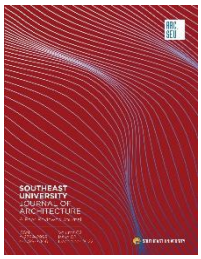

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Bengal Delta: the Definition, Boundaries and the Anthropogenic Aspects

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ABSTRACT

Bengal Delta is one of the largest river delta in the Bengal region of Bangladesh and India. Two Himalayan rivers the Ganges and the Brahmaputra which drain into the Bay of Bengal together, carry the largest amount of sediment and contributed to the world's biggest delta. This delta construction operations lead to the creation of Bangladesh or the land of Bengal. Bangladesh occupies the major part of the delta. Bengal delta has its own ethnicity and cultural diversity. The objective of this study is to identify the boundaries of the Bengal Delta through interpretations of secondary sources. The methodology of this study focuses on the review of the published literature and historical evidence for a clear understanding. The boundary of the Bengal Delta sometimes coincides with the boundaries of the Bengal Basin and Bangladesh. They are related to each other, there are significant differences among them. Bengal Delta consisted of an environment where land and water meet and where the boundaries between these elements are in constant flux. The topography of the Bengal Delta acts as a social and economic resource that shaped many anthropogenic aspects.

1. Introduction

The Bengal Delta is a river delta in the Bengal region of the Indian subcontinent, consisting of Bangladesh and the Indian state of West Bengal. It is the world's largest delta and empties into the Bay of Bengal the combined waters of several river systems, mainly those of the Brahmaputra river and the Ganges river. Bengal Delta is also known as the Brahmaputra Delta, the Sunderbans Delta or the Ganges-Brahmaputra Delta. It is also one of the most fertile regions in the world, thus earning the nickname 'The Green Delta'. The delta stretches from the Hooghly River on the west to the Meghna River on the east.

Two Himalayan rivers, the Ganges and the Brahmaputra, which drain into the Bay of Bengal as a combined river, carry with it the largest amount of sediments. Together, these two rivers have contributed to the world's biggest delta, known as the Ganges-Brahmaputra Delta or the Bengal Delta (Schendel, 2009, Rashid, 2020a). However, although these two rivers had previously debouched separately to the Bay of Bengal, they are now combining into the bay before eventually emptying. These river delta construction operations lead to the creation of Bangladesh or the land of Bengal (Rasid and Paul, 1993). The Bengal Delta is the largest delta in the world (Mertes and Dunne, 2007). It drains almost all of the Himalayas, the most sediment-producing mountains in the world, through the three main river systems: the Ganges, Brahmaputra, and Meghna (Figure 1). These systems carry the world's largest sediment load, more than 1 billion tons of sediment every year, of which nearly 80% is delivered during the four monsoon months (Auerbach et al, 2015, Rashid 2022).

Bengal delta has its own ethnicity and cultural diversity as well as the human settlement pattern (Rashid, 2020a, Rashid, 2020b). The boundary of the Bengal Delta sometimes coincides with the boundaries of the Bengal Basin and Bangladesh, but though they are related to each other, there are significant differences among them.

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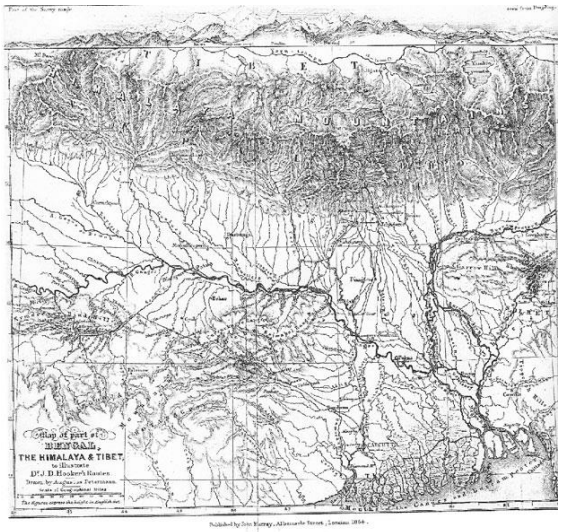

Figure 1: Map showing the Himalayas and the water regime of the Bengal Delta. (Source: J.D. Hooker, 1854).

2. Objectives and Methodology

The objective of this study is to identify the boundaries of the Bengal Delta through interpretations of secondary sources, which are focused on different geo-climatic and ethnographic studies on it. Also to find the relationship between the Bengal Delta, Bengal Basin and Bangladesh is another objective of this study.

The methodology of this study focuses on the review of the published literature for a clear understanding of the definition of the Bengal Delta where the Bengal Delta has been considered as the context of geo-climatic and anthropogenic studies and research. Historic interpretation of the secondary sources of documents and maps is used as the tool for this study. By this study, an attempt is made to explain the definition and boundaries of the Bengal Delta and also give a conceptual basis for the anthropogenic aspects of the Bengal Delta.

For this study, authentic secondary sources of data included books, historic maps, journal articles, documented conference proceedings, degree-awarded dissertations, government publications, publications by Non-Government Organizations and valid internet sources. Review of secondary source materials provides an understanding of boundaries and definitions of the Bengal Delta. Through analysis, an attempt was made to define Bengal Delta, Bengal Basin and Bangladesh.

3. Geo-climatic Characteristics of the Bengal Delta

The Ganges Delta has the shape of a triangle and is considered to be an "arcuate" (arc-shaped) delta. It covers more than 105,000 km2 (41,000 sq mi), and although the delta lies mostly in Bangladesh and India, rivers from Bhutan, Tibet, India, and Nepal drain into it from the north. Approximately 60% of the delta is in Bangladesh and, 40% in West Bengal, India. Most of the delta is composed of alluvial soils made up of small sediment particles that finally settle down as river currents slow down in the estuary. Rivers carry these fine particles with them, even from their sources at glaciers as fluvioglacial. Red and red-yellow laterite soils are found as one head farther east. The soil has large amounts of minerals and nutrients, which is good for agriculture.

It is composed of a labyrinth of channels, swamps, lakes, and floodplain sediments (chars). The Gorai-Madhumati River, one of the distributaries of the Ganges, divides the Ganges Delta into two parts: the geologically young, active, eastern delta, and the older, less active, western delta. (Chowdhury et al, 2012)

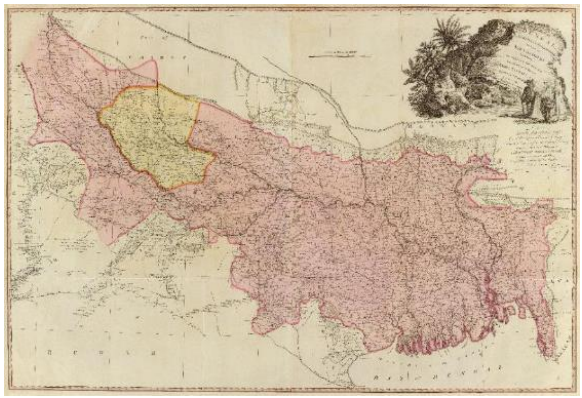

Figure 2: Map following the Ganges River by James Rennell in 1786 (Rashid, 2022).

The overall deltaic coastline can be generalized as the western inactive or old delta and the eastern active Meghna deltaic plain (Figure 2 and 3), in conjunction with the occupation of several river courses and shifting depocentres. Although the inactive old delta is relatively ancient, the plain of the Meghna delta is geologically very new. Bengal Delta is bordered to the west by the Indian Shield, to the north by the southern margins of the Barind Tract and to the east by the Tippera Surface. The delta's main progradation is continuing to the South-South-East into the Bay of Bengal (Figure 4).

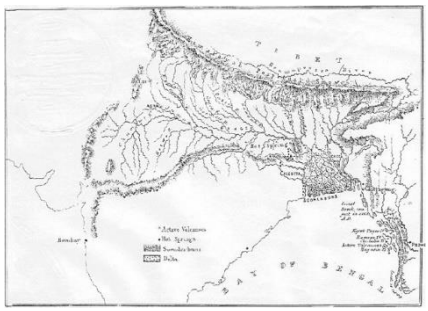

Figure 3: Map showing the geological setting of the Bengal Delta. (Source: The Calcutta Review, March 1859)

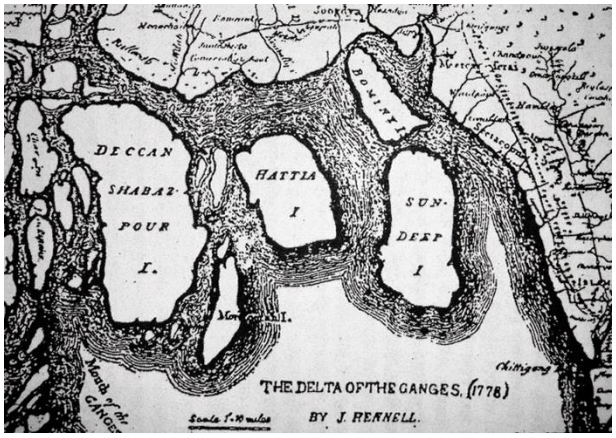

Figure: 4. The delta of Ganges drawn by Surveyor J. Rennell (1779)

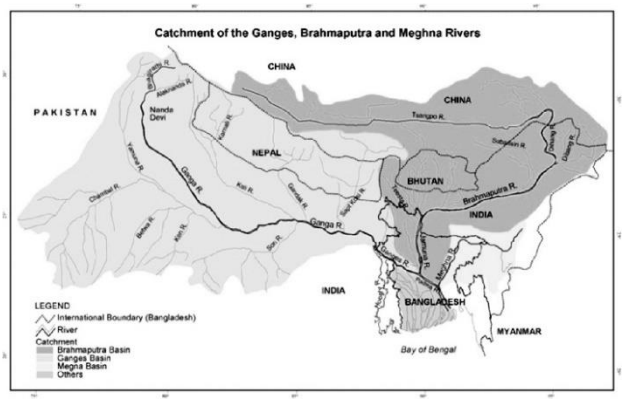

Figure 5: Location map of the Ganges, Brahmaputra, and Meghna catchments. (Source: CEGIS, 2010)

Bangladesh occupies the major part of the basin (Figure 5). Geographically, the basin is the entire lowland, which is bounded by the Shillong Plateau on the north, the Burma Arc foldbelt on the east, the Bay of Bengal on the south, and the Indian craton on the west (Steckler et al., 2010). The basin is separated from the Chittagong region by the Feni River. The geology of the Bengal Delta is mostly characterised by the uplifting of both the Himalayan Mountains to the north and the frontal belt of the Indo-Burman Range to the east, tectonic subsidence, and refilling by rivers that has progressed towards the south. The basin comprises Tertiary highlands, the Barind and Madhupur Tracts as uplifted deposits of the Pleistocene (Morgan and McIntire, 1959), and the Comilla Terrace of the Holocene (Goodbred and Kuehl, 2000). These are the natural controls that regulate river course shifting or avulsion (Goodbred and Kuehl, 2000).

3.1 Geological setting of the Bengal Delta

A nuanced and long-term perspective on the environmental history of the Bengal Delta should take into account the spatial specificities of the ecological regime of north-eastern South Asia: high mountain peaks, the deltaic plains and the vast coastline of the Bay of Bengal. A key feature of the landscape of the region is the combined river system of the Ganges, Brahmaputra and Meghna rivers, together constituting the largest delta on earth (Figure 6). These rivers, winding in innumerable branches through the delta and emptying into the Bay of Bengal, carry the highest proportion of sediment of any world river system, amounting to about 25 per cent of the world total. It is estimated that some 40,000 million cubic feet of silt settle in the deltaic plain on their journey to the Bay of Bengal, creating enormous areas of new land, known as chars and diaras. Diaras and Chars often first appear as thin slivers of sand. On this is deposited layers of silt till a low bank is consolidated. Tamarisk bushes, a spiny grass, establish a foot-hold and accretions as soon as the river recedes in winter; the river flows being considerably seasonal. For several years the Diara and Char may be cultivable only in winter, till with a fresh flood either the level is raised above the normal flood level or the accretion is diluvated completely (Rashid, H 1991, cited by Iqbal 2010).

The process of sedimentation reaches its peak during the annual monsoon downpour. At the same time, the ocean currents are impeded by the heavy outflow from the rivers, and in turn deposit a huge amount of sand in the coastal region. Thus a double process of land-making continues amidst the mutual confrontation of silt-laden rivers and the sand-carrying sea. This process of land formation has been encouraged by various species of mangrove, which have facilitated the consolidation of the shoreline through natural succession. (Blair 1990).

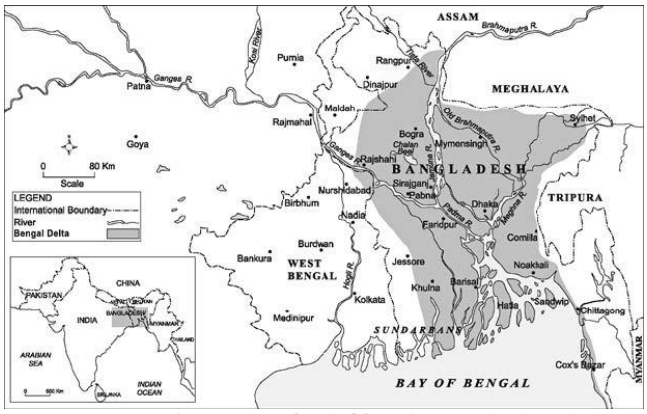

Figure 6: Map of Bengal and neighbouring territories. (Source: Iqbal 2010)

3.2 Bengal Delta as a Land of Water and Silt

The delta is huge because almost all water running off the Himalayas, the highest mountain range on earth, has to pass through it (Figure 7). On the southern side, numerous rivulets and rivers run together to form the mighty Ganges that flows eastwards through India for hundreds of kilometres before it enters western Bangladesh, where it is also known as the Padma (Steven 1978). On the northern side of the Himalayas an equally majestic river, the Brahmaputra (or Tsangpo), forms in Tibet. It too flows

east, past the capital, Lhasa, and then makes a sharp turn, breaking through the mountains into the far north-eastern corner of India. It then flows west till it enters northern Bangladesh, where it is known as the Jamuna. It joins the Ganges in central Bangladesh and together they empty into the sea. Both rivers are truly gigantic: the Ganges is up to eight kilometres wide and the Brahmaputra spreads to the improbable width of eighteen kilometres. (Schendel, 2009)

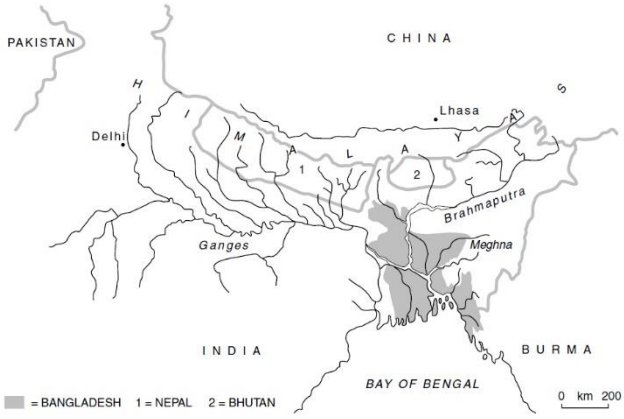

Figure 7: Map of the catchment area of the Bengal delta. (Source: Schendel, 2009)

There are many more rivers criss-cross Bangladesh. A third giant is the Meghna, which enters Bangladesh from the east, and over fifty other rivers flow from India across the border into Bangladesh. They join, split and join again in a crazy pattern of channels, marshes and lakes. In historical times there has been a tendency for the water to be discharged through more easterly channels and for the western reaches of the delta (now in India) to become drier. Together these many rivers have deposited very thick layers of fertile silt that now form one of the largest river deltas on earth. Not all the silt ends up in Bangladesh, though. Every year, over a billion metric tons are delivered to the Indian Ocean, building up the world's largest underwater delta, the Bengal Fan. The Bengal delta is surrounded by higher land and hills to the east, north and west; it acts as the narrow end of a funnel through which an area more than ten times its size annually discharges a mind-boggling 650,000,000,000m3 of water. And almost all this silt-laden water flows through the delta between May and October, when the rivers are in spate. These huge forces have shaped the natural environment of Bangladesh, and they continue to exert an enormous influence on human life today. But majestic rivers are not the only source of water. There are two other forms in which water has always played a vital role in Bangladesh: rain and seawater. Each year in June, as the rivers are swelling rapidly, the skies over Bangladesh begin to change. In winter they are blue and hardly any rain falls, but in late May or early June, as temperatures shoot up, immense clouds form in the south. As they float in from the sea they release torrential downpours that continue off and on till late September.

The wet monsoon has arrived, and in this part of tropical Asia it is truly spectacular. Not only may rains continue for days on end, turning the soft soil into a knee-deep muddy slush, but the sheer amount of water being discharged over Bangladesh is impressive. It is rain that has made Cherrapunji a household word among meteorologists the world over. This little village just across the border between north-eastern Bangladesh and India claims to be the world's wettest place. Here the monsoon clouds hit the hills of Meghalaya in a downpour that continues for months. Annually a staggering 11 metres of rain fall here; the maximum rainfall ever recorded during a 24-hour period was over 1 metre (Schendel, 2009).

Seawater is a third companion of life in Bangladesh. During the dry season (October to May), saline water from the Bay of Bengal penetrates watercourses up to 100 km inland and the lower delta becomes brackish. In addition, the lower delta is very flat: its elevations are less than three metres above sea level. As a result, it is subject to tidal bores from tropical cyclones that make landfall here about once a year. These are particularly hard on the many islands and silt flats that fringe the coast of Bangladesh. Some protection is provided by the Sundarbans, a mangrove forest that used to cover the coastal delta but has been shrinking since the eighteenth century as a result of human activity. This largest mangrove forest in the world is not impervious to the power of tropical storms, however. In 2007 it took a direct hit when a cyclone raged over it, destroying much vegetation.

These three forms of water – river, rain and sea – give Bangladesh a natural Janus face. In winter, the rivers shrink in their beds, the skies are quietly blue and saline water gently trickles in. Nature appears to be benign and nurturing. In summer, however, nature is out of control and Bangladesh turns into an amphibious land. Rivers widen, rains pour down and storms at sea may hamper the discharge of all this water. The result is flooding (Bandyopadhyay 2004).

4. Bengal Basin, Bangladesh and Bengal Delta

One of Bangladesh's physiographic units is the Ganges-Brahmaputra delta. The region is almost plain ground, with elevations ranging from 15 meters in the north to almost one meter in the south. The gradient on the surface of the delta is around 0.016m / km (Figure 8). In Khulna, Barisal, the southern part of Faridpur and the eastern part of the Noakhali district, the average elevation of the delta is less than two meters. Bangladesh's Bengal delta region is densely populated, with agricultural activities prevalent due to the high fertility of the land. In terms of land cultivation, fishing, navigation, common property resources (e.g. from the Sundarbans mangrove forest), and other economic activities, the livelihood of most people depends on the environmental conditions of the delta. In this wide and constantly evolving delta, continual land accretion and erosion affect the lives and life of people, the pattern of settlement and the socio-cultural structure of

Bengal Delta (Schendel, 2009). Historically, this region now called Bangladesh is emerging from continuous land accretion towards south and south-east (Paul and Rasid, 1993). Interpreting the geo-climatic conditions and the historic records, it may be safely assumed that the present active delta presents a similar context available thousands of years ago in its northern plains.

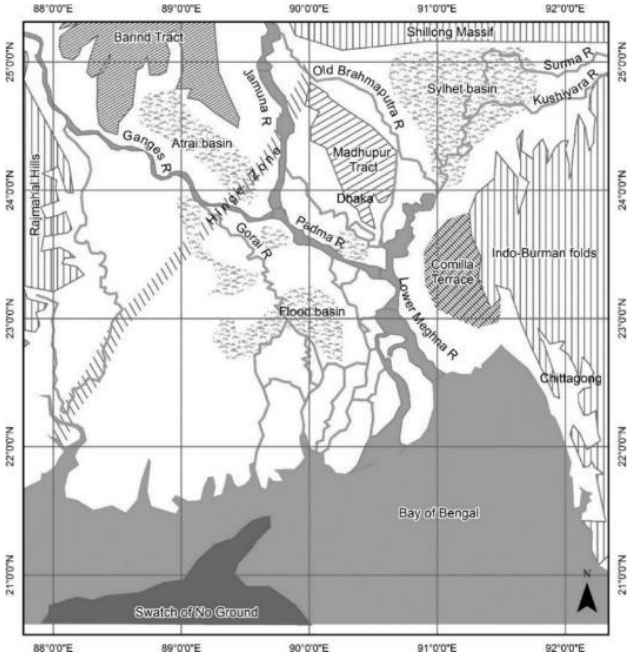

Figure 8: Geological setting of the Bengal Delta. (Source: Akter et al, 2016 cited in Rashid 2022)

The Bengal basin is one of the most important alluvial basins of the world because of its size and location distributed within the political boundaries of Bangladesh and a part of India (Banglapedia, 2017). A large area of the Bengal Basin, which comprises the total territory of present-day Bangladesh, encompasses the Bengal Delta (Lindsay et al, 1991; Goodbred, 1999). The Ganges–Brahmaputra–Meghna River Delta is located in the Bengal basin (Morgen and Mclntire 1959; Goodbred and Nicholls 2004). The Ganges–Brahmaputra–Meghna (GBM) River Delta is also called the Ganges delta or Ganges–Brahmaputra (GB) river delta, Green delta or Bengal delta (Bagchi 1944; Goodbred and Nicholls 2004; Islam 2006) (Figure 9). Three powerful rivers-The Ganges, the Brahmaputra and the Meghna in Bangladesh portion formed and created the new active delta by the sediment deposition. (Goodbred and Kuehl 1999). The delta in Bangladesh and West Bengal of India occupies an area of about 115,000 km² (Woodroffe et al. 2006). The natural flow and annual flooding of the rivers bring the silts and sediments and as a result, the delta begins to expand into the coastal zone and offshore areas (Bagchi 1944; Goodbred and Keuhl 1999). The livelihood of the Bangladesh portion of the Bengal delta depends on the supply of fresh water in the downstream Ganges (Padma-in Bangladesh portion) (Rahman 1988; Khan et al. 2008, Khan 1996, Rashid 2022).

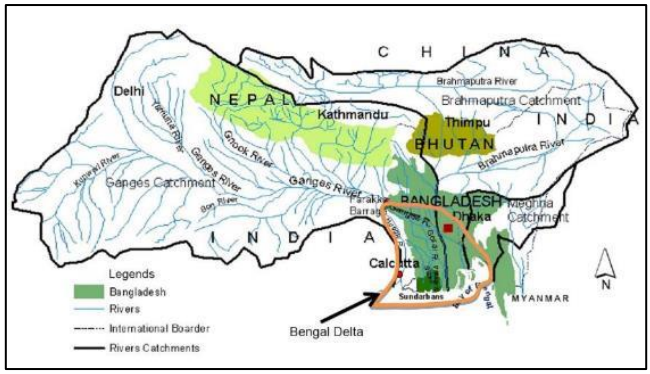

Figure 9: Geographical location of the Bengal Delta, Bangladesh and the GBM catchments (Source: Islam and Gnauck 2008 cited in Rashid 2022)

5. Anthropogenic Aspects of Bengal Delta

Rivers have nurtured civilization throughout human history (Hefny and Amer, 2005). The Nile River allowed Egypt, known as one of the oldest agricultural civilizations and a sedentary agricultural society, to develop thousands of years ago. The Nile River and its delta have been altered by anthropogenic intervention that has turned a prograding delta into an eroding coastal plain (Stanley, 1996). The agricultural-based civilization was initiated based on the fertile lands of delta and tidal plains. Similarly, to produce more food from floodplains and tidal plains and to make social life safer, the people of Bangladesh started to intervene in the natural systems in primitive ages. Those early interventions in the delta could not negatively affect the natural system, because they were not significant in terms of altering the flow and sediment regime. Over the centuries people made earthen dykes with their limited efforts to protect their homes and homesteads from tide and salinity intrusion. However, during the last century, large-scale interventions in the river systems have been made in the South West region of Bangladesh to improve communication networks, increase agricultural production, and enhance safety in the coastal environment.

According to Akter J, Sarker M. H, Popescu I and Roelvink D. (2016), in the first half of the 20th century, during the British regime, several alterations were made to maintain or improve the navigation in the riverine delta- at that time the main mode of transporting goods and passengers. The British connected different rivers such as the Gorai-Madhumati with the Nabaganga at the beginning of the 20th century and excavated canals such as the Heliflax cut, MBR, Gabkhan Canal, and Mongla-Ghashiakhali Canal. The Heliflax cut, made in 1910 to shorten the distance from Dhaka to Khulna, connected the Madhumati River with the Nabaganga River. As a consequence, a significant amount of flow of the Madhumati River started to be diverted through the Nabaganga River. After excavation of the 23-km MBR during 1910–12, part of the Arial Khan River flowed into the Madhumati River.

Gabkhan Channel was excavated in 1918 to connect the Shandhya River of the Pirojpur district and the Sugandha River of the Jhalakati district with a view towards reducing the navigation distance by around 118 km. Several other modifications to river courses were made in early 20th century during the British regime. Then the Bangladesh Inland Water Transport Authority excavated the Mongla-Ghashiakhali Canal, which was opened for navigation in 1974, to reduce navigation distance. All these connections modified the flow and sediment in the South West region of Bangladesh. Other additions, such as construction of railways and highways transversely crossing the flood plain, also restricted free flow of floods over the terrain.

In the second half of the 20th century, changes in the delta plain and in the catchments upstream of the delta were enormous. Several flood embankments and polders were constructed in the floodplain and tidal plains of Bangladesh in the 1960s and 1970s, aiming to protect flood and grow more food by improving water management, on the basis of the recommendations from the master plan for what was then the East Pakistan Water and Power Development Authority (EPWAPDA), prepared by the International Engineering Company of San Francisco in 1964. Those coastal polders limited the flooding on the tidal plains by restricting the tide from entering the tidal plain. After construction of the polders under flood control and irrigation projects, people initially benefited. However, after coastal embankment projects, especially in the South West region of Bangladesh, the adverse effects were enormous. Several tidal channels died within a few years to a few decades, drainage congestion become severe in many of the embanked polders even as tidal amplification increased flooding of the unintervened tidal plains, and riverbed sedimentation deteriorated the navigability of many important navigation routes. The tidal amplification could sometimes be disastrous, such as seen in the effects of the cyclone Aila (2009) in the South West. These are common features in the Satkhira, Jessore, Khulna, and Bagerhat districts. Different studies found that tidal amplification and sedimentations in the riverbed occurred because the tidal prism was cut down by the coastal embankment. The tidal river management concept (creating a tidal basin for an increasing tidal prism in the tidal channels; EGIS, 1998) has become popular, although numerous constraints in the implementation process exist. Moreover, the Bangladesh Water Development Board has recently been working to improve coastal embankment projects, considering an expected SLR of 0.5m over the next 50 years and subsidence 12 mm/y.

Other than the internal human-induced changes, intensive agricultural practices, such as deforestation, and construction of dams and barrages for storing and diverting water in the catchment of the G-B Rivers, such as Farakka Barrage on the Ganges, occurred beyond the international border (Mirza, 2004; Mirza and Sarker, 2005; Sarker, 2004). Those interventions have also contributed to change the flood, sediment, and dry season flow regimes of Bangladesh. Low flow during dry season causes an increase in salinity intrusion further upstream. Therefore, manmade changes both within and outside the country and ongoing natural processes are acting on this delta, along with continuous adjusting and combating of SLR and changed sediment and flow conditions.

Human settlement has occurred for thousands of years. More recently, settlements grew and were influenced by trade, ports and shipping. Kolkata become a major port, partly under European influence over the last few hundred years (Schendel, V., 2009). As the general regional population expanded by the late 18th century, dikes and dams were required to hold back flood water from the river, prevent salinisation and provide agricultural lands, via conversion from mangroves (Islam, 2006, Kausher et al., 1996). Management intensified in the late 19th century where landlords continued to build and improve upon small embankments. In 1948 the delta was split between two countries: India and East Pakistan (now Bangladesh). Significant impacts to control river flow and reduce salinity intrusion were not made until the 1960s when the Coastal Embankment Project in what is now Bangladesh initiated the building of a larger, planned network of earthen embankments (Kausher et al., 1996). Funded by the World Bank and other organizations, the aim was to create land to satisfy agricultural production for the growing population, and hence to increase well being. The land was polderised and drained. However, by the 1990s, adverse effects were noted, including drainage congestion inside and heavy siltation outside of the polders in south-west Bangladesh. This made some of the land unsuitable for agriculture (Islam, 2006). A lack of siltation on the delta plain due to embankments, compounded by subsidence, meant that land levels lowered (Figure 10). For example, Auerbach et al. (2015) found that after five decades of polderisation, the difference in height between natural and artificial landscapes equated to approximately a metre, or an average 2 cm/yr. This is an order of magnitude greater than global sea-level rise over this period. Now, remedial projects have tried to better facilitate the coastal zone and its land use policies (Islam, 2006), most recently by the World Bank Coastal Embankment Improvement Program (World Bank, 2015).

Figure 10: A settlement of Bengal Delta. (Source: Rashid, 2022)

In Bangladesh the natural environment has never been a mere backdrop against which human history unfolded. On the contrary, time and again natural forces have acted as protagonists in that history, upsetting social arrangements and toppling rulers. For example, in the 1780s an earthquake and floods forced the Brahmaputra river into a new channel, wiping out villages in its course and causing trade centres along its old channel to collapse. More recently, in 1970, the mishandling of cyclone damage robbed the government of its legitimacy and precipitated a war of independence. And floods in 1988 cost Bangladesh more than that year's entire national development budget.

6. Conclusion

Deltas are important dynamic environments that are constantly reshaped and reformed. Worldwide, they are home to hundreds of millions of people, including many large and growing cities. They contain intense ecosystem services and economic activities that support these populations and often rapid economic growth. Environmental change is widespread including in the catchments and the deltas themselves (e.g. through reservoir creation, dredging and channelling to control water availability or reduce flood risk).

Floodplains dominate life in Bangladesh – they cover about 80 per cent of the country – but not all of Bangladesh is flat. On the eastern fringes some steep hills surrounding the delta have been included in the national territory and they provide an altogether different terrain. These hills (in the Chittagong Hill Tracts and Sylhet) point to geological processes occurring far below the smooth surface of Bangladesh. Here tectonic plates collide: both the Himalayas and the Bangladesh hills (and beyond these the mountains of Burma and north-east India) are fold belts resulting from these collisions. The faults running underneath Bangladesh also push up or draw down parts of the delta, creating slightly uplifted terraces that look like islands in the floodplain (notably the Barind in the north-west and Madhupur in central Bangladesh) and depressions (haor or bil) that turn into immense seasonal lakes.

Managing the natural environment has been a central concern for all societies and states that have occupied the Bengal delta. The people of Bangladesh have never been able to lull themselves into a false belief that they controlled nature. They live in an environment where land and water meet and where the boundaries between these elements are in constant flux. As a result, settlement patterns have always been flexible and often transient. Bangladeshi villages have been considered as elusive. They are not clustered around a central square, protected by defensive walls or united in the maintenance of joint irrigation works. Instead they consist of scattered homesteads and small hamlets (para) perched on slightly elevated plots that become islands when moderate floods occur. Few dwellings are built to last, and traditional irrigation requires hardly any joint organisation because it is largely rain-fed. As the lie of the land changes in the active delta, villagers are often forced to relocate and rebuild their houses. Thus nature's changing topography acts as a social and economic resource, and the mobile and fragmented nature of settlement has shaped rural politics. Bangladeshi villages are not tightly organised communities under a single village head. Instead, they are dominated by continually shifting alliances of family and hamlet leaders. States seeking to control the rural population have always had to find ways of dealing with this flexible pattern of power sharing adapted to life on the frontier of land and water.

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