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Trends analysis of river bank erosion at Chandpur, Bangladesh: A remote sensing and GIS approach

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ABSTRACT

Bangladesh which is mainly formed by alluvial deposits faces riverbank erosion very often due to regular shifting of river channels. The present study has undertaken to study the trends of riverbank erosion at Chandpur district. Landsat TM & MSS Satellite image from 1980-1990 and Google Earth high resolution satellite imagery from 2002-2010 were used to delineate the historical changes of the river especially to the left bank alignment of the river course. The study revealed that for long time this area has been suffering with the erosion problem and shifting characteristics of Meghna River. Analysis also showed that in the history of last thirty years erosion rate was higher in the decade of 1990 to 2002 than other two decades and about 3517 sq meter area was eroded. But in the recent interpretation results shows deposition is higher than erosion.

Keywords: Riverbank erosion, Channel shifting, Remote sensing, GIS, Bangladesh

1. Introduction

Riverbank erosion is a common geomorphological process of alluvial floodplain rivers. It corresponds to bank adjustment, bank trampling, navigations, changes in bed elevation and topography in reaction to modified flow conditions (stream power, bed load) or bank resistance, exceptional flooding and rising intensity of tidal waves (Lane, 1955; Madej, *et al*., 1994; PieÂgay and Bravard, 1997; Chowdhury *et al.*, 2007). In Bangladesh, riverbank erosion is a regular phenomenon which is located in the delta of some of the world's largest rivers- the Ganges, the Brahmaputra and the Meghna. Bank erosion and channel shifting of the untrained alluvial rivers of Bangladesh are big problems to the socio-economic and environmental sector of the country (Klassen, et al., 2002).

The mighty rivers of Bangladesh (the Jamuna, the Ganges, the Padma, the upper Meghna and the lower Meghna) change their courses all on a sudden and sometimes causes to riverbank erosion. Studied found that massive amounts of melted water increases the downward flow of rivers (Chowdhury et al, 2007). In a general sense river bank erosion is breaking down or carrying away the bank of the river by itself and it affects the changes in river channel courses in alluvial plains (Fujita et al, 2000). Erosion has been defined as the mechanism of detachment of sediment particles and other materials from the land surface or erosion is the combining the processes of detachment and transportation of soil materials by the action of flow, waves, tidal fluctuations and other hydrological factors governing the flow condition of a channel (Ahmed, 1989). Researchers also emphasized that the major rivers of Bangladesh shows different channel pattern with dynamic characteristics (Alam and Hoque, 1998). For example, Padma (Ganges) shows a meandering pattern characterized by a high sinuosity single channel; while the Jamuna (Brahmaputra) is a typical multi-channel braided system characterized by extensive development of multiple regularly shifting channels and sand bars. Moreover, it stated that fluvial geomorphic process is very much active in Bangladesh and most of the river channels are shifting in nature (Hossain, 1984). As a result, river erosion is common in the study area. The Meghna and Padma rivers together flow southward and develop the Meghna estuary before falling into the Bay of Bengal. Moreover, morphologically the Meghna river is a low-energy, multi-channel fluvial system characterized by a network of interconnecting channels and inter-channel area (Alam, 1991). The channels of the Meghna system transport predominantly fine to medium grained sands as bed materials, and their banks are composed mainly of silt- mud with little sand, and thickly root penetrated (ibid). The very low-gradients and cohesive fine-grained bank sediments of the anastomosed channels essentially confine them, limiting their freedom of lateral movement. Bank vegetation may also be an important factor in stabilizing the channels by reducing flow velocity, and hence erosion along the banks (Alam, 1991).

At the confluence point of the Padma-Meghna, Meghna maximum discharge 20,000 cumec, maximum discharge of lower Meghna 160,000 cumec and slope 5 cm per km (Haskoning, 1990). The river system at the confluence is not only characterized by a wide river bed of several kilometers in which various channels develop in combination with large propagating sand bars, but also by a gradual shifting of the whole lower Meghna in eastward direction. This means that the erosion problems at Eklaspur, Chandpur and Haimchar originate mainly from this eastward shifting and that permanent solutions sites, have to be considered. The research issues on riverbank erosion are very recent concern and very few works have been done to investigate the trend analysis of river erosion at Chandpur district. The present study examines the trends of left bank line movement in the last three decades, measures the erosion and deposition area and identified the category wise erosion and deposition zone by observing its aerial coverage due to erosion at Chandpur district.

2. Study area

The study area lies between latitude $23^0 29^/ 40.93^{//}$N to $22^0 52^/ 13.86^{//}$N and longitude 90^0 $35^/ 48.54^{//}$E to $90^0 44^/ 47.79^{//}$E from upper reach Matlab upazila to lower reach Haimchar upazila (Figure 1). From the total river courses only left bank considered for the entire study because major erosion had been occurred in the left bank and its adjacent area. Total distance of the left bank considered for this study is 76.8 km.

Chandpur is one of the severe erosion prone deprived areas caused by river Meghna and Dakatia in which Chandpur Sadar, Haimchar and Matlab Upazila are seriously affected. The three study sites Chandpur Sadar, Haimchar and Matlab Upazila are showing in figure 1. It has already devoured 200 years old Chandpur port, launch ghat, railway station, ice mills, steamer ghat and vast areas of this district (Irin, 2010).

3. Data and methodology

In the present study, series of high resolution Google earth satellite imagery considered for the delineation of the left bank line of the study area. By using Google earth historical imagery toolbar option different year wise satellite imagery were used for this research to know the recent bank line shifting status compare to the previous SPARRSO provided satellite imagery. The Bangladesh Space Research and Remote Sensing Organization (SPARRSO) provided some sequential satellite imageries (1980 & 1990) from which the nature of channel shifting and erosion trends of the study area can be observed.

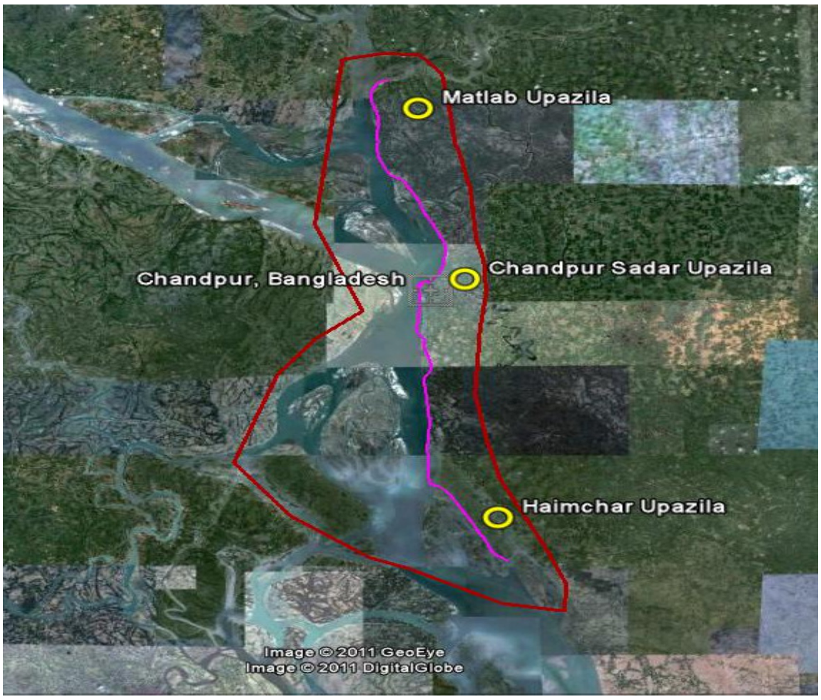


Figure 1: Location of the study area (showing on Google Earth Satellite image) where magenta color line indicates the left bank line

3.1 Satellite data

River bank line were derived, using certain precise zooming of pixel where bank line was demarcated and digitized accurately in between bank line and adjacent water features pixel. Geo-referenced Landsat TM and Landsat MSS were considered at the preliminary stage to delineate the river left bank line. All the satellite data were acquired on same dates, viz., 5 January 1980 and 7 January 1990, but at different times. Due to non-availability of recent satellite imagery after 1990 researchers choose the worldwide acceptable Google Earth high resolution satellite imagery to know the latest scenarios of the bank line displacements compare to the previous decade. Additionally, series of Google Earth high resolution satellite imagery on the basis of its availability (using historical imagery toolbar) were also acquired from 10 March 2002 to till 4 May 2010 at different times with different dates. For that Google earth latest 6.2v was used to acquire the satellite imagery. Among these, only four imageries are shown in Figure 2 with four different plates. Other relevant GIS ready map such as district, upazila and union level map of study area were used as ancillary data. The detail information of used maps and images for this study are listed in table 1.

Table 1: Details of data used in the present study

SL No.	Types of Data	Year	Source
1	Landsat TM	1990	SPARRSO
2	Landsat MSS	1980	SPARRSO
3	Google Earth Imagery	2002-2010	Google Earth
4	Chandpur District, Upazila & Union Map	2010	LGED, SOB

Source: Survey of Bangladesh (SOB), SPARRSO and Google Earth-6.2v.

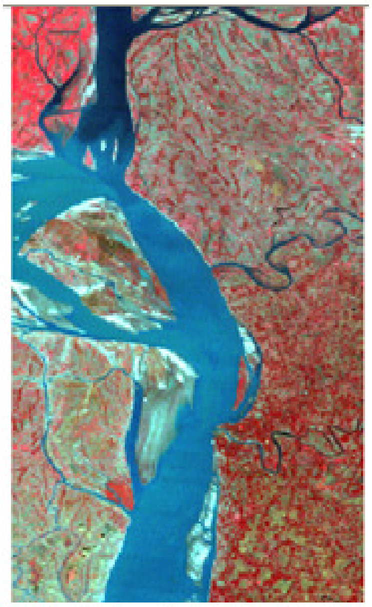


Plate A Landsat TM Image Acquisition
Date: 07-Jan-1990
Source: SPARRSO, Bangladesh

Plate B Landsat MSS Image Acquisition
Date: 05-Jan-1980
Source: SPARRSO, Bangladesh

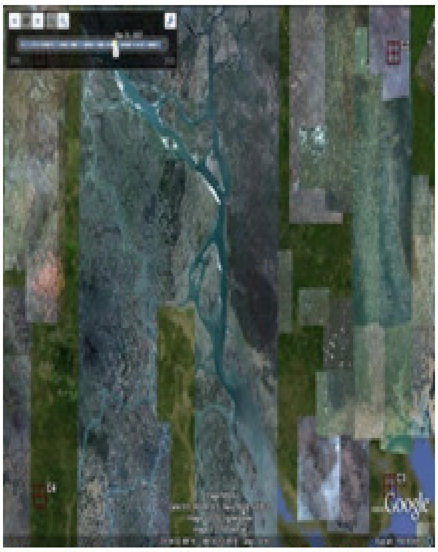


Plate-C Google Earth-March 10, 2008

Plate-D Google Earth-May 04, 2010

Figure 2: Landsat MSS, Landsat TM and Google Earth satellite imagery of the study area from 1980-2010.

3.2 Methodology

The years were chosen on the basis of availability of imagery as well as for better understanding of the frequency of river bank migration or left bank line shifting**.** The river banks and the chars could be mapped precisely that enabled local characterization in more details. The imagery selected for the study was obtained from Bangladesh Space Research and Remote Sensing Organization (SPARRSO) and Google Earth. In this research work, to create precise and comparable maps of river channel features, bank lines were delineated through relative interface of land and water criteria.

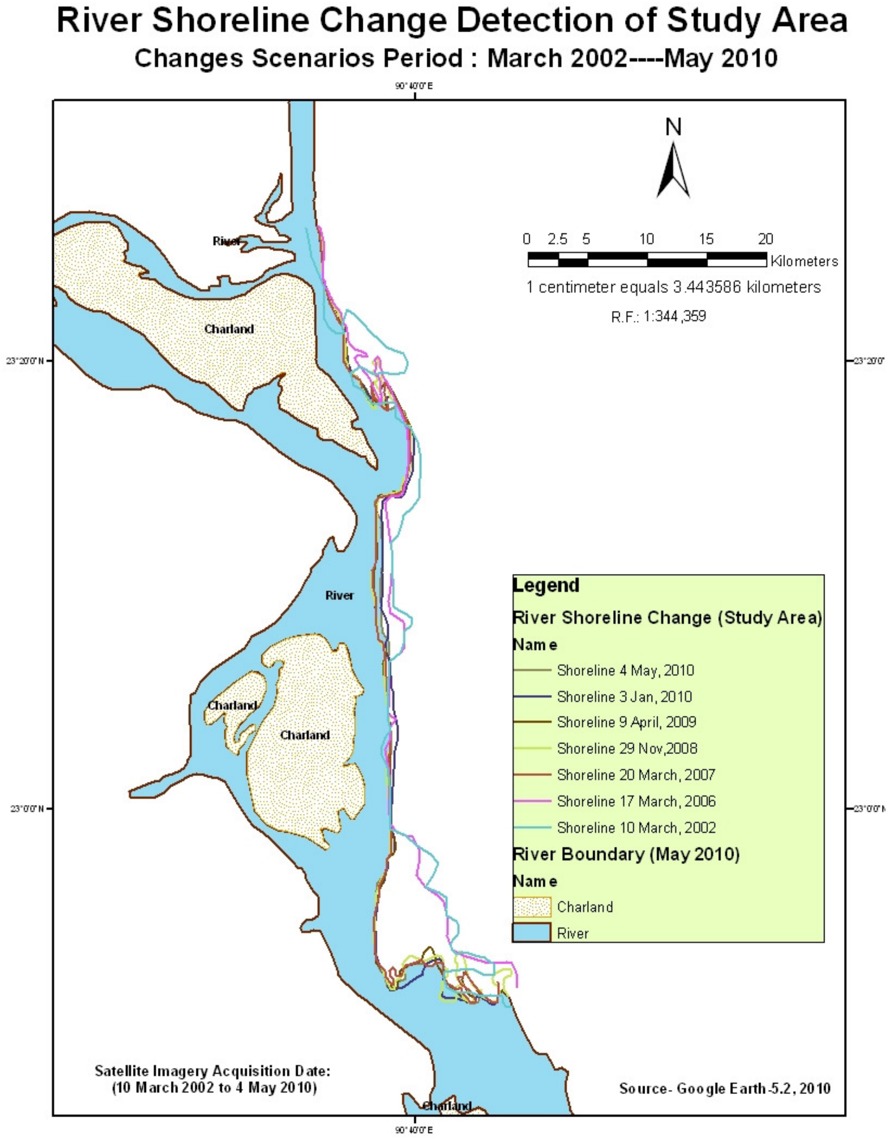


Figure 3: Left bank line dynamics of the study area from 2002-2010.

Geographic Information systems (GIS) and Remote Sensing (RS) are used in data encoding and analyzing purposes. ArcGIS 9.3 and ERDAS Imagine 9.2 version software and human interpretation have been used in extracting the data from the high resolution remote sensing image. The interpretation results are processed under the above environment by applying multi-temporal approach. The data of river left bank line is extracted from the available satellite imagery in different time period, based on spatial overlays techniques. To maintain and fixed in Eye Altitude of 150 km and selecting whole study area, series of satellite Imagery were acquired from Google Earth-6.2v. All the collected Satellite imagery prevewing in each single window viewer and then putting Add Control Points marks in Top Left, Top Right, Bottom Right and Bottom Left on each of the satellite images. Total 4 Ground Control points mark putting on single satellite image and newly developed historical imagery tool bar was used to collect satellite imagery in differrent time interval (year wise) by applying the sliding bar adjustment techniques. Different shapefile layers (i.e.-District, Upazila, Union Boundary, River, Charland, River Shoreline etc.) for vector data were created and assigned projection in each shapefile in the ArcGIS (Arc Catalog) environment. All the satellite images were opened in Arc map and used to extract information from it. Digitization was performed to collect shoreline or bankline layers from individual year basis.

For river left bank shoreline delineation, consecutive year's satellite imagery from 2002-2010 were considered as shown in Figure 3. Recent 2010 imagery considered as the base reference and all previous years' imagery were superimposed with one by one. Edge detection techniques give a clear idea about demarcation of land and water boundary.

4. Results and discussion

4.1 Erosion and deposition area analysis

At Chandpur an imbalanced hydro-morphological conditions exist due to wave action, tidal effect and the presence of the Dakatia outfall (Ahmed, 1989). The bank of the lower Meghna near Chandpur has been eroded continuously and information on the river bank line for the last 73 years shows progressive recession of the left bank (Siddique, 2004). The rate of erosion and its location have, however, changed from year to year. Results of interpretation and extracted layers from satellite images were transformed into GIS layers in vector format. Change of river segments was detected by superimposing data layers together by the order of raster-vector or vector-vector. Erosion and accretion of the river were digitized considering three different decades (i.e.1980-1990, 1990-2002, and 2002-2010) with vector shape file.

The estimation of the area was made with the aid of GIS and finally again all those data estimated in the AutoCAD environment for re-checking. Data of different periods (from 1980-2010) were considered for erosion and deposition area calculation. The shoreline change map prepared and superimposed techniques applied layer by layer as a vector file with backdrop base imagery of May 2010. All the layers superimposed one by one maintaining sequential order, there after change detection was performed, demarcated and calculated the erosion and deposition of the study area from 1980-2010 and final layout were developed for visual interpretation and presentation which are showing in figure 4.

Google Earth recent available imagery was considered in 4 May 2010 for the base and standard bank line. All the previous bank line shifting in different time periods were demarcated and calculated the erosion and deposition area on the basis of recent available 4 may 2010 imagery. From the calculated results of different erosion and deposition, different types of erosion and deposition zone were identified and finally presented in the map to know the exact scenarios of the study area showing in Figure 5.

The year wise data (last three decades) on erosion and deposition are calculated and showing in Graph (Figure 6) which has been constructed from these values (year vs. erosion area) to interpret the trends of river left bank erosion. The erosion and deposition bar diagram indicates increase in erosion in between 1980-1990 and 1990-2002 periods.

Analyzing the tabular and graphical (Figure 6) representations of the obtained values, the following trends, erosion and deposition zone for the study area can be noted and marked with different color coded circle and line. From the visual interpretation with GIS and Remote Sensing investigation, it is clearly observed that the study area (3 Upazilas) facing erosion and deposition in different spot. The width of the channel is varied from upper reaches to lower reaches. The erosion and deposition rate also varied in different parts of the study area. From the analysis and visual observation, category wise zone area identified on the basis of three decades data. Moderate erosion zone and low deposition zone indentified in the Ekhlaspur Union under Matlab Upazila. The second identified category is low erosion and moderate deposition zone which found in the two unions of Sakhua and Ibrahimpur under Chandpur Sadar Upazila (Figure 5).

On the other hand, from lower part of Chandpur sadar towards upper part of Haimchar is currently facing severe deposition and in some part have fallen in low erosion zone category. According to calculated result and visual observation from the satellite imagery the lower most part shows severe erosion. Upstream part shows moderate erosion but in the downstream of the river near left bank part of Uttar Algi and Dakshin Algi of Haimchar Upazila are facing severe erosion and most remarkable changes observed over the last 30 years period showing major left bank line shifting but very severe erosion observed during the 1980-1990 period. River is widening a lot in that part and left bank line shifted from westward to eastward portion due to developments of vast char land in the central part of the river which means huge volume of water hit in the left bank of Haimchar.

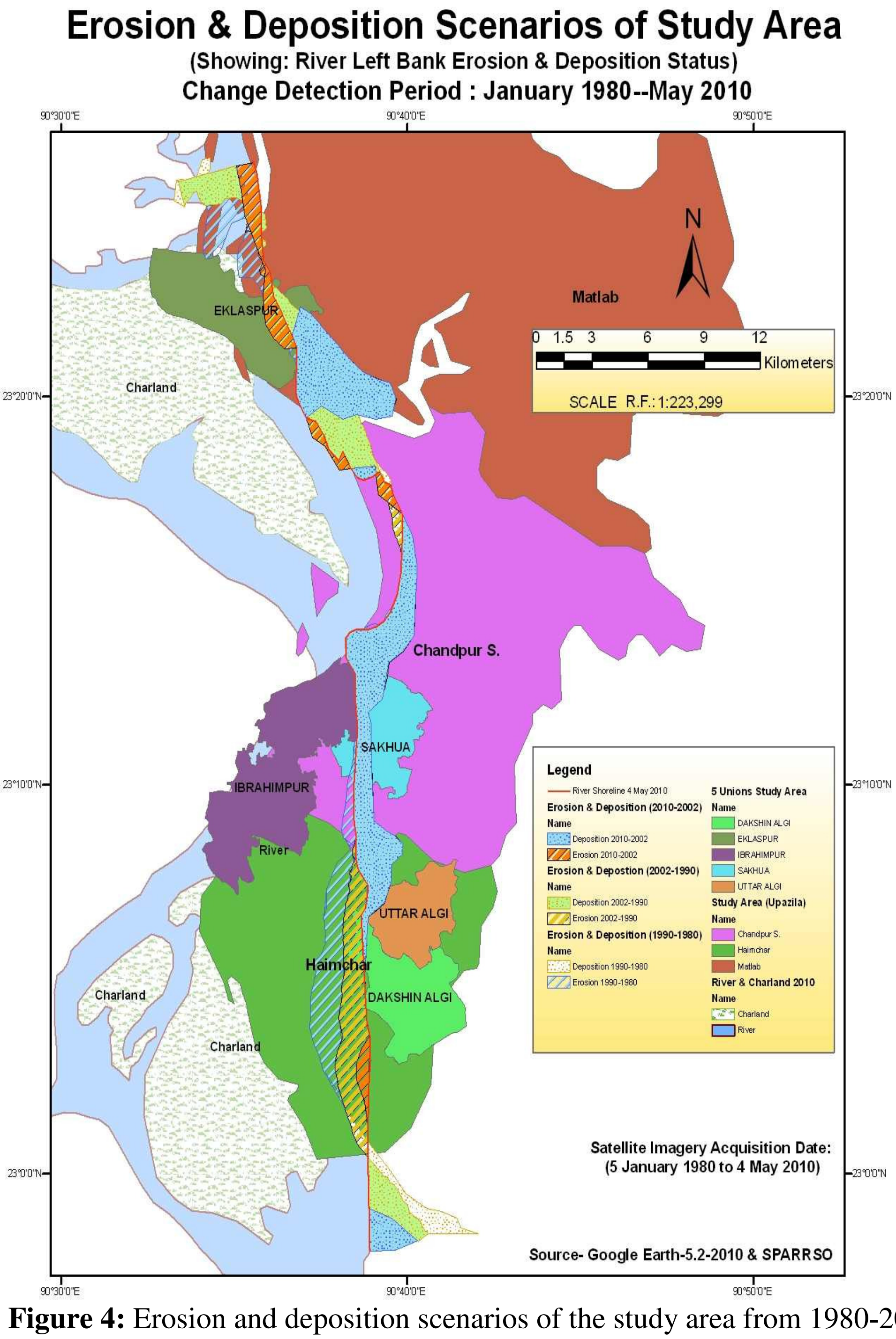


Figure 4: Erosion and deposition scenarios of the study area from 1980-2010.

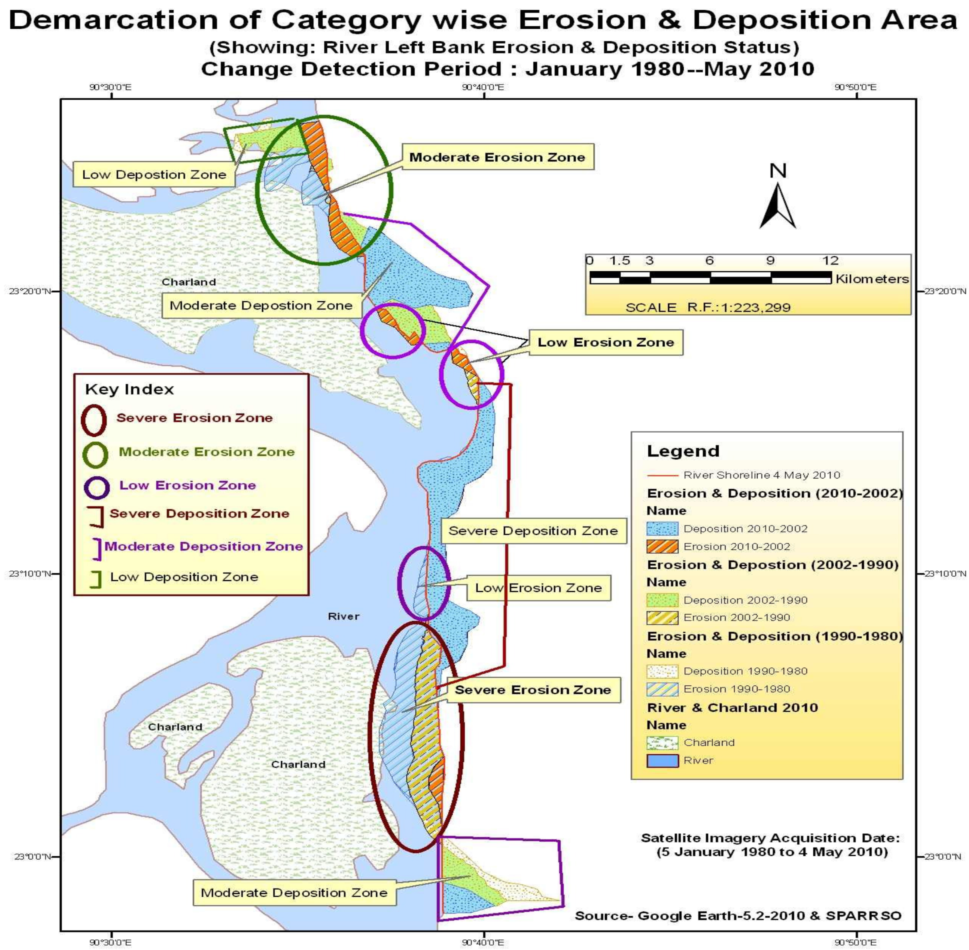
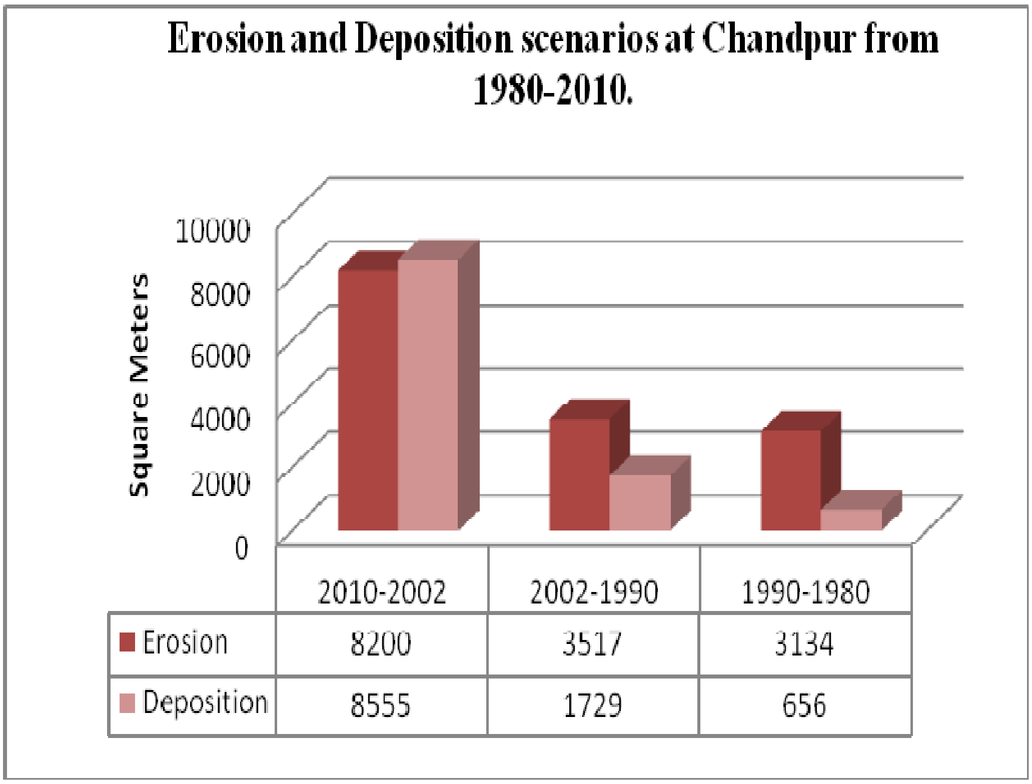


Figure 5: Demarcation of category wise erosion and deposition zone from 1980-2010.



	2010-2002	2002-1990	1990-1980
Erosion	8200	3517	3134
Deposition	8555	1729	656

Figure 6: Erosion and deposition status at Chandpur from 1980-2010.

The above figure shows that erosion rate at Chandpur was higher (8200 sq meter) in the decade of 2010 to 2002 than other two decades and the average rate of erosion in this decade is 1025 sq meter/year. Whereas the decade 1980-1990 and 2002-2010 shows the average erosion rate is 313.4 sq.m/year and 1025 sq meter/year respectively. The area of deposition was 656 sq meter in 1980-1990 and but in recent decade (2002-2010) it is about 8555 sq meter (Figure 6).

As a result, the severe erosion has been occurred in the Haimchar area. On the other hand almost lower part of downstream area of Haimchar upazila showing moderate deposition which is opposed to erosion in that part. At that portion river experienced further major widening activities. The overall trend of the present left bankline migration is north-westward and south-eastward. In Chandpur Sadar upazila upper and central part is an exception where the bank line is moving westward direction. In the mole-head area of Chandpur Sadar the bank line is moving north-eastward and in the Matlab upazila the trend of the bank line is north-westward. But Haimchar upazila shows south-eastward migration (Figure 4).

5 Conclusion

Data analysis of the last three decades from 1980-2010 showed that average erosion rate was 495.03 sq meter/year and from three study locations Haimchar upazila is more vulnerable for erosion. From the period 1980 to 1990, the erosion rate was high in Chandpur. Recently in the decade of 2010 to 2002, deposition rate is higher than the erosion rate. In the last 30 years total eroded area on the left bank of the Meghna was 14851 sq meters and total deposition was 10940 sq meters. The river course shows an overall migration of the left bank is north-westward and south-eastward direction. The tidal effects, combined flow of Padma and Meghna and regular channel shifting are mainly responsible for erosion in that area. Higher rate of deposition may help to form submerged land or char land which may divert the water flow to the mainland resulting severe erosion. Past protections or embankments which were given to reduce erosion, failed in most of the areas and also increased erosion rate in the unprotected areas. However, further research should be focused on future channel shifting pattern, erosion rate and vulnerability of different locations as well as determining effective measures to decrease erosion severity and its consequences.

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