Historical Bankline Shifting Since 1760s: A GIS and Remote Sensing Based Case Study of Meghna River Plate of Rennell's Atlas

Md. Rejaun Nabi* Dr. Md. Shahedur Rashid** Mohammad Ismail Hossain***

*Post Graduate Department of Geography and Environment, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh, e-mail: nabige40@gmail.com

**Professor Department of Geography and Environment, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh,e-mail: m.s.rashid@gmail.com

***Post Graduate Department of Geography and Environment, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh,E-mail: ismailhossain_995@yahoo.com

Abstract- Change detection is one of the most important research techniques in analyzing images that shows the interactions between human activities and the natural environment. According to time sequence of the concern area is active deltaic part of Bangladesh, particularly in the Meghna Estuary and its surroundings at Rennell's Atlas Plate-19. This research highlights the GIS and Remote Sensing approaches for shifting bankline since1760s the Rennell's survey of the Meghna River. For fulfillment of this purpose, Rennell's map 1760s; Landsat Imagery 1988 and 2014 are identified and compared; bankline shifting is assessed. Maximum bankline shifting occurs at cross section 5 from 1760s-1988 where right bankline shifting Eastward 12.87 km. and left bankline shifting Westward 9.67 km. that shows depositional features more active than erosional features. Gradually, The Meghna River channel width is becoming narrow by 11.13 km. from 1760s-2014 due to sedimentation, water level fall etc. The methodology produces high quality map of change detection of bankline shifting map of the study area across space and time.

***Index Terms* -** Bankline Shifting, Change Detection, Cultural Features, GIS, Landsat Imagery, Physical Features, Rennell's Atlas, Remote Sensing.

I. INTRODUCTION

Detecting change of Earth's surface features provides the foundation for better understanding of relationships and interactions between human activities and natural phenomena. Increased understanding is necessary for improved resource management (Alex et al., 2003). Detecting change involves applying Multi-temporal datasets to quantitatively analyze the temporal effects of phenomena (Austen, 1996). Land use is influenced by economic, cultural, political, and historical and land tenure factors at multiple scales. Land use referred to as man's activities and the various uses which are carried on land (Baker et al., 2007). Major data sources for such analyses include base on Rennell's Atlas 1760s, Landsat TM 5 and Landsat 8. Landsat multispectral and temporal imagery is a particularly important source of data for observing changes in physical and cultural features (Bruzzone and Serpico, 1997). Remote sensing thus provides a unique opportunity to characterize the Spatio-temporal distribution of these changes (Bauer et al., 2003) and to collect important baseline of information that is too difficult to obtain using field-based methods. Early images paired with more recent images can be used to detect changes in the landscape over that period (Chen, 1998). Remotely sensed images are being used to address critical resource management problems, providing researchers with the ability to make rapid decisions about large spatial areas using recent data (Dixon and Candade, 2008). Dynamics operate at multiple spatial and temporal scales, requiring researchers to be able to make multi-scale observations using Satellite images (Coppin, 1994). Satellite images can easily detect and map both local and large area land use/land cover changes, and the impact they have on river processes (Chen et al., 2007). Concern about change in the size and quality of many of the world's river systems has been growing as more and more areas are being converted to agricultural or urban use and affected by natural factors like erosion and deposition (Coppin et al., 2004).

Bangladesh, occupies the major portion of the Ganges Delta in the northern apex of the Bay of Bengal. Substantial parts in the east of the country incorporate some tertiary hills and the middle north and north is occupied by elevated tracts known as the Pleistocene terraces. The process of delta formation here started billions of years ago with the mountain building movement that created the Himalayan mountain systems (Dewidar, 2004). Change detection requires a comparison of the spectral reflectance values between two or more periods of time (Diuk-Wasser et al., 2004).

The main aim is to identify the historical changes in Bankline Shifting since Rennell's Survey of Meghna River,

- To assess the Historical Bankline Shifting Nature among 1760s, 1988 and 2014
- Comparing the Bankline Shifting among 1760s-1988-2014
- Assessing the Causes of Bankline Shifting of Meghna River

II. Material and Method

Data

The basic data used in this paper are historical map of Rennell's Atlas and satellite images of sensor, comprising of scenes for the years 1760s, 1988 and 2014. The other collateral data used in the present study are Landsat TM and Landsat 8 images (Path/Row 137/43, 137/44), which are freely downloadable from the website http://usgs.gov//. ERDAS Imagine 2014 image processing software has been used for processing the satellite images. ArcMap 10.2.1 GIS software has been used for analysis of the river bank data.

Methodology

Satellite images for years 1988 and 2014 have been processed to obtain the required information about the area. The following section describes the preparation of satellite images for information extraction Study area (**Figure 1**). Therefore, the data need to be geo-referenced before commencing the analysis. Since the Rennell's map procured from Survey of Bangladesh belongs to year 1760s, there are increased chances of error, if the map data is taken as a reference for geo-referencing the satellite images. Therefore, Landsat TM and Landsat images have been taken as reference. Map has been used for assistance in identification of features. The Landsat images are precisely ortho-rectified with the following parameters:

Projection Type: Universal Transverse Mercator (UTM)
Spheroid Name: WGS 84
Datum Name: D_Everest_Bangladesh
Zone: _46

Landsat TM and Landsat 8 images for the study area have been downloaded and a mosaic has been prepared. Then individual image of IRS has been registered with respect to the Landsat image. For each images have been taken and geo-referencing has been carried out using second-order polynomial with nearest neighborhood resampling keeping grid size as 30 m. RMS (root mean square) error has been kept below 30m pixel. Map has been utilized for accurately identifying the GCPs on IRS and Landsat images. The geo-referenced images of the same year have been mosaiced together. Meghna River is covered with clouds for most part of the year, therefore the satellite images of one year couldn't be procured for same date or month. Therefore, radiometry of the images differ a lot. Making a mosaic without balancing the radiometry will not give good results. Therefore, radiometric normalization has been performed before mosaicing by histogram equalization and matching. This has given very good results, providing uniform brightness levels for similar features for the entire river basin. Also, feather option has been used for mosaicing to get the seamless boundaries between different images of same year. The mosaics for the years 1988 and 2014 have been prepared in this manner.

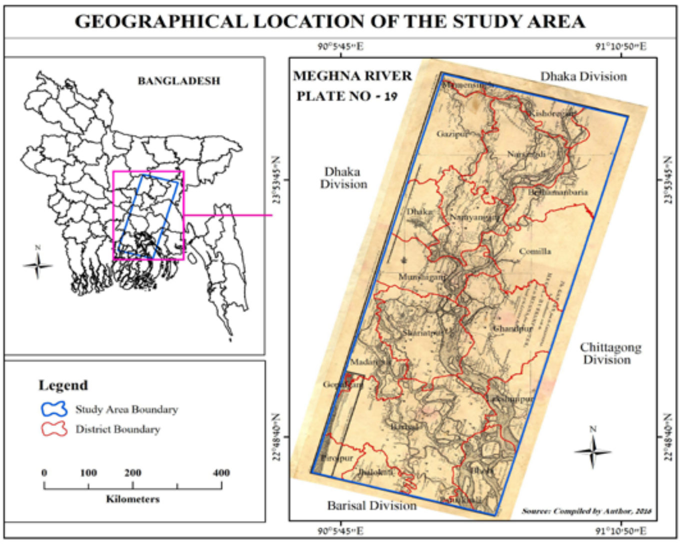

Figure 1: Study Area

Delineation/Digitization of River Bank Line

Meghna River (Plate no-19) of Rennell's Atlas is the most prominent area of Bangladesh. It is the active flood plain zone in Bangladesh. Originated through the Lucy hill in Assam and finally meet with the Bay of Bengal. This river covers the 19 districts in Bangladesh. It has been divided into 7 strips at an equal spacing of approximately 25 km, reference cross sections 7 have been drawn at the boundary of each strip. Each of 7 cross sections has been grouped as a reach with numbering from downstream to upstream of the river. Base line of latitude 25.966˚N and longitude 90˚E has been taken as permanent reference line so that they maintain their identity when the morphology is changed. Table 1 shows some important locations within various reaches of the river. The river bank-line has been identified and delineated for all the satellite image mosaics of 1988 and 2014. NDWI image proved very useful in identifying the river bank line. While the shallow water channels have been considered the part of river, old and new soil/sand deposits at the river banks posed some ambiguity of interpretation as the river. A few of these soil/sand patches are at considerable distance from active water channel, but have dark tone on satellite image, indicating higher moisture. On the other hand, several soil patches very close to the active water channel bear bright signature, an indication of low moisture. NDWI has been used in delineating the soil/sand areas which have higher moisture content. It has been observed that the areas with recent soil deposits have higher moisture in comparison to other areas adjacent to river bank, due to the river related activities associated with them. Either the river was flowing through that area in the recent past, or that area was submerged in water, when there was high flow in the river. These areas have been marked as a part of river. Thus the use of NDWI image helped in delineating/demarcating the river bank line. The identified river bank lines for the left (south) and right (north) banks of the river, have been digitized using ArcMap10.2.1 software. Three river bank lines have been prepared for the years 1760s, 1988 and 2014. The length of arcs of both the left and right banks for all the above years have been calculated using GIS software. Erosion and deposition area has been estimated through area estimation using GIS software tools for polygon areas with the shifting bank-lines in study period.

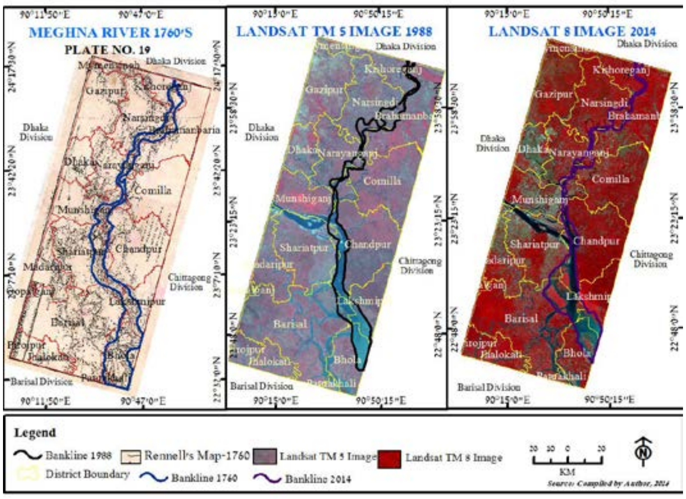

Figure 2: River bank lines have been prepared for the years 1760s, 1988 and 2014

Study Area

Meghna River (Plate no-19) of Rennell's Atlas is the most prominent area of Bangladesh. It is the active flood plain zone in Bangladesh. Originated through the Lucy hill in Assam and finally meet with the Bay of Bangle. This area Rennell's Surveyed in 1760s and it was published in 1780. This area covers the 19 districts in Bangladesh. Meghna River is also one of the major rivers in Bangladesh, especially famous for its great estuary that discharges the flows of the Ganges-Padma, the Brahmaputra-Jamuna and the Meghna itself. The downstream of SURMA River from Ajmiriganj is often referred to as the Meghna. The matter would be simpler but for the fact that from Madna downstream for about 26 km (in a straight line) one of the two channels of the Surma-Meghna is `known as the Dhaleshwari. The channel from Ajmiriganj down to the confluence with the Dhanu is referred to as the Surma. This confluence is five kilometres east of Kuliarchar and north of Bhairab Bazar. Downstream from this point, the river is referred to as the Meghna.

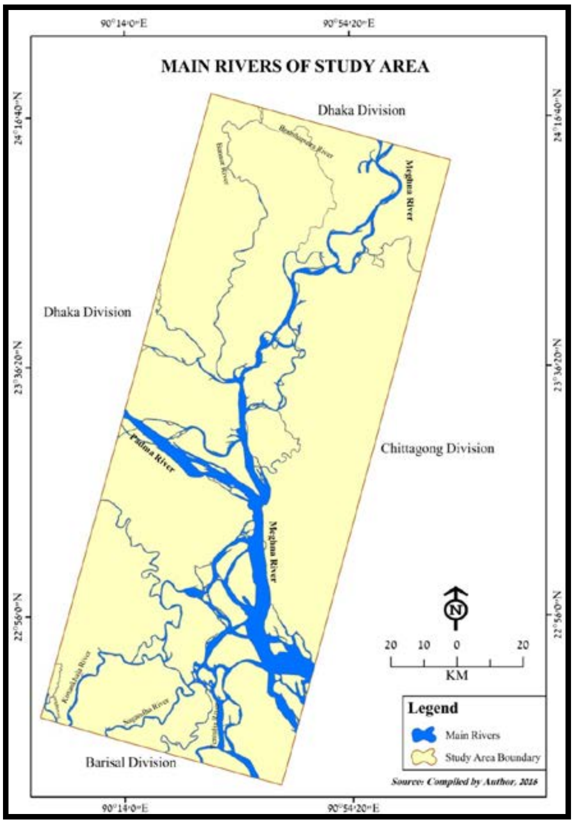

Figure 3: Meghna River

III. RESEARCH FINDINGS AND DISCUSSIONS

Fluvial channel form and its dynamics over the period of time have been a major interest of study in fluvial geomorphology. The present study deals with the fluvial morphological characteristics of the Meghna River in slightly southeast Bangladesh. Morphological and Morpho-dynamic maps of the Meghna River were prepared using Remote sensing techniques. Channel shift and width of the study area were estimated for the year of 1760s, 1988 and 2014 respectively. Results showed a remarkable change in position of bank and channel as well as bars along with their geometry and morphology over time. Result also demonstrates that the bankline is unstable and migrated continuously towards westward to eastward in the recent decades. In addition, the study reveals that overall width of the Meghna River is varied significantly during the last 254 years. Different maps and Landsat TM5, 1988 and Landsat 8, 2014 depict that the river shifting is irregular which is important for the existence of the study area people. For planning and sustainable development of Bangladesh, identification of fluvial channel morphology of a river like the mighty Meghna River is essential.

Assessing the Causes of Bankline Shifting

Geomorphological units consist of recent alluvium plain in the study area. Geomorphological features of the Meghna River differ from one place to another in the slightly southeastern Bangladesh. It is recognized on the basis of the satellite image characteristics (e.g. tonal variation, texture, size, shape) and fluvial features. Geomorphological units are identified by different erosion processes. Remote sensing data are effective to map geomorphological units. The major causes of bankline shifting are-

Active Channel

Active channel is perpetual water flow in all over the year. This unit is the main feature of the study area (**Figure 4**).

Mid Channel Bar

This channel bar is ephemeral in nature and position of the bar within the channel is likely to be changed with each sizeable flood. The channel bar is located within the active channel which is exposed during the late winter and summer seasons. This bar consists of course to medium grained sand (**Figure 4**).

Lateral Bar Deposit

Lateral bar is connected to the main floodplain deposit. This bar is longitudinal, elongated and transverse to the stream alignment which is exposed only during the winter and summer period (**Figure 4**).

Old Bar Deposit

The old bar is the main geomorphological units within the channel area. This bar contains several cycles of sedimentation that forms multistoried changing sequences. This bar identifies by its geomorphic forms and light tone (**Figure 4**).

New Bar Deposit

New bar is small scale bar within the channel floors, which is characterized by sand waves without any vegetation covers. This bar consists of loose, light gray to white and medium to fine-grained sands. The new bar is comparatively lower than that of the older bar. In satellite images, it identifies by light tone (**Figure 4**).

Abandoned Channel Deposit

The unit is extended thin depressions and narrow discontinuous water courses with or without water throughout the year. It consists of silty clay, lies beneath by silty sand to fine sand deposits. Vegetation forms elongated shape like geometry (**Figure 4**).

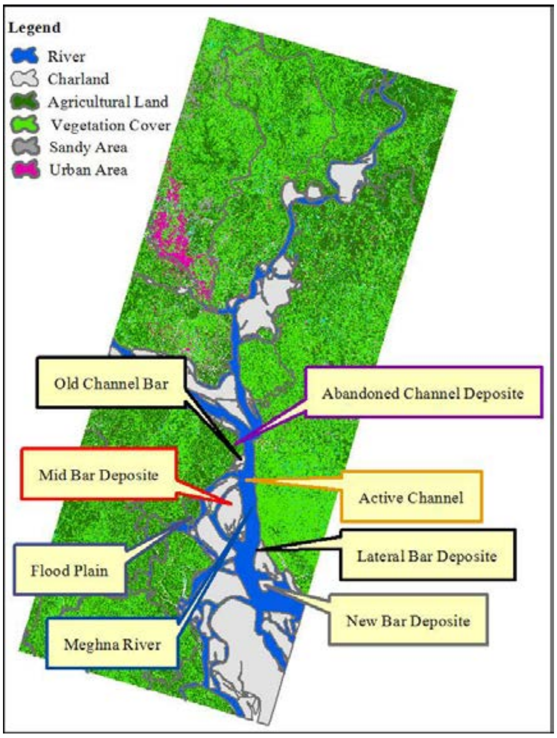

Figure 4: Assessing the Causes of Bankline Shifting

Historical Bankline Shifting Nature among 1760s, 1988 and 2014

The channel pattern of the Meghna River Plate-19 of Bangladesh changes continuously; large channels being abandoned and new channels developing in a few years only are common features (GSI, 1977). It is seen from the Map, that during 1760s, 1988 and 2014. To show the changes of Meghna River Plate -19, I have taken image of 1760s, 1988 and 2014. To acquire necessary information of the changes of this plate, I drew 7 cross-sections of this river. The distance of one cross-section to another is near about 25 kilometers. It can be seen from the map that the bankline of this plate is changing from year to year, though I have not enough images to describe precise changes. According to the map of 1760s, it can be mentioned that, the changes is more 2014 than 1988.

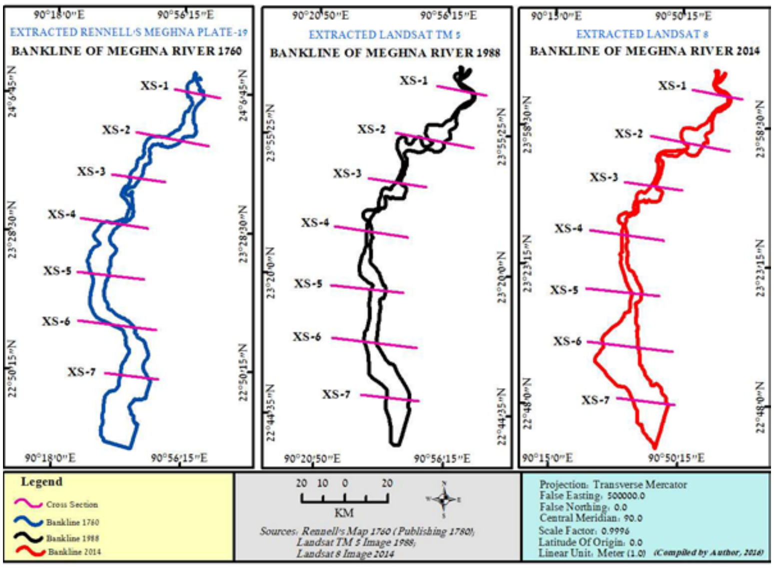

Figure 5: Bankline Shifting Nature among 1760s, 1988 and 2014

Assessing the Historical Bankline Shifting

Bank-line migration is a direct consequence of interactions and interrelationships between various aspects like extent of river activities (erosion, transportation and deposition), volume of river water during peak season, soil and geological structure including mass human interference with the river.

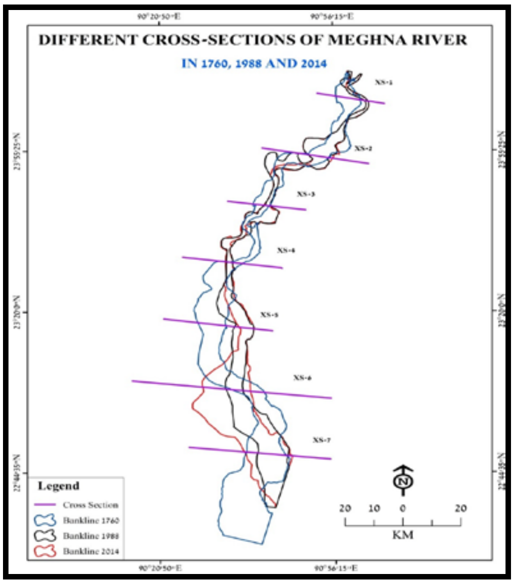

Figure 6: Different Cross Section of Meghna River

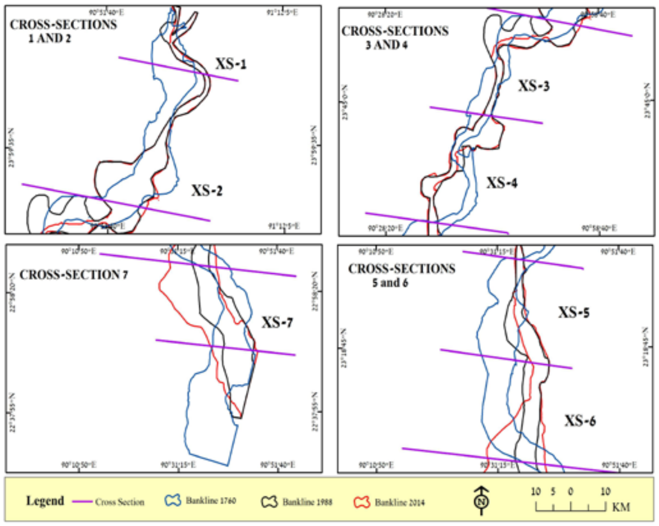

Figure 7: Different Cross Section of Meghna River

Although erosion and northward channel shift is common in north bank but it is not so as alterations and modulations in the controlling factors (structure, process and stage as envisaged by Davis) of the dynamic river tend to bring dynamism in the resultant landforms. Along the cross section (Table 7.1), the bank shift is generally from east-west to west-east for all the concerned years. But the cross-section reveals a completely different scenario1760s and 2014.

Bankline Shifting1760s-1988

In the present study, the shifting of river course has been estimated from 1760s to 2014. To assess the channel shifting, it has been prepared 3 years maps (1760s, 1988, and 2014). To assess the channel shifting properly, this river is divided into 7 cross-sections on the basis of its bend. Here these cross-sections have been recognized as reach. First channel shifting was assessed according to cross-sections.

Table 1: Shifting along both Banks of the River from 1760s to 1988 (in km)

Cross Section	Right Bank shift (km) 1988	Left Bank shift (km)1988	Direction of Migration
XS-1	9.85	2.63	Eastward
XS-2	2.82	0.14	Eastward
XS-3	4.15	0.61	Eastward
XS-4	2.45	-3.42	Westward
XS-5	12.87	-9.67	Westward
XS-6	-2.02	-7.47	Westward
XS-7	3.86	0.66	Eastward

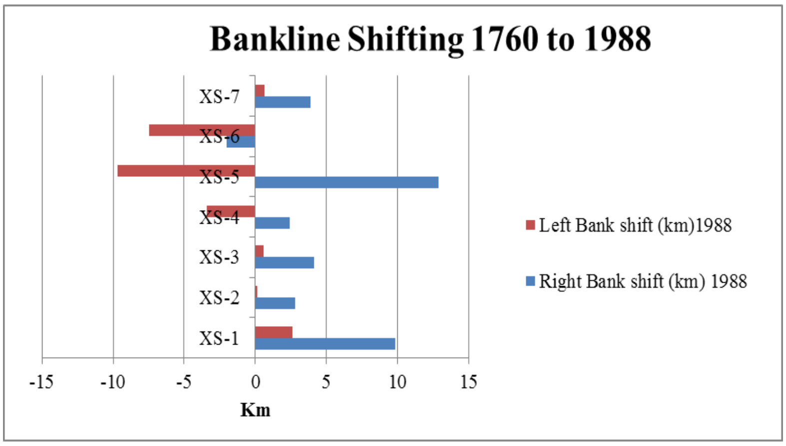

Figure 8: Changing the Bankline Shifting of Meghna River from 1760s, 1988.

During the year 1760s and 1988, the channel shifted from west to east (along the east bank) and so is the bank-line of the year 1760s-1988. But during the year 1760s-1988, the shift was from west to east direction. The negative values (-) indicate the shifting due to erosion and the positive values (+) indicate the shifting due to deposition. This clearly reveals that during the year 1760s to 1988, there was extensive deposition along the right bank, whereas the process of erosion dominated the scene during 1760s-1988. It is noteworthy that the bank shift along the west bank is highest along the XS-5 cross-section where during the year 1760s-1988, there was eastward shifting of the bank to about 12.8kms (Table-1).

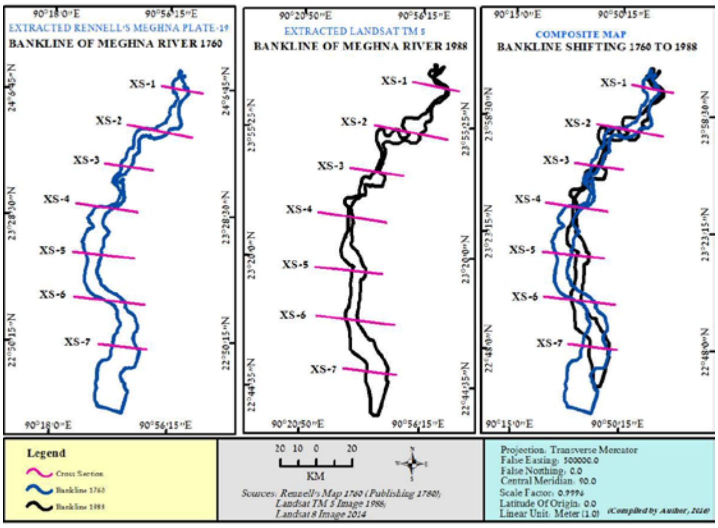

Figure 9: Bankline Shifting1760s-1988

Bankline Shifting1760s-2014

In the present study, the shifting of river course has been estimated from 1760s to 2014. To assess the channel shifting, it has been prepared 3 years maps (1760s, 1988, and 2014). To assess the channel shifting properly, this river is divided into 7 cross-sections on the basis of its bend.

Table 2: Shifting along both Banks of the River from 1760s to 2014 (in km)

Cross Section	Right Bank shift (km) 2014	Left Bank shift (km)2014	Direction of Migration
XS-1	9.88	2.79	Eastward
XS-2	2.45	1.48	Eastward
XS-3	3.76	0.46	Eastward
XS-4	2.24	-3.47	Westward
XS-5	14.39	9.73	Eastward
XS-6	-10.08	-4.93	Westward
XS-7	-0.81	2.04	Eastward

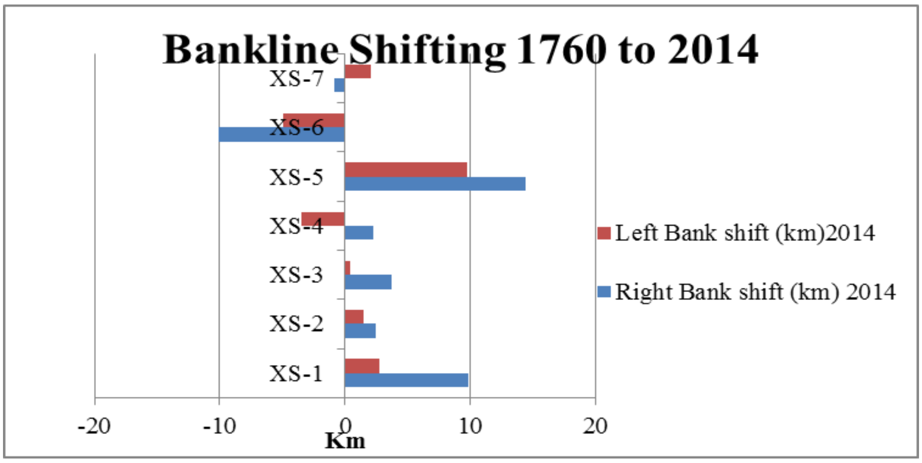

Figure 10: Changing the Bankline Shifting of Meghna River from 1760s, 2014.

During the year 1760s and 2014, the channel shifted from west to east (along the east bank) and so is the bank-line of the year 1760s-2014. But during the year 1760s-2014, the shift was from west to east direction. The negative values (-) indicate the shifting due to erosion and the positive values (+) indicate the shifting due to deposition. This clearly reveals that during the year 1760s to 2014, there was extensive deposition along the right bank, whereas the process of erosion dominated the scene during 1760s-2014. It is noteworthy that the bank shift along the west bank is highest along the XS-5 cross-section where during the year 1760s-2014, there was eastward shifting of the bank to about 14.39 km (Table-2).

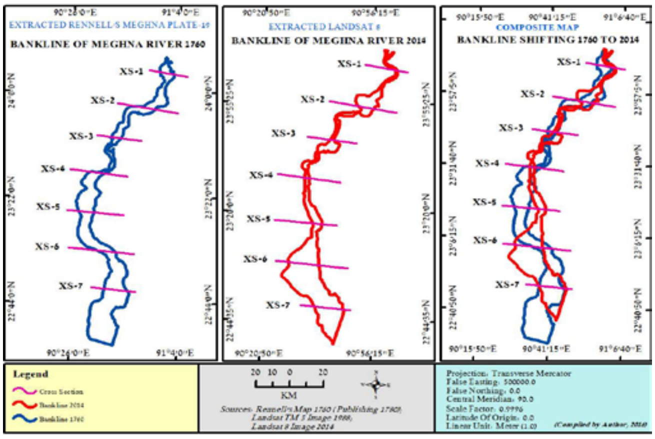

Figure 11: Channel shifting

Comparing the Bankline Shifting among 1760s-1988-2014

During the year 1760s and 1988, the channel shifted from west to east (along the east bank) and so is the bank-line of the year 1760s-1988. But during the year 1760s-1988, the shift was from west to east direction. This clearly reveals that during the year 1760s to 1988, there was extensive deposition along the right bank, whereas the process of erosion dominated the scene during 1760s-1988 in cross-section (XS), right bank XS-1 (9.85kms), XS-2 (2.82kms), XS-3 (4.15kms), XS-4 (2.45kms), XS-5 (12.87kms), XS-6 (-2.02kms), XS-7 (3.86kms) and left bank XS-1(2.63kms), XS-2 (0.14kms), XS-3 (0.61kms), XS-4 (-3.42kms), XS-5 (-9.67kms), XS-6 (-7.47kms), XS-7 (0.66kms). It is noteworthy that the bank shift along the west bank is highest along the XS-5 cross-section where during the year 1760s-1988, there was eastward shifting of the bank to about 12.87kms.

In the year 1760s and 2014, the channel shifted from west to east (along the east bank) and so is the bank-line of the year 1760s-2014. But during the year 1760s-2014, the shift was from west to east direction. This clearly reveals that during the year 1760s to 2014, there was extensive deposition along the right bank, whereas the process of erosion dominated the scene during 1760s-2014 in cross-section (XS), right bank XS-1 (9.88kms), XS-2 (2.45kms), XS-3 (3.76kms), XS-4 (2.24kms), XS-5 (14.39kms), XS-6 (-10.08kms), XS-7 (-0.81kms) and left bank XS-1 (2.79kms), XS-2 (1.48kms), XS-

3 (0.46kms), XS-4 (-3.47kms), XS-5 (9.73kms), XS-6 (-4.93kms), XS-7 (2.04kms). It is noteworthy that the bank shift along the west bank is highest along the XS-5 cross-section where during the year 1760s-2014, there was eastward shifting of the bank to about 14.39kms.

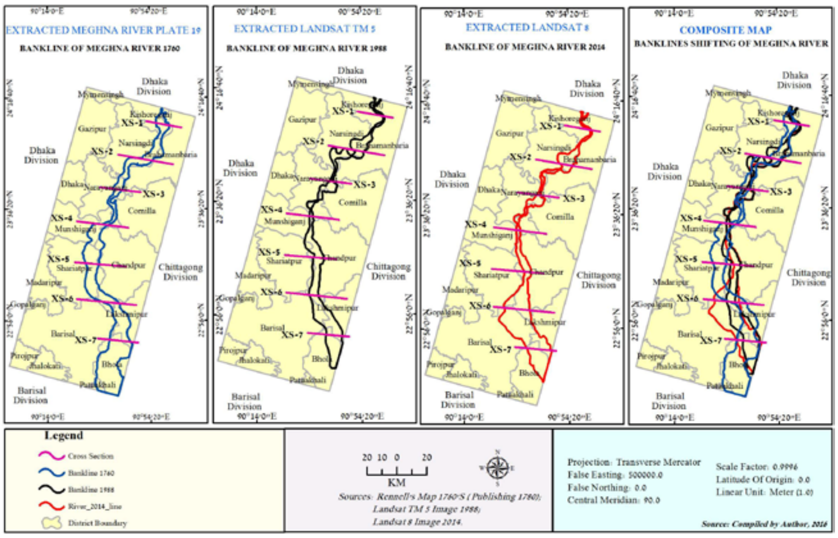

Figure 12: Comparing the Bankline Shifting among 1760s-1988-2014

Changing Channel Width

In the present study, the shifting of river course has been estimated from 1760s to 2014. To assess the channel width, it has been prepared 3 years maps (1760s, 1988, and 2014). To assess the channel width properly, this river is divided into 7 cross-sections on the basis of its bend.

Table 3: Variation of Channel Width in Different Cross-Sections

Cross Section	Channel Width 1760s (Km)	Channel Width 1988(Km)	Channel Width 2014(Km)
XS-1	8.45	1.21	1.28
XS-2	9.92	7.32	8.67
XS-3	5.6	2.18	2.33
XS-4	5.54	2.5	2.47
XS-5	9.74	6.68	5.1
XS-6	11.34	5.93	16.57
XS-7	13.76	10.51	16.8
Total	**64.35**	**36.33**	**53.22**

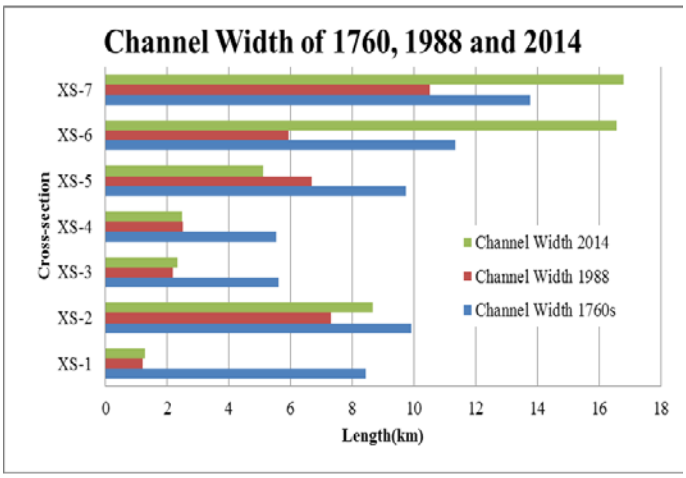

Figure 13: Changing Pattern of Width of the Meghna River from 1760s, 1988 and 2014.

The channel width of the river in cross-section in 1760s, 1988 and 2014 is 64.35kms, 36.33kms and 53.22km respectively. In 1988 the river channel decrease 28.02km from the channel width of the river in 1760s.again the channel width of the river in 2014 is approximately increase 16.89 km than the channel width of 1988.

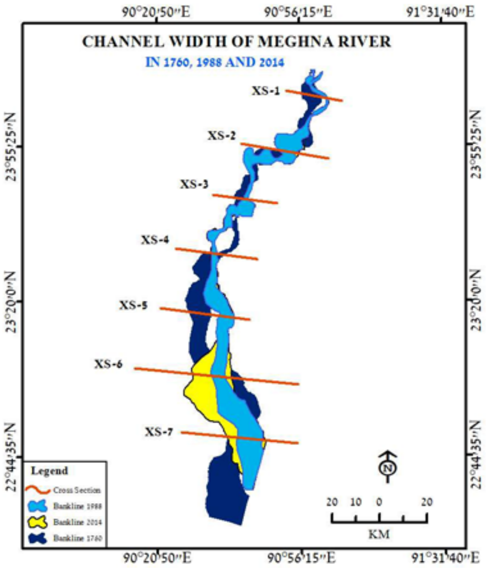

Figure 14: Changing Channel Width

IV. CONCLUSION

The present work using Remote Sensing and GIS based approaches with on multi-date satellite data has revealed sharp changes in fluvial land form in recent years resulting in considerable inhabited land loss. The Meghna River within the study reaches exhibits differential rate of erosion and deposition during 254 years (1760s-2014). It is observed that in general the river has eroded both the banks throughout its course except at a few sites where its banks are well defined as the river is constricted due to presence of rocks. River adjustment processes that affected fluvial system of the Brahmaputra include the channel control points, surmised to be the major co-actors, working in unison with other forcing functions like channel degradation and aggradation, lateral river migration, widening or narrowing, avulsion, changes in the quantity and character of the sediment load at spatial and temporal scale, intensely powerful monsoon regime, recurring earthquakes and adverse impact of anthropogenic factors. Many reaches along the Meghna River have been perceived as suffering from high erosion that endanger nearby settlements and infrastructure. The reaches have been prioritized with respect to the land area loss of the years. There arises the need for in-depth study of interaction of geo-tectonic activities conjunctively with fluvial regime in the region to understand the complex physical processes completely for suggesting more practical result oriented river management interventions.

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AUTHORS

First and corresponding Author - Md. Rejaun Nabi, Post Graduate Department of Geography and Environment, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh, E-mail: nabige40@gmail.com

Second author- Dr. Md. Shahedur Rashid Professor Department of Geography and Environment, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh,
E-mail: m.s.rashid@gmail.com

Third author- Mohammad Ismail Hossain, Post Graduate Department of Geography and Environment, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh,
E-mail: ismailhossain_995@yahoo.com