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Climate Change Impact and Frequency of Cyclone Surge in Bangladesh Coast: Proper Plan to Address Sustainably

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Abstract: The Bay of Bengal (BoB) is a familiar ground for tropical cyclones. Consequently, cyclone surge and tidal inundation are very common in the Bangladesh coast which causes massive loss of human lives and properties. The present paper is an attempt to delineate the frequency of cyclones in the BoB, and loss of human lives and properties of Bangladesh coast on the basis of published reports, open source data and field checking, and finally to propose an effective way out to protect the area from cyclone surge. This study exposes that the frequency of cyclones in the area increased recently due to rise of global temperature. It further reveals that though the frequency of cyclones is increased, the loss of human lives is significantly decreased. Death toll in the last two decades decreased a lot for similar strength of cyclones comparing to the toll in last thirty or fifty years. Improvement in the early warning system, evacuation plan with proper training and construction of good number of cyclone shelter all over the coastal region are the main reason for this improvement. Though the loss of human lives is significantly reduced, the loss of economic resources in the coastal areas of the country is enormous as in earlier episodes. Therefore, adaptation for the Climate Change effect is needed to expedite with afforestation in the coastal region. Economic loss might also be reduced obstructing the cyclonic surge in the coastal region. Considering the cyclone path and tidal amplitude of cyclonic surge, upgradation or reconstruction of the coastal embankments all along the coast is essential. In this process, it is important to ensure that the tidal channels act as an inlet and outlets all over the coast to keep the natural processes active. An integrated approach including geoscientists, engineers, planners, policy makers, etc. is required to protect the resources as well as proper management of the coastal areas of the country.

Keywords: Bay of Bengal; tropical cyclone; sustainable management.

Introduction

The Bengal delta is one of the largest deltas in the world, which is more or less flat, gently sloping towards the south and merges into the Bay of Bengal (BoB). Before merging, the delta is forming a wide coastal area (Fig. 1). The average elevation of this coast is about 3 meter (m) from sea level (Khan, 2001). This coast is rich in resources and hosts about 35 million peoples. However, some processes like coastal erosion (Ahsan et al., 2009; Islam et al., 2011; Rashid and Mahmud, 2011; Ahsan and Rashid, 2016), sea level rise due to climate change (Milliman et al., 1989, IPCC, 2001, Khan, 2003, Khan and Islam, 2008), water logging (Rashid et al., 2013; Rashid et al., 2016), land subsidence due to unplanned construction of embankments, polders (Rashid et al., 2013; Rashid et al., 2022), upstream barrages (Higgins et al., 2018; Khan, 2010), lack of sedimentation and also compaction of sediments (Rashid et al., 2013; Rashid et al., 2022), saline water intrusion (SRDI, 2001; Asib, 2011; Siddique et al., 2021), cyclone storms related surge and tidal inundation (Murty et al., 1986), etc. are hampering the coastal natural system, peoples living condition and also many times people's life's as well as destroy the resources of the coast. In this coast, the sedimentation rate varies from 1.16-8.1 mm yr^{-1} with a average of about 4.59 mm yr^{-1} (Rashid et al., 2022). The estimated range of relative sea-level rise is 1-9 mm yr^{-1} (Milliman et al., 1989; IPCC 2001; Pethick and Orford, 2013). Therefore, this coast is in vulnerable situation in consideration of sedimentation rate and sea level rise. The present paper focuses on one of the very common and disastrous events of the BoB that occurs almost every year (Fig. 2) i.e. cyclonic storm and its effect on Bangladesh coast. Therefore this study will help to understand the effect of cyclone in the Bangladesh coast, and finally in sustainable coastal area management of the country.

Materials and Methods

Geomorphologically, the coastal region of Bangladesh can be classified into three regions (Khan et al., 2001; Ahsan et al., 2017; Fig. 1). These are the Deltaic coast, the Estuarine coast and the Cliff coast. The deltaic coast, is the main part of the Ganges-Brahmaputra delta, extending east-west and covers the south-west coast of the country. The estuary coast covers mainly the Meghna estuary and is located between the deltaic and the cliff coast. The eastern part of the coast is known as the Cliff coast, located between Chittagong-Cox's Bazar Tertiary hilly region of the country and the BoB, and lies almost in north-south direction. The sediments carried by the three powerful river systems, the Brahmaputra, the Ganges, and the Meghna, gradually formed the delta and estuary (Rashid et al., 2014). Parts of the main estuary are made up of a large number of small and large islands and mouth bars that are irritated by tidal and distributary channels and rivers. The present study mainly based on documents collected from Bangladesh

Meteorological Department (BMD), Bangladesh Bureau of Statistics (BBS) and published reports, open source data as well as subsequent field checking.

Results and Discussion

Frequency of Cyclone

Climate change due to some anthropogenic activities is the real truth of the world (IPCC, 2021). The costs of climate change include melting polar ice, rising sea levels, intense droughts, severe fires, water scarcity, catastrophic storms, flooding, and declining biodiversity. The BoB is the familiar ground for creating cyclone and consequently cyclone surge, and thereafter huge loss of lives, properties and tidal inundation in the coastal areas of Bangladesh. Tropical cyclones hit Bangladesh coast almost every year, though the intensity and severity of disasters and human impacts vary substantially (Sammonds et al., 2021). Alam and Hossain (2003) calculated that the average number of storms and depressions crossing the country in a year is 1.58. But recently its frequency is increasing (Figs. 2, 3). This is a clear indication about climate change effect in the BoB.

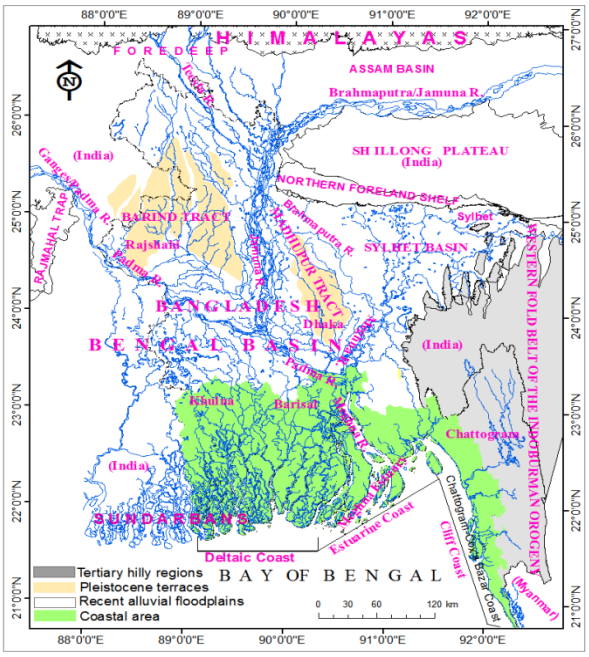

Fig. 1 Major physiographic provinces of Bengal basin and coastal area of Bangladesh.

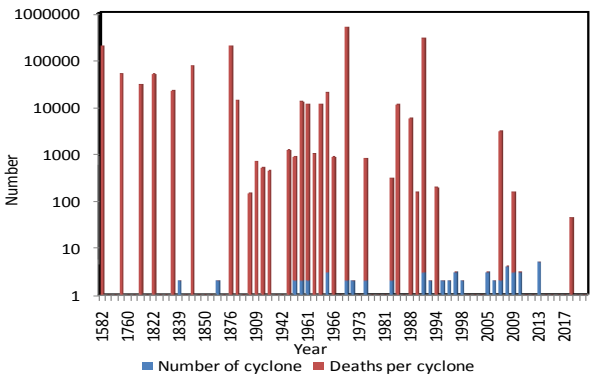

Fig. 2 Frequency of cyclone and casualties in Bangladesh coast.

Casualties and Resource Damage

Historically, cyclones have killed many people of the coast of Bangladesh at different times (Figs. 2, 3). Bangladesh made huge investment in cyclone preparedness, community-based early warning systems, hydro met initiatives, and adaptive delta management, combined with sound structural interventions (Kazi 2020; Sammonds et al., 2021). Thereore, the death toll has dropped significantly in recent times but the loss of properties is still enormous (Figs. 3, 4). For example, cyclone Sidr (Anon, 2008) hit the coast of Bangladesh on 15 November 2007 with winds up to 240 km/hr. It was category-4 storm and tidal waves up to five meters high and surging up to 6 meters in some areas. High winds and floods caused damage to housing, bridges, roads, and other infrastructures. Communication and electricity infrastructures were destroyed, and waterways and roads became unusable. About 2.3 million households were affected. The total economic loss was US$ 1.7 billion, and 3,406 people died, with 1,001 missing and more than 55,000 physically injured. The cyclone Aila hit the country on May 25, 2009 (Anon, 2009). It damaged over 500,000 houses, about 1,000 km of embankments, some 7,000 km roads and crops on more than 123,000 hectares, livestock and other properties in eight districts in coastal areas. The economic loss was about US$ 269.28 million and 179 people died. The cyclone Mahasen (Anon, 2013) hit the country on May 16, 2013. Nearly 49,000 houses were completely and 45,000 houses partially destroyed, and over 1.2 million people were affected and 13 people died. The economic loss was about US$ 35.3 million.

Fig. 3 a) Vast area was inundated due to cyclone Amphan at Nolchira union, Hatiya, Noakhali (Anon, 2020a); **b)** Area was inundated due to damage of embankments of the Kabodak and Shakbria rivers by cyclone Amphan at Koyra, Khulna, Noakhali (Anon, 2020b); **c)** The tress were uprooted and fallen over settlement houses by cyclone Mora (Anon, 2017b); **d)** The tress were uprooted and fallen over settlement houses by cyclone Amphan (Anon, 2020c)

The cyclone Mora (Anon, 2017a) struck the country on 30 May, 2017. About 3.3 million people were affected

and 55,000 houses were destroyed, and 135 people died. The economic loss was about US$ 297 million.

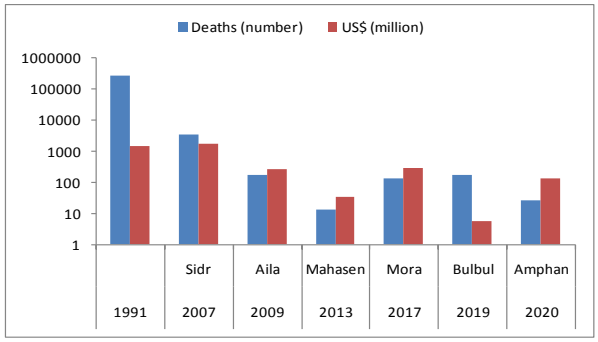

Fig. 4 Casualties and economic loss due to cyclone from 1991 to 2020.

The cyclone Bulbul hit the country on 9 November, 2019 (Raju, 2019). It destroyed 47,000 houses, damaged shrimp enclosures, croplands, and uprooted trees in different areas. Most of the low-lying areas in the coastal districts went under water. The economic loss was about US$ 5.5 million and 179 people died.

Cyclone Amphan (Anon, 2020e; Anon, 2020f) hits Bangladesh coast on 20 May, 2020. Overall, 76 upazilas of 19 districts were affected, where 8 districts were recognized with severe to moderate effect. The death toll was recorded at 266, where 10 millions of people were affected. More than 200,000 homes were completely or partially damaged, including about 176,000 hectares of productive land, including permanent crops and fish / shrimp farms. A large number of people lost their livelihoods. The total cost of damage was US$ 130 million.

Coastal Erosion

Erosion is another risk in the coastal part of the country. Islam et al. (2011) conducted study on the issue of changing the form of the coast of Bangladesh and concluded that about 1121 km^2 of land was eroded from 1972 to 2010. The erosion is taking place mainly in the Sundarbans, Cox's Bazar - Teknaf and Kuakata coast, Kutubdia, Sandwip, Hatiya and Bhola Islands, and it increases further during the occurrence of cyclones (Fig. 5a,b).

Fig. 5a) Severe erosion occurs at Kalatoli beach, Cox's Bazar due to cyclone Mahasen; b) Severe erosion occurs at Kuakata beach, Kalapara, Patuakhali due to cyclone Mahasen.

Embankment Damage and Saline Water Intrusion

Water logging is one of the major problems in Bangladesh coast, especially in the southwestern coastal parts of the country (Rashid et al., 2013). During cyclone surge as well as spring high tide, the coastal areas are submerged by saline tidal water and hamper the crops production. Therefore, in 1960s and 1970s, coastal embankments were constructed in the areas to protect from tidal saline water. These activities successfully protected the areas from saline tidal flooding and land worthy of cultivation. However, due to embankments and poldering, the sedimentation by regular tidal activities as well as during monsoon from the upstream could not take place in the tidal and fluvio-tidal plains. The sediments deposited within the channels (Rashid et al., 2016; Rashid et al., 2022). Moreover, due to upstream barrage (Higgins *et al.,* 2018; Khan, 2010), in the dry season, the flow of water from the upstream is very low, especially in the southwestern rivers or distributaries of the Ganges. Therefore it also further enhances the tidal sedimentation into more landwards within the channels during dry season through flood tide from the BoB. Due to these activities, most of the tidal channels of the southwestern coastal areas of the country are gradually congesting and many of them have already abandoned due to channel sedimentation rather than in the tidal and fluvio-tidal plains. On the other hand, the tidal and fluvio-tidal plains are going below the sea level day by day due to lack of sedimentation and compaction of sediments. As a result, during monsoon when heavy rainfall occurs, the excess water cannot pass through the channels which causes water logging in the areas. Rashid et al. (2013) stated that the water logged areas in the southwestern coastal parts of the country are gradually increasing during last few decades. Moreover, recently, the frequent cyclone storms and related tidal surge further delicate the situation. Because, in most parts of the coast, the embankments along the rivers are very weak (Fig. 6a, b) and it can not protect the flood water. Furthermore, many embankments and polders are damaged or destroyed during cyclone surge and tidal saline water inundated the areas (Fig. 6b, c). In some cases tidal water overtopped the banks of the rivers and inundated the areas, and thereby long time water logging (Fig. 6d), as the water can not easily pass through the abandoned or congested tidal channels. In many cases the river bed is higher than the height of nearby plain lands due to channel sedimentation and at the same time lack of sedimentation in the surrounding plains. The Bangladesh Soil Resources Development Institute has shown that during 1973 to 2000, about 0.170 million hectares (20.4 percent) of coastal land was affected by salinity (SRDI, 2001). At present crops in different parts of the coastal area cannot give proper yield. Agriculture is the main sector of the economy of Bangladesh and more than thirty percent of the total cultivable land is in the coastal areas. Among the 2.85 million hectares of coastal and off-shore land, about 1.05 million hectares of arable land was affected by

various levels of salinity (Asib, 2011). The whole coastal area is suffering from freshwater crisis due to salinity. Salinity is also found in deep tube well water in the area.

Fig. 6 a) Weak embankment at the right bank of the Kabodak river at Pratapnagar, Asasuni, Satkhira; **b)** The collapsed embankment of 35/1 polder of Water Development Board (WDB) in Sharankhola upazila of Bagerhat by Cyclone Amphan (Anon, 2020d); **c)** A broken road submerged in water due to cyclone Amphan (Islam, 2020a); **d)** Saline water overtopped the river banks due to cyclone Amphan (Islam, 2020b).

Conclusion

It is concluded that the embankment should be wide enough with sufficient height considering the tidal amplitude during cyclone surge. The embankment should be covered with vegetation to protect erosion. The appropriate slope must be maintained and also distances from the main channel need to be carefully maintained to protect it from surge. More cyclone shelters need to be constructed to protect human and livestock during the cyclones and surges.

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