CENTURY-SCALE DYNAMICS OF THE BENGAL DELTA AND FUTURE DEVELOPMENT

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ABSTRACT

While most of the large deltas in the world are suffering from sediment starvation, the Bengal delta is prograding at a substantially high rate. The progradation expedites the shifting process of delta building estuaries as well as their associated distributaries, which play an important role in the eco-system of the delta by influencing the salinity, sediment and also the flooding pattern. A future projection of the delta shifting is essential for long-term development planning of the delta. This article reports the findings of a preliminary investigation using available data. Historical maps, time-series satellite images, digital elevation maps based on topographic surveys of the 1950s and 1990s, as well as water level and hydrographic surveys have been used for the investigation. During the last two hundred and forty years, the main delta building estuary has changed its location as well as the associated distributaries. It has been observed that huge sediment generated from the 1950 Assam earthquake expedited the shifting processes. However, due to lack of time-series and reliable data, quantification of the shifting process is not possible. It also makes future projection more uncertain. Nevertheless, it can be assertained that delta shifting processes, especially shifting of the distributaries towards the southwest direction will continue in the coming decades, which is very much relevant for long-term planning of the delta.

Keywords: *Bengal delta, delta progradation, long-term development, Meghna estuary, delta shifting, distributaries*

1. INTRODUCTION

Deltas are the habitats of more than half a billion of the world's population (Syvitski *et al*. 2009). Most of the deltas in the world suffer from sediment deficiency and coastal erosion due to human interventions, such as construction of a large number of dams, water diversion structures and improved sediment management. Moreover, the deltas are vulnerable to climate change and global sea level rise. It is suspected that the Bengal delta would be the worst victim of climate change (Ahmed, 2006). Unlike other large rivers in the world, the catchment of the Ganges-Brahmaputra rivers are less disturbed by human interventions. These rivers drain both the northern and southern slopes of the Himalayas, which are the most sediment producing mountains in the world and thus the rivers transport more than a billion tons of sediment every year. As a result, the delta is being prograding and the rate of progrdation in the last five decades has been 17 km^2/y along the Meghna estuary (Sarker et al., 2011).

The Bengal delta is a tide-dominated delta, i.e. tides play an important role here in the sediment dispersal processes. Huge knowledge has been generated on river dominated deltas, especially the

Mississippi delta, but little is known on the morphological processes of the tide-dominated deltas (Hori and Saito, 2007) A number of research studies have been carried out on the Holocene development of the Ganges-Bramaputra (Goodbred and Kuehl, 2000 a&b; Allison et al., 2003, Kuehl et al., 2005). However, research on the century-scale development of the delta is sparse. Enhanced knowledge on the century to decade-scale development processes of the Bengal delta and its response to the different exogenous and indigenous factors has become essential for improving the lives and livelihoods of the people, as well for facing the threat of climate change and sea level rise. This article describes the dynamics of the Bengal delta for the last two and a half centuries along with the responses of the delta to different factors, and projects the probable future developments.

2. SETTING THE SCENE

The Bengal delta is one of the largest deltas in the world. The sediment carried by the Ganges, Brahmaputra and Meghna rivers has contributed to the present size of the delta which is about 100,000 km^2. The Brahmaputra and Ganges rivers drain the northern and southern slopes of the Himalayas, the most sediment producing mountain range in the world. Most of the water equivalent to one trillion m^3, and sediment equivalent to one billion tons per year are delivered into the Bay of Bengal through the Lower Meghna River, which is a combined flow of the Jamuna, Ganges and Meghna rivers (Figure 1). The annual average flood discharge along the Lower Meghna River is 90,000 m^3/s and minimum flow is close to 4,000 m^3/s. About 80% of the sediment entering into the Meghna estuary is silt and clay, and the rest is fine sand.

There are two major distributaries that contribute in transporting fluvial inputs, water and sediment into the bay other than the Lower Meghna system. The Gorai, a right bank distributary of the Ganges River delivers about 30 billion m^3 of water and 30 million tons of sediment to the bay annually (EGIS, 2001). Several years ago, two large distributaries, the Bhairab and the Kabodak, also played an important role in the delta building processes. The perennial connection of these distributaries from their parent river the Ganges however, became disrupted a couple of centuries ago (Williams, 1919). The Arial Khan River, a right bank distributary of the Padma River, which is the combined flow of the Ganges and Jamuna rivers, supplied about 30 billion m^3 flow and 25 million tons of sediment every year.

Presently, the delta building processes are continuing in the Mehgna estuary area. There are three major distributary channels, Shabajpur, Hatiya and Tetulia, through which a major part of the water and sediment enters into the system. In addition, there are several other southwesterly aligned right bank distributary channels that carry fresh water and sediment to the central part of the delta. One of these distributary channels is the Shandhya which takes off from the joint flow of the Lower Meghna and Arial Khan rivers and finally merges with the large Baleswar estuary. It is now the main fluvial source for the estuary. There are two other large estuaries, the Bishkhali and the Burishwar, that are also connected with the Tetulia Channel through southwest aligned distributary channels.

Tides are semi-diurnal along the coast of the Bengal delta and the average tidal range varies from 1.5 m in the west to more than 4 m in the northeastern tip of the Meghna estuary (MESII, 2001). Huge tidal energy thus redistributes the sediment within the delta, which enters mostly with the monsoon flow into the bay and estuaries.

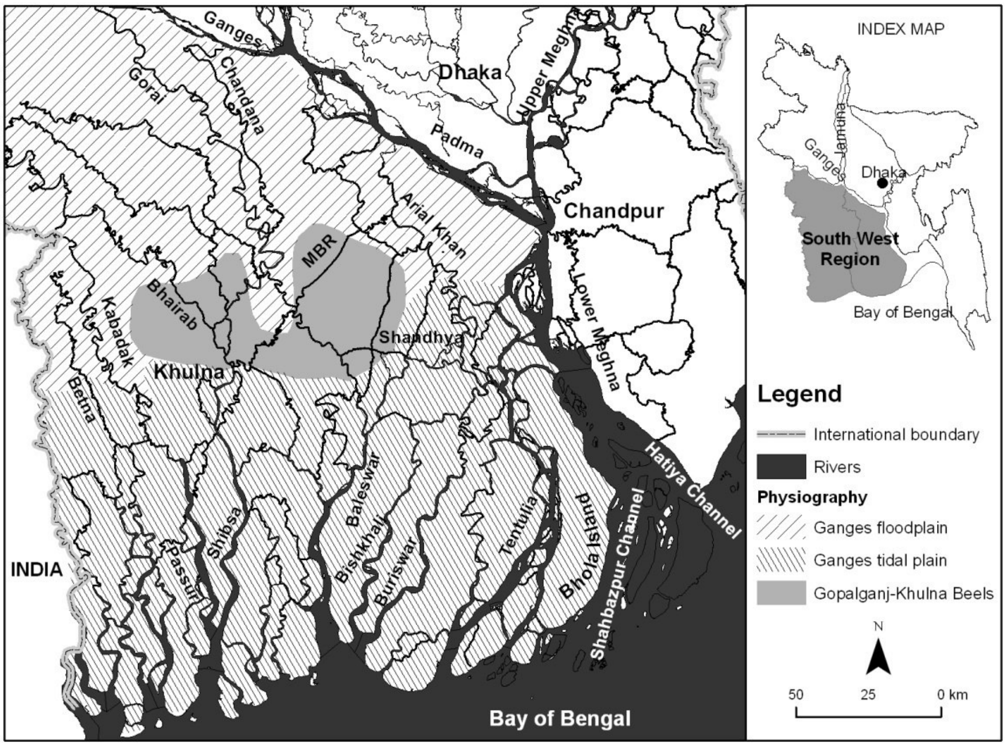

Figure 1: Present river system in the southwest region of Bangladesh

3. APPROACH

This research has been a preliminary investigation of the century-scale development of the Bengal delta based on knowledge on the Holocence development of the delta and information gathered from the analyses of historical maps, satellite images, digital elevation models (DEM), time-series water level data and recent knowledge on the morphological processes of the fluvial system in the Bengal delta. The delta dynamics have been assessed by comparing the changes in river courses from historical maps and their directions associated with delta building processes. The observed changes have been interpreted in conjunction with the delta progradation and changes in topography due to the progradation. Future projection of the delta could not be done by simple extrapolation of the past. The effects of extreme natural events such as the sediment pulse due to the 1950 Assam earthquake and human interventions in the system have been assessed.

4. HOLOCENE EVOLUTION

Several studies on river evolution in the Holocene period were carried out by Fergusson (1863), Williams (1919), Umitsu (1993), Goodbred and Kuehl (2000a and 2000b) and Allison et al. (2001). Among those the most comprehensive account of the development of the Ganges-Brahmaputra (GB) delta from the late Quaternary and extending through the Holocene was presented by Goodbred and Kuehl (2000 a&b); Allison et al. (2003); Kuehl et al. (2005). Their account was based on further borehole data they collected themselves, as well as from Umitsu (1993) and other sources. Based on the compiled data, they developed palaeo-geographic maps

(Figure 2) of the Ganges and Brahmaputra (GB) delta during the Holocene. They concluded that changes to the courses of the Ganges and the Brahmaputra were a consequence of the delta building process, which was itself driven by abundant sediment input from erosion of the Himalayas, conditioned by sustained sea-level rise that began during the Late Quaternary, and modified internally by regional tectonics within the Bengal basin. The paleo-geographic maps show the shifting of the Ganges River from west to east and the avulsion of the Brahmaputra River occurred several times between the east and west sides of the Madhupur Tract.

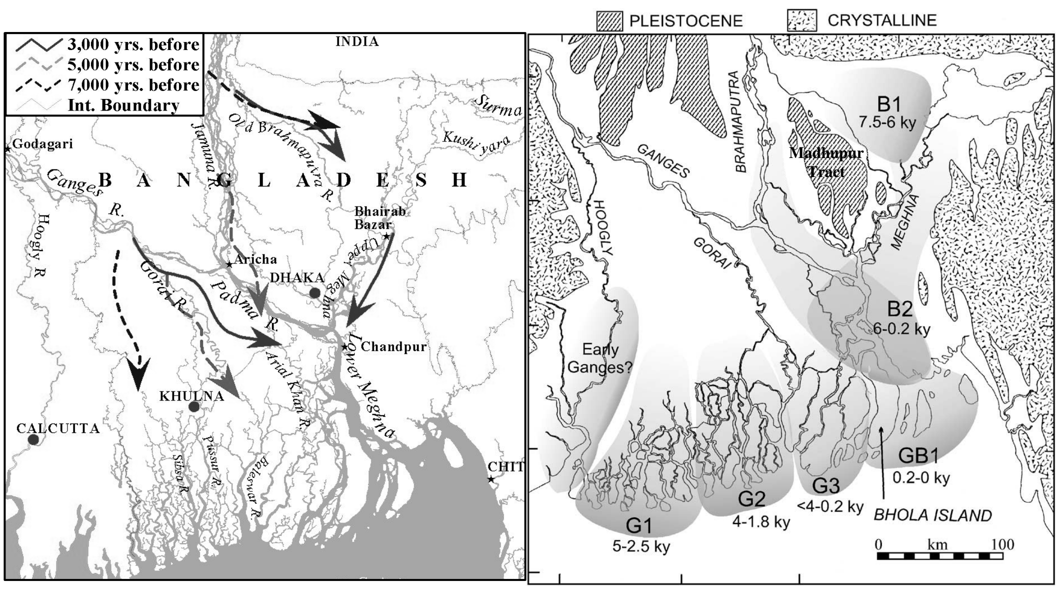

Figure 2 : Map of (A) Paleo-geographic map after Goodbred and Kuehl (2000a) and (B) the pathways and timing of the phases of late Holocene growth of the lower delta plain associated with the Ganges (G1, G2, G3), Brahmaputra (B1, B2), and combined Ganges–Brahmaputra (GB1) after Allison *et al* (2001).

Allison et al (2001) have examined the mineralogical properties of sediment for assessing sedimentary sequence resulting from the lower delta plain progradation in the late Holocene. A total of 38 core sites were selected in the Sundarbans, Kuakata and Hatiya/Noakhali. Clay mineralogical and radio-carbon evidence from that study agree that the lower delta plain progradation after the maximum transgression may have been in five phases (Figure 2). The earliest phase (G1), which was formed by the Ganges, took place in the westernmost delta. Clay mineralogy from this area shows an increasing influence of the Ganges at the upper section that may suggest a progradation of Ganges distributaries into this area. The early (5,000 cal years BP) deltas of the Brahmaputra (B1) and the Ganges were located far inland of the present shoreline as there was an enormous amount of accommodation space available in the tectonically active Bengal basin. They have also found that the shoreline progradation associated with the two rivers was separate after 5000 cal years BP until they merged into the present Meghna estuary about 200 years ago. A series of eastward stepping formed by the Ganges was among three main phases (G1-G3). Delta progradation in each phase took place over a wide front that encompassed several active island-shoal complexes. On the other hand, delta plain formation of the Brahmaputra took place inland along two loci created by channel avulsions east and west of the Pliestocene Madhupur terrace. The Sylhet basin, in the east of the Bengal delta, faced southward into the Meghna estuary following the Meghna River course. Delta progradation into the Meghna estuary

(GB1) becomes limited until they meet the historical times from west to east. This progradation direction matches well with the finding of Goodbred and Kuehl (2000).

5. EVOLUTION OF THE DELTA DURING THE LAST CENTURIES

In line with the evolution of the river system during the Holocene, the rivers have changed their courses several times during the last centuries. About 250 years ago, the Brahmaputra River flowed through the east side of the Madhupur Tract to the meet the Meghna River, occupying the easternmost corridor and finally fell into the Bay of Bengal keeping Bhola district on its west. Till then the Padma River was simply the downstream continuation of the Ganges River. At that time, the Ganges, presently the Padma, entered the Bay of Bengal approximately along the present course of the Arial Khan River keeping Bhola island on its east (Figure 3). All the distributaries in this region along with the Ganges River were flowing southeast in that period. The Chandana-Barasia, a south-east flowing river, was the main source of sweet water for the southwest region with a small link with the Gorai River. The Kabodak River was connected by a narrow link with the Ganges.

In the natural system, a single change may induce a series of many other changes. When the Brahmaputra avulsed to the present Jamuna in the early 19th century and merged with the Ganges, it caused many significant changes to the river systems of the southwest region of Bangladesh.

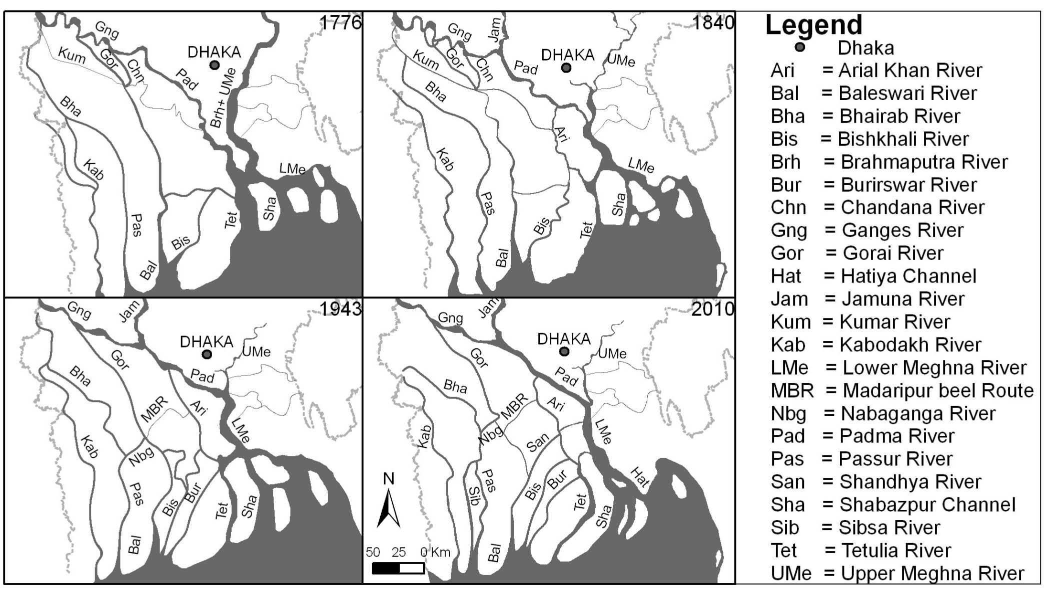

Figure 3: Development of the main rivers in Bangladesh over time

Tassin's map (1840) shows that a significant amount of the Brahmaputra flows was diverted to the present Jamuna River to meet the Ganges. The combined flow met the Meghna at Chandpur through a course named "Kirtinasha". The old course of the Ganges, the Arial Khan River, had become the right bank distributary of the Ganges River. It is believed that the joining of the Jamuna to the Ganges had raised the water level in the Ganges River, which led to the enlargement of the Gorai (Ferguson, 1863). The southeast flowing Kumar River was dissected by the course of two big south flowing rivers, the Gorai-Modhumati and the Chandana-Barasia. By this time, the

Meghna estuary had started to develop the delta on the east side flowing in the southeast. The Shahbajpur channel in the estuary was found to be small compared to the Lower Meghna.
By the early 20th century, most of the Brahmaputra flow was diverted to the Jamuna River. Consequently, most of the Padma flow was also diverted to the Meghna River abandoning its old course. In that period, the Meghna estuary was at its most easterly aligned. The main flow of the Lower Meghna River had started to divert through the Shajbajpur channel. Both the Meghna and Shahbajpur channels attained equal width and several new right bank distributaries started to flow in the southwesterly direction. During this time, the Chandana River turned into a much smaller river while the Gorai turned into an important distributary.

Many interventions were implemented in the river system during the early twentieth century, such as the Helifax Cut, the Madaripur Beel Route (MBR) etc. 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, a part of the Arial Khan River flowed into the Madhumati River.

In the last few decades, considerable changes have been observed in the river systems and their distributaries. The eastern Meghna branch of the Meghna estuary totally dried up and subsequently the western distributary, Shahbajpur channel became enlarged. Several right bank distributaries from the Meghna and Arial Khan rivers developed in the southwesterly direction, such as the Bisarkand-Bagda Khal, the Tarki Khal, the Nunda-Otra, the Belua, the Shyandha and so on. A few other small rivers are still developing in the southwest direction. By this time, most of the Gorai flow had diverted to the Nabaganga River.

The major changes during the last 250 years in the Bengal delta are the avulsion of the Brahmaputra River from the east of the Madhupur Tract to its present course and its joining with the Ganges at Aricha. Instead of two separate estuaries, it became a unified delta building estuary during this period and shifted to its most easterly course. During the late 18th and early 19th century all the distributaries and the main course of the Ganges flowed in the southeast direction. There were enormous changes in the 20th century, a few of which were induced by human interventions. The Gorai-Madhumati had started to divert its flow through the southwest flowing Nabaganga River. A part of the flow of the Arial Khan River was diverted to the MBR. These two changes were human induced, but it was also supported by the topography of the delta. The major natural changes inlcuded shifting of the delta building estuary to the west, progradation of the delta by several tens of kilometers towards the south and development of several southwesterly distributaries from the Lower Meghna and the Arial Khan.

6. TOPOGRAPHY

Two sets of DEMs have been used for characterizing the topography of the delta. The resolution of the DEM, generated from agricultural maps of 1950s collected from the National Water Resources Database (NWRD) and FIN maps of 1990s collected from the Integrated Coastal Resources Database (ICRD), are 300m and 50m respectively. The DEM of the 1950s covers the whole of Bangladesh, except the Sunderbans, the Madhupur jungle and the Chittagong Hill Tracts. The DEM of the 1990s only covers the coastal part of Bangladesh. These two DEMs however, show similar characteristics of the delta. For assessing the changes in topography over a period of four decades the 50m resolution DEM of the 1990s has been normalized to 300 m resolution for better comparison with the 300m DEM of the 1950s.

The topography of the delta is characterized by a very gentle slope and a large part of the delta lies 2m below the PWD datum, which is equivalent to about 1.5 m above Mean Sea Level (MSL) (Figure 4). Based on elevation, the southwestern part of the delta, bounded by the international border in the west, and the Ganges, the Padma and the Lower Meghna rivers on the north and east sides can be characterized into three distinct features. The elevated areas at the northwestern tip has a higher gradient and mainly consists of the Ganges floodplain (Brammer, 1996). Next to this unit, there is a southwest to northeast aligned stretch of low lying area having minimum elevation below MSL, which is classified as the Gopalganj-Khulna beels. This depression is dissected by recent and old courses of the rivers. River courses from the west margin are the Betna, the Kabodak, the Bhairab and the Madhumati. This depression was clearly marked in Rennel's map (1976). Two remarkable changes occurred here – although the course of the Gorai-Madhumati passed through the depression it was not able to raise its levee and the Gopalganj depression was extended up to the south of Barisal.

The southernmost areas along the coast consist of the Ganges tidal plain at a higher elevation than the Gopalganj-Khulna beels. The terrain has a reverse slope to the south. Elevated lands are in the east and south.

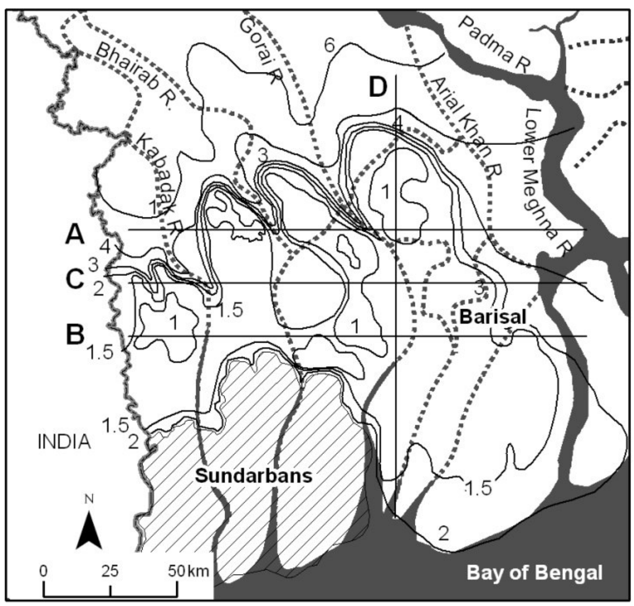

Figure 4. Contours of elevation are in mPWD based on the DEM of the 1950s and the river courses based on the 1943 map are shown by dashed line

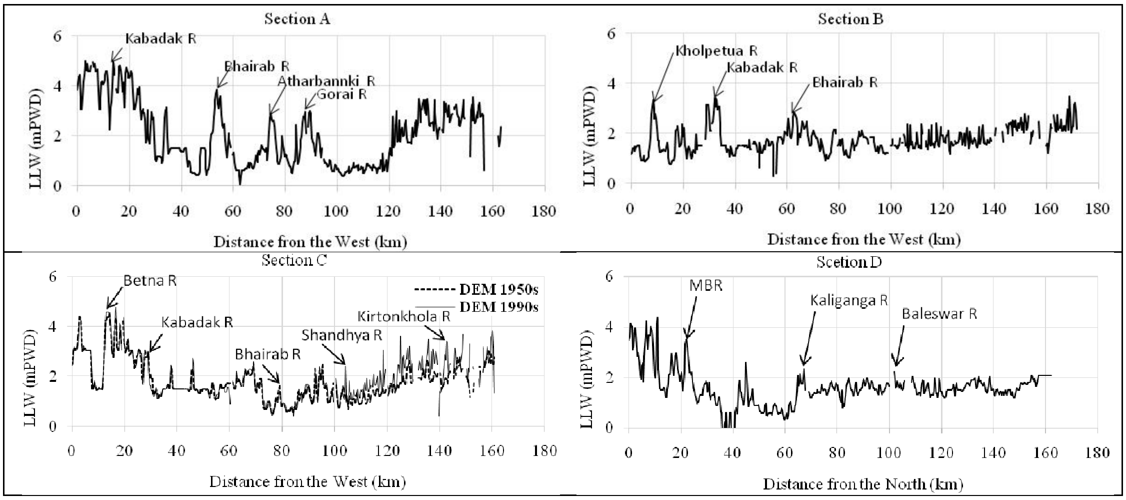

Figure 5. Terrain cross-profile Section A, Section B, changes in elevation along Section C from the 1950s to the 1990s and north and south cross-profile along Section D (sections are shown in Figure 4)

The west to east aligned section passing through the Gopalganj Khulna beels (Figure 5, Section A) shows the Ganges floodplain at its 20 km long west margin and the Gopalganj-Khulna beels, where the Bhairab, Atharobanki and Gorai-Madhumati rivers dissected the depression. Section A also shows the wide and elevated ridge formed by the Arial Khan and the Lower Meghna rivers. Mimimum elevation of the beel is close to 0 mPWD i.e. below MSL. Elevation of the Ganges Floodplain is about 5 mPWD, where the wide ridge formed by the Arial Khan and Meghna Rivers is 3 mPWD as per the DEM of the 1950s.

Section B, 20 km south of Section A, which starts from the western margin of Gopalganj-Khulna beels, is dissected by the Kholpatua and Kabadak rivers. The rest of the section, however, is in the Ganges tidal plain, where the difference between the natural levee and tidal basins is less compared to that in the depression areas. Elevation of land along the section in the tidal plains does not vary in a wide range. However, it shows higher elevation in the east close to the wide ridge formed by the Lower Meghna system.

The north-south aligned Section D starts from Active Ganges floodplain, where the elevation difference between the ridges and flood basin is very high, more than two meters (Figure 5, Section D). Elevation of the Gopalganj depression is below 0 mPWD, indicating that the minimum level is more than 0.5 m below MSL. The natural levee of the Kumar River at the upstream end of the MBR dissects the depressions. In this section, the natural levee of the Madhumati River is the boundary of the Gopalganj-Khulna depression. The rest of Section D, however lies in the Ganges tidal plain, having a very flat terrain elevation of below 2 mPWD.

Comparing the DEM of the 1950s with that of the 1990s, it can be observed that there is almost no change in elevation in the western part of the section i.e. in the Ganges floodplain and Gopalganj-Khulna beel areas. The rising of elevation is pronounced at the eastern margin of the section at the wide ridge formed by the Arial Khan and the Lower Meghna River. The average rise of elevation of the 40 km eastern length is 0.30 m. Delta progradation during the period might have contributed to rise in the level of the floodplain. This rise of the elevation may also trigger the development of the Shandhya River, the course of which is very close to the alignment of this section.

7. ROLE OF THE 1950 EARTHQUAKE

Comparing the changes from the late 18th century to the mid 20th century, it can be observed that the changes during the last six decades have been very large (Figure 6). Sarker et al. (2011) showed that net accretion in the Meghna estuary was 750 km^2 in 167 years, while it has been 1700 km^2 during the last six decades. The delta along the Meghna estuary, especially along the Shahbajpur Channel has prograded several tens of kilometers. The map of 1943 indicates that at the northern tip of Bhola island the Lower Meghna divided into three distributary channels; the eastern branch itself was the Lower Meghna River, flowing by the side of the then Noakhali town, while the middle distributary was the Shahbajpur channel and the western distributary was the Tetulia channel. The map of 1943 also indicates that the upstream flow coming through the Lower Meghna River diverted through three large distributaries at the northern tip of Bhola Island. After abandonment of the eastern distributary, upstream flow diverted mainly through the Shahabapur and Haitya channels, 50 km downstream of the previous location.

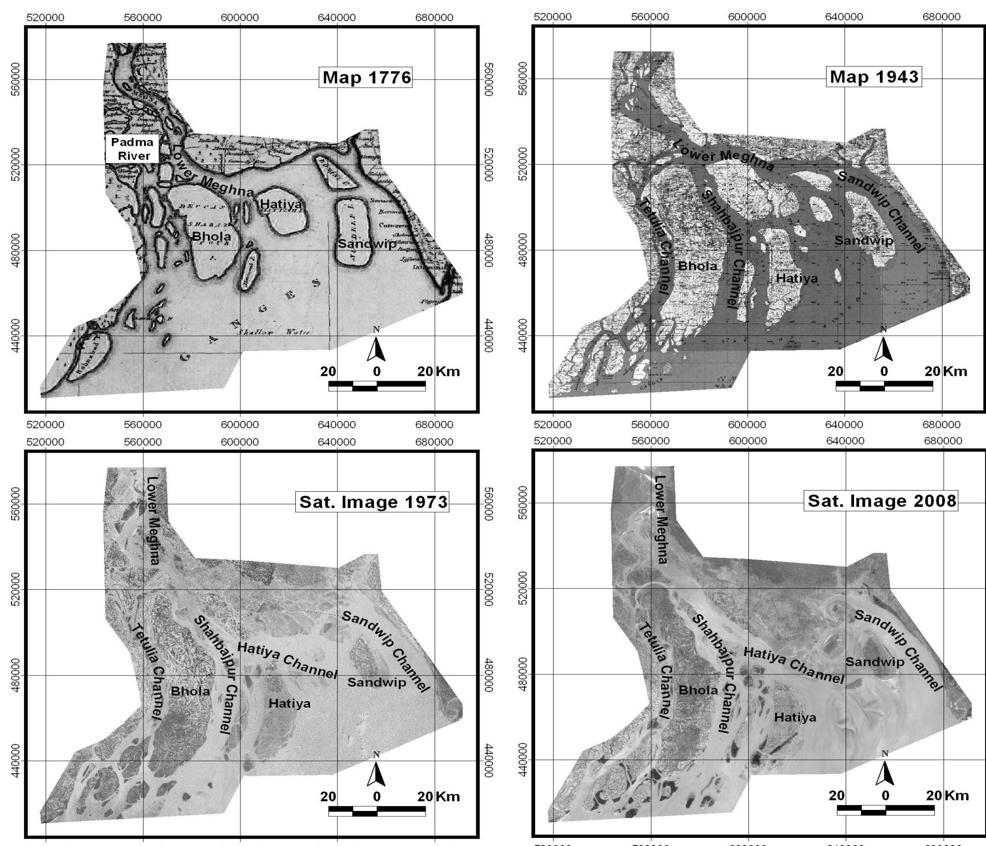

Figure 6: Meghna estuary 1776, 1943, 1973 and 2008 (source Sarker *et al.,* 2011)

Sarker et al. (2011) indicated that sediment generated by the 1950 earthquake, which was transported through the Brahmaputra, caused huge sedimentation in the Meghna estuary. The fine fraction of sediment rushed into the estuary within a few years. On the other hand, the coarse fraction (fine sand) propagated downstream as sediment wave and took nearly five decades to complete its journey to the bay (Sarker and Thorne, 2006; Sarker, 2009). The progradation of the delta would have effects on the water level in the Shahbajpur channels and also in the Lower Meghna River. Analysis of monsoon water levels of different gauging stations in this system shows a high increase at in the Shahbazpur channel and small increase in the Lower Meghna River (CEGIS, 2010). However during the preceding decade, water levels of all these stations showed a receding trend, the reason for which probably lies with the sediment input in the system/changes of local morphology of the downstream channels. Unfortunately, there is no sediment data available for this period. Sarker (2009), however, indicated that as the trailing edge of the sediment wave already entered into the bay, it could have caused sediment deficit in this area and a temporary phase of channel degradation.

During the inflow of a large amount of sedimentation immediately after the 1950 earthquake, water levels rose, which probably caused subsequent raising of the elevation of land (Figure 5 Section C) and influenced the development of the distributary flowing in the southwest direction where land elevation is less. During the last six decades the large distributary Shandhya has emerged from the Lower Meghna River dissecting the Arial Khan River. Several other distributaries are also in the process of development.

8. RECENT CHANGES

During the last four decades, several changes occurred in the distributaries flowing in the southwest. During this period, the Gorai River has diverted its flow from 50% to 95% to its southwest directed distributary, the Nabaganga River (EGIS, 2001). Many of the distributaries generated from the Lower Meghna and/or Arial Khan river are getting enlarged. River widths observed in satellite images and historical maps have increased. Among these, the Shandhya is a newly developed river (Figure 7). The images show that in 1943 there was almost no connection between two parallel rivers which started to develop after the 1940s and became visible in the 1973 image.

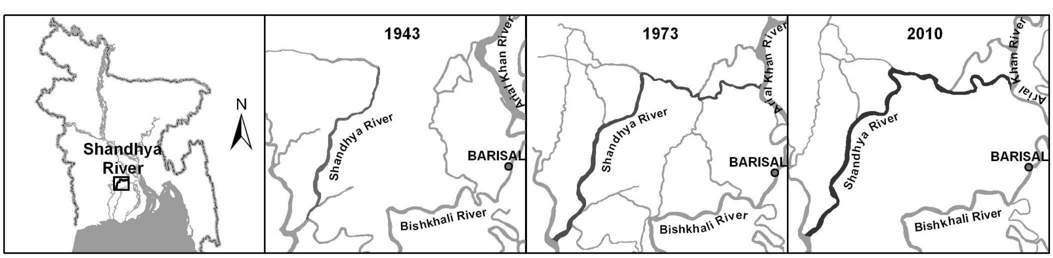

Figure 7: Evolution of the Shandhya, a southwesterly flowing distributary of the Arial Khan and Lower Meghna rivers

Along with the enlargement of the river widths, some of the rivers are also found to have deepened further. Hydrographic survey charts of the Bangladesh Inland Water Transport Authority (BIWTA) have been used for checking the change in the river depths. Most of the cross-sections made from this chart show an increase in the conveyance area of the sections (Figure 8). Two selected cross-sections showed increase in both the depth and width of the river within 17 years from 1993 to 2008. No survey charts before 1993 was found and hence comparison with previous data was not possible.

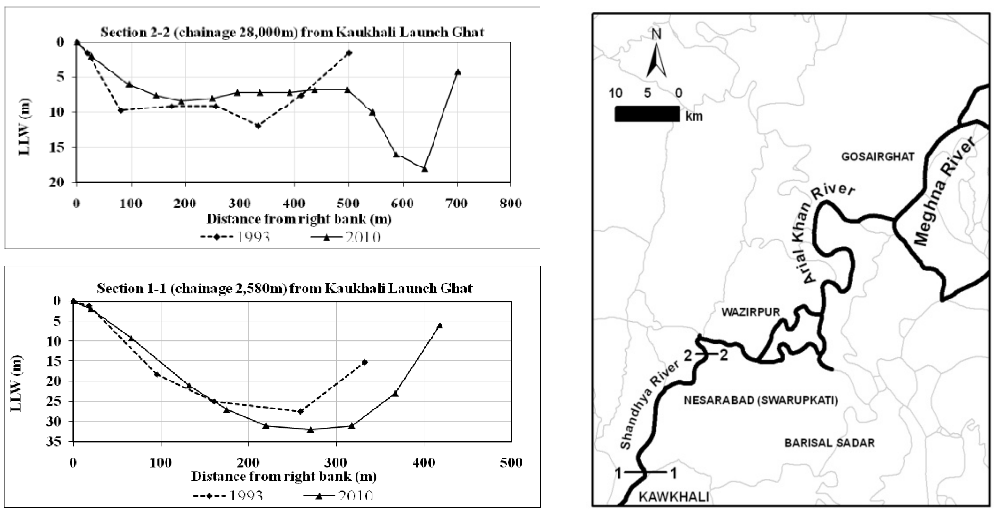

Figure 8: Changes in cross-profile of the Shandhya River

9. DELTA SHIFTING

The delta building processs is continuing, which is causing the active delta to shift at different locations. The assessment of delta shifting is mainly based on indicators such delta progradation (Figure 9), shifting of the delta building estuary and also shifting of the direction of the distributaries (Figure 10), which is however, a qualitative assessment. According to Sarker *et al.* (2011), net accretion in the Meghna estuary was only 4.5 km^2/y, which increased to 42 km^2/y for a period of 30 years and reduced again to 17 km^2/y in the preceeding four decades. It is likely that huge accretion in the 1950s and 1960s caused the delta progradation and thus expedited the shifting process.

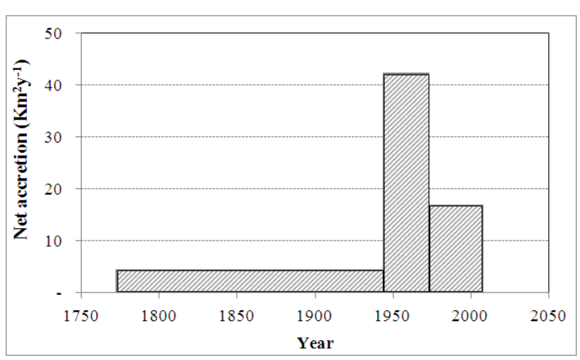

Figure 9: Net accretion in the Meghna estuary over time (modified from Sarker *et al.,* 2011)

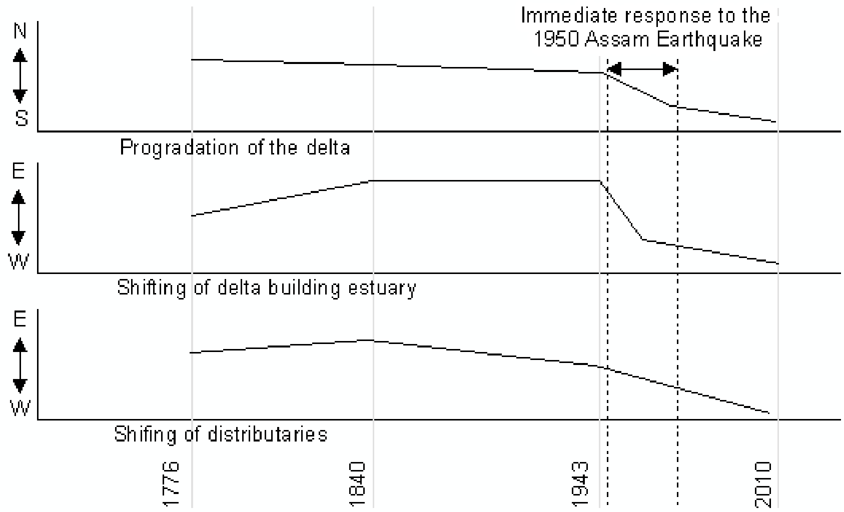

Figure 10: Qualitative shifting of the delta and its associated distributaries

In the late 18th century, the Ganges and the combined flow of the Brahmaputra and Meghna were active in two separate estuaries in building the delta. The Ganges estuary was very close to the northern upstream reach of the Tetulia Channel and the Lower Meghna River had been delivering fluvial inputs to further east of the present active estuary. After joining of the avulsion of the Brahmaputra, enormous changes had occurred in the following decades. The active delta building estuary shifted towards the east, and the process continued till the middle of the 20th century. The eastern most channel the Lower Meghna estuary has been abandoned resulting in the initiation of a reverse shifting of the active delta building estuary towards the west (Figure 10 a).

Most of the distributaries of the Ganges during in the 18th and 19th centuries flowed towards the southeast direction. By the middle of the 20th century, the flow of the Gorai-Madhumati started to flow southwest along with a few other distributaries from the Lower Meghna and Arial Khan rivers. During the last six decades, more than 90% of the flow of the Gorai River was diverted to the southwest directed channel. Moreover, a number of smaller distributaries from the Arial Khan and the major distributary Shandhya from the Lower Meghna and Arial Khan rivers were developed. The rate of change appears to have been very high in the later period (Figure 10 c).

Time-series salinity data or hydrographic survey charts may provide a qualitative but confirmatory assessment of the freshwater diversion to the southwest directed distributaries. It may also provide quantitative assessment over time, but unfortunately there is a lack of reliable data. Analyses of water level conducted at different locations of these distributaries have also not provided any consistent trend based on which any conclusive decision could be made.

The active delta building estuary and associated distributaries have shifted their courses. The rate of shifting appears to have been faster during the last six decades, especially after the 1950 Assam earthquake, which might have had a pronounced role in expediting the shifting process. This makes extrapolation for projecting the future very difficult. Considering the centennial and decadal processes, it can be inferred that the shifting process will continue in the coming decades. Based on the information available, it is not possible to quantify the shifting rate or project the future rate. It is very unfortunate that Bangladesh does not have any reliable data on sediment concentration of the major rivers for the last two decades. Another uncertainty for future projection is the uncertainty of sediment input, which depends on the land use changes occurring in the upstream riparian countries.

10. CONCLUSIONS

Historical maps, time-series satellite images, digital elevation models, hydrographic survey charts and water level data have been analyzed to study the shifting processes of the fluvial inputs into the bay, which contributes in the delta building processes. The Bengal delta is prograding mainly along the Meghna estuary. During the last two hundred and fifty years, the location of the delta building estuary shifted eastward and later westward. In the same period the distributaries, which also contribute in the delta building processes, shifted their courses to the southwest direction, the dominating direction of which was mainly southeast about two hundred years ago. It appears that sediment generated by the 1950 Assam earthquake had a pronounced effect on the delta shifting processes, which makes it difficult to extrapolate the trend for future projection. Nevertheless,it is very likely that the shifting process will continue in the future.Due to the lack of good quality and long time-series data on salinity and hydrographic surveys, it is not possible to quantify the shifting assessment. For planning development work in the delta, it is very important to know the future development of the delta. More comprehensive research is required for quantifying the processes and predicting the future, but reliable time-series data are very much required for that purpose.

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