height and energy. Areas buffered by mangroves were less damaged by the Indian Ocean Tsunami than areas without tree vegetation at 2004. Mangroves trap and stabilize sediment and reduce the risk of shoreline erosion because they dissipate surface wave energy. This attribute makes mangroves a potential natural solution for particular coastal protection problems. (Rahman et. al. 2011).With an aim to enhance coastal environmental sustainability, the Community Based Adaptation to Climate Change through Coastal Afforestation project was undertaken by UNDP from 2009 to 2015. Under this project, total 6372 hectares of land in four coastal districts – Barguna, Noakhali, Bhola and Chittagong were afforested. Such initiative is believed to safeguard life, property and crops from natural disaster, stabilize newly accreted land, promote aquatic ecosystem and habitat. (UNDP 2012)

The chief strategy adopted by Bangladesh Government to protect the coastal areas by constructing the raised earthen embankments or polders, parallel to the shoreline. These polders have proven successful in mitigating salinity intrusion, coastal erosion and storm surge inundation. To permit passage of water inside the polders for irrigation purposes, to facilitate stormwater drainage, and to provide communication of water vessels in and out of the polders, various hydraulic structures such as regulators, flushing sluices, irrigation inlets, boat passes, navigation locks, etc. are constructed within the polders. These are gated structures, which allow the regulation of flows in and out of the polders. The local Water Management Groups or communities are mostly responsible for operation of the gates. However, due to lack of maintenance, in many regulators or sluices, the gate operation mechanism is fully damaged. As a result, they cannot be operated and the local communities do not get the full

benefits of the structures. Moreover, the recent cyclones of SIDR, AILA and Mahasen have washed away or dislodged many gates of the regulators, and the structures require replacement of gate shutters for proper functionality. The current worldwide accepted and adopted concept of structural coastal protection measures include "Living Shorelines", which involve the use of locally available materials and promote the natural coastal processes.The living coastline may consist of rocks, concrete blocks, sand, and marsh plants. There are various such technologies such as breakwaters, revetments, sills, groins, beach nourishment, vegetation etc. which may be adopted depending on the wave energy, wave height, construction cost, availability of materials, and local needs. In major parts of the Bangladesh coastline, sills, consisting of marsh plants with base protection by rocks as shown in Fig. 6 may be a feasible solution. They are easy and cheap in construction, and may be adopted in conjunction with the existing coastal polders, to dissipate the wave energy and mitigate the coastal erosion.

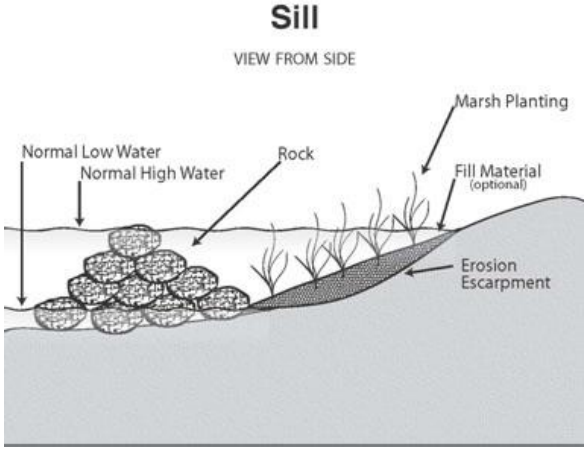

Figure 6: Side View of Proposed Coastal Protection Sill
(Source: North Carolina Department of Environmental Quality)

Salinity intrusion problem is significant in the South-West costal region, which has been further aggravated due to Ganges flow diversion upstream by the Farakka barrage. As a result, the major source of freshwater flow in the south-west coast, the Gorai offtake of the Padma river, receives very little flow in the dry period. Several projects (Gorai River Restoration Project Phase-I & II) were undertaken to ensure diversion of adequate flow from Padma into Gorai. But due to unplanned dredging and low water flow in the Padma, these projects have failed to ensure sufficient water flow in Gorai, and lower the salinity intrusion problem. Even after dredging, several 'Chars' were seen at the river bed, and very little flow was observed in the river during the dry period (The Independent, 2017). The failure of these projects reveal the fact that, a combination of technical and diplomatic aspects, including revisioning the 1996 Ganges treaty need to be adopted to restore the Gorai River.

Although the coastal polders protect, to some extent, against surface water salinity, groundwater salinity is still an unresolved issue. Currently there is no effective regulation or legislation about drilling and extraction from groundwater aquifers. Very little research or data is available regarding groundwater and aquifer characteristics in Bangladesh. Excessive dependency on and extraction of groundwater for agricultural uses promote salinity intrusion. In the current socio-economic and technical setup, conjunctive use, regulation of well extraction, rainwater harvesting could be some potential adaptation measures to groundwater salinity intrusion. For medium term protective measures, well extraction regulations may be adopted based on mathematical model analyses regarding groundwater and saline water interaction. Horizontal well technology, involving injection of fresh/treated wastewater into the saline water interface through a short length of horizontal well, can be a potential technical solution, in changing climate and sea-level rise scenarios.

CONCLUSIONS

Due to the dynamic nature of the coastline and tropical disaster-prone climate of the coastal zone, coastal protection is a resource-intensive challenge for Bangladesh Government. Every year, a considerable amount of national budget has to be reserved for coastal protection measures. This study focuses on the structural as well as non-structural and soft protective and adaptive measures to reduce,

mitigate and recover from the various coastal challenges. Community based disaster management practices have become the most effective and feasible strategy to combat the coastal challenges. Also, involving the stakeholders and local representatives the during the planning stages of coastal management projects significantly increases the sustainability of the proposed interventions. Comprehensive Disaster Management Program (CDMP) has been designed to adopt an umbrella programme approach that encompasses all aspects of risk management and in so doing facilitates to move from a single agency response and relief strategy to a whole of government holistic strategy that addresses the issue of community vulnerability. National Disaster Management Plan undertaken by the Government of Bangladesh defines in broad outline the systemic and institutional mechanisms under which disaster risk reduction and emergency response management is undertaken in Bangladesh. It outlines disaster management vision, strategic goals and conceptual framework. It establishes disaster management regulative and planning frameworks, and identifies priority areas for disaster risk reduction and emergency response management. In the recent years, Bangladesh has been appreciably successful in mitigating the coastal hazards and associated human casualties and destruction of property.

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