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River channel shifting over the last 50 years of Upper Brahmaputra River, Bangladesh

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Abstract

River erosion in the Brahmaputra basin is a common phenomenon, but it also causes adverse effects on human beings and the environment. This study illustrates the dynamics of channel shifting and bank erosion for the last five decades of the mighty Brahmaputra River. It was found that the Brahmaputra River was expanding/widening over time and is about 45% from its previous width in 1972. During 1972-2020, a total of 199.00 sq. km of land (agriculture/vegetation) area was eroded by the river in a particular area of Interest (AOI) alone. The Char area also increased simultaneously as the riverine area increased, but different features were seen after 2015. Google Earth and land viewer imagery indicate that a substantial basal erosion was observed and might be caused by limited sediment supply from upstream or human interference caused by decreased char area. The massive erosion and instability of chars/islands were observed, influencing the victims' life patterns.

Introduction

Riverbank erosion in the alluvial floodplain is a common geomorphic phenomenon caused by the detachment and transportation of soil particles with other materials by the action of water. It also refers to bank adjustment, bank trampling, navigations, and bed elevation and topography changes in reaction to modified flow conditions (Lane, 1955; Madeji et al., 1994; PieAgay and Bravard, 1997, Chowdhury et al., 2007; Nath et al., 2013).

Bangladesh or Bengal basin is the largest alluvial delta in the world, and river erosion is a common phenomenon, especially during rainy sessions. The great rivers like the Brahmaputra (Jamuna), Ganges (Padma), and Meghna flow through the deltaic system and carry 1-2.4 billion tons/year of sediments from upstream Himalayas (Rahman et al., 2018). Most of the rivers change their course of flow suddenly, which causes severe riverbank erosion. Riverbank erosion is a serious problem hampering the national development and socioeconomic and environmental sectors. Due to river erosion, millions of people were displaced from their origin and lost their land and houses, which made them Internally Displaced Populations (IDP). River erosion-accretion procedures continue every year. The associated river planform adjustments resulted in a net loss of about 8700 hectares of land, displacing nearly a hundred thousand people (WARPO, 1999; Baqutayan, 2015; Arobi, 2019). Due to riverbank erosion, the displaced people are marginalized regarding livelihood patterns and psycho-physical troubles (Arobi et al., 2019). Due to riverbank erosion, the replaced and floating people experience substantial socio-economic insolvency and downgrading due to forced displacement from their original homes (Hoque, 1988; Dekaraja and Mahanta, 202).

Brahmaputra River is a tremendous and active morphologically multi-channel braided river in the Bengal basin that carries the highest amount of water and sediments. This river's total length and discharge areas are 2882 km and 520,000 km2, respectively. The Brahmaputra has a vast sediment load of around 390-1160 million tons annually

(Rahman et al., 2018), most of which are silt (Colin et al., 1993). It also carries a significant amount (15-25%) of sand (Halcrow, 1991) and a small amount of clay (Colin et al., 1993). After a long journey through Tibet (China), Bhutan, and Northeastern India, it enters Bangladesh through the Kurigram district. Upstream of this river is structurally controlled by complex rock formation, but it becomes wider while entering the alluvial plain lands. However, significant variations in width, gradient, and discharge channel pattern occur throughout its course. Historically this river once flowed to Yangon before the Shillong Plateau uplift (Goodbred et al., 2000). This river might also change its present channel (Jamuna) from the old Brahmaputra after a significant earthquake in 1950 (Goodbred et al., 2000). Multi-channel flow and riverbank shifting in the Kurigram district is hurting livelihood and distressing the people. It is categorized by massive bank erosion in places leading to hundreds of meters of annual bank retreats (Mosselman, 2006). The Eastern bank of shifting of this river has been more prominent over the last 50 years, causing erosion of hundreds of fertile lands.

The current work provides a brief description of a study conducted using an integrated approach of remote sensing and geographic information systems (GIS) for 50 years (1972–2020) on the upper part of the Brahmaputra River, including its entire course in Kurigram district and some portions of Gaibandha and Jamalpur districts. The satellite data has consistently shown information on the river system's channel configuration, exposing critically important information on changes to river morphology, erosion/deposition patterns and their impact on the land, stable and unstable chars and stretches of the river banks, changes to the main channel of the Brahmaputra River, etc.

This study also aimed to assess the consequences of the Kurigram district's socio-economic indicators during the period mentioned. It anticipates that the combined use of the data from this study and statistical information will significantly contribute to a more relevant approach to planning and carrying out means and strategies to combat recurrent flooding and erosion.

Study area

The area of Interest (AOI) lies between latitude 25°20′13′′ to 25°48′57′′N and longitude 89°39′10′′ to 89°49′55′′E in Kurigram district and some part of Jamalpur and Gaibandha district of Bangladesh (Fig. 1). The area comprises of alluvial sandy loam soil. Geographically the AOI is located west of Garohill of the Shillong Plateau, a tectonically active region of the world.

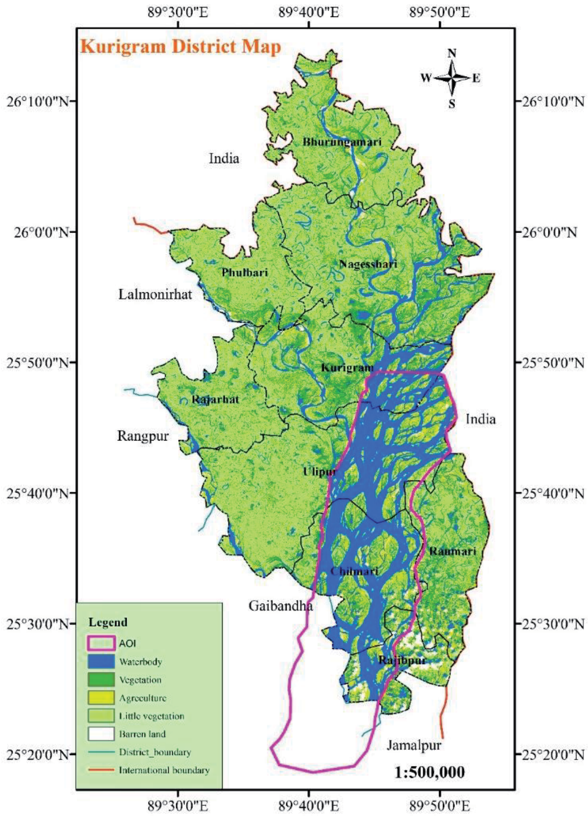


Figure 1 Map of Kurigram district including Area of Interest (AOI)

Materials and Methods

Satellite imagery, google earth imagery, and administrative and general data, including shape files of District and Upazila maps, are used in the study from various sources.

Satellite and google earth pro imagery

Initially, a series of high-resolution Google earth pro satellite imagery was used for the delineation of riverbank erosion of the left and right banks of the Brahmaputra River. The riverine area, char area, and river bank were marked using the polygon tool of Google Earth Pro and exported as a KML file. The area of each polygon traced on google Earth Pro was recorded for areal calculation. The edited KML files were imported and converted as a layer in ArcGIS (ArcMap 10.3) using ArcToolbox options. A shape file was produced for imported data in a new map with the same coordinate system. Processed remote sensing images for AOI were superimposed on the map area.

A detailed study was conducted based on Landsat imagery (Landsat 1-5 MSS C1 Level 1, Landsat 4-5 TM C1 Level 1, and Landsat 7 ETM + C1 Level 1 Landsat 8 OLI/TIRS C1 Level 1) of Tiles number 148042 downloaded from GloVis (Table 1) as raster shape files and processed by ArcGIS (ArcMap 10.5) software. 13 Landsat photos from various years, such as 1972, 1976, 1980, 1986, 1987, 1988, 1992, 1996, 2000, 2005, 2010, and 2015, have been collected (Figure 2) extracted the physical data (land, water, vegetation, etc.,) based on the color band composition (Table 1) for raster files using Raster Processing option in ArcTool. The color bands were selected based on the guideline of USGS (Table 1). To identify geomorphic changes, these digitized maps were divided into five categories (water body, high vegetation, low vegetation, agriculture land, and barren land) using unsupervised classification in image processing. This classification also provides the distribution of land, water, and vegetation cover of the AOI. The changing of river banks and the accretion and erosion of land over multiple years are depicted on various maps from different years. ArcGIS was also used to demonstrate social and economic parameters on the Map.

Table 1 Satellite images used for ArcGIS analyses

Landsat imagery data set	Date of imagery	Color bands selection	Source
LM01 (Landsat 1-5 MSS C1 Level 1)	19721123	4, 5 and 7	https://glovis.usgs.gov/app
LM02 (Landsat 1-5 MSS C1 Level 1)	19761217	4, 5 and 7	
LM03 (Landsat 1-5 MSS C1 Level 1)	19800116	4, 5 and 7	
LT05 (Landsat 4-5 TM C1 Level 1)	19860327	1, 2 and 3	
LT05 (Landsat 4-5 TM C1 Level 1)	19871208	1, 2 and 3	
LT05 (Landsat 4-5 TM C1 Level 1)	19881108	1, 2 and 3	
LT05 (Landsat 4-5 TM C1 Level 1)	19921018	1, 2 and 3	
LT05 (Landsat 4-5 TM C1 Level 1)	19961130	1, 2 and 3	
LE07 Landsat 7 ETM + C1 Level 1	20001117	1, 2 and 5	
LT05 (Landsat 4-5 TM C1 Level 1)	20051107	1, 2 and 3	
LT05 (Landsat 4-5 TM C1 Level 1)	20101105	1, 2 and 3	
LC08 (Landsat 7 ETM + C1 Level 1)	20151221	1, 2 and 3	
LC08 (Landsat 7 ETM + C1 Level 1)	20201218	1, 2 and 3	

Administrative data and Map

Administrative data including population, education, riverine area, and other socioeconomic parameters, were taken from the Bangladesh Bureau of Statistics (BBS, 2020). Shapefiles of the District and Upazila map are taken from the Local Government Engineering Department (LGED) website, Bangladesh.

Result and discussion:

The Brahmaputra River's channel migration and erosional features were tabulated and visualized using statistical approaches in Figures 3, 4, and 5. Figure 3 illustrates river morphological changes, including east- and west-ward bank migration. From the satellite imagery, an apparent shifting of both banks was observed. The east-eastward migration is prominent in some places, which causes considerable landscape loss. The instability of chars/islands within the Brahmaputra River was also seen.

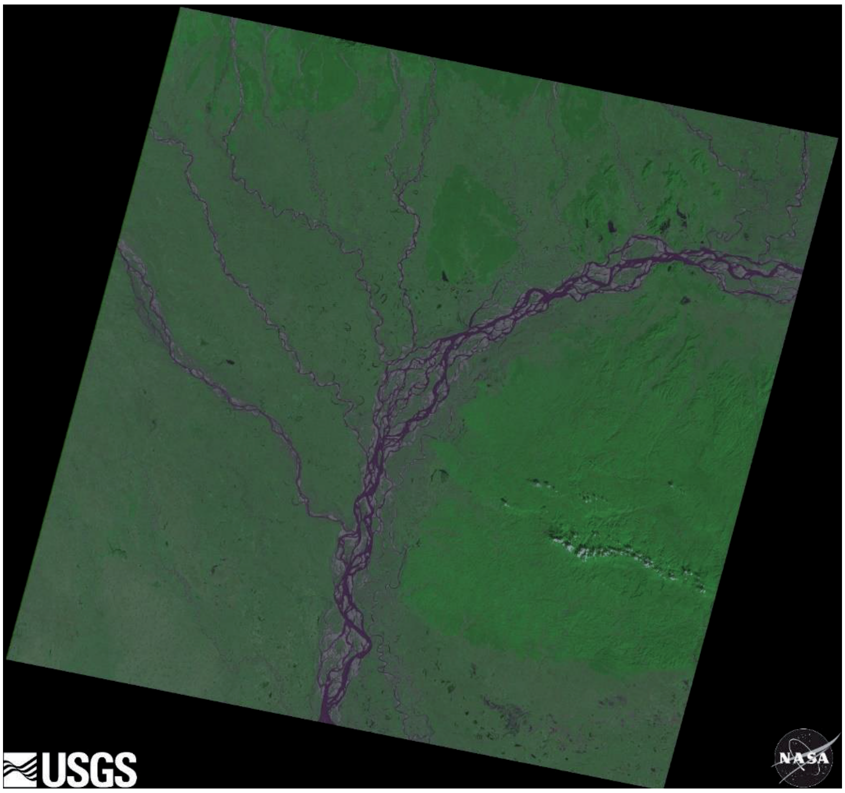


Fig. 2 Landsat imagery of Tiles No. 148042 (LM01_L1TP_148042_19721123_20180429_01_T2) of 1972

Fig. 3 shows the river dynamics of the Brahmaputra River over the last 50 years. The total river and char area are displayed, indicating the river dynamics. The entire river area of the Brahmaputra River continuously increased until 2010, when it ceased (**Fig. 3, 4**). Both banks were moved outward, causing enormous erosion. Over the last 50 years, the riverine area was increased by about 45%, resulting in 191.33 km^2 of land area diminished by the river. Char area also increases simultaneously with the total river area. After 2015, the charred area is decreasing alarmingly, which might have some natural or anthropogenic effect. A decrease of 53 km^2 (**Figure 4)** in the charred area is observed in 2020, less than in 2015, caused by upstream basal erosion (Figure 5 from google imaginary). Furthermore, a high-resolution land-water Landviewer map (**Figure 6**) was presented here to show recent upstream erosional features which support the decrease of char area from our analysis.

River shifting and channel migration occur at the braided river. However, it is a severe problem in some places of the Brahmaputra River. Erosion tends to broaden the river causing, destroying the permanent infrastructures or plantations to be eroded and end up falling into the river (Mohamad et al., 2018). **Figure 3** shows the areal distribution and migration of the river bank in 1984 and 2020. Both banks are possessed much erosion rather than accretion. Still, the outer bank (west side) river migration is supposed to have lesser decay. In contrast, the river shifting towards the inner bank (East side) is considered due to significant erosion activities.

Causative factors of river bank erosion

Numerous operating dynamic forces are changing the landforms and related morphology. Fluvial morphology changes are more frequent than arid, glacier, karst, and coastal morphology (Aher et al., 2012). Severe soil erosion has led to environmental problems, such as high alluvial sedimentation rates, streambed elevation rises, frequent geohazards, and ecological deterioration. Several natural factors, such as precipitation, vegetation cover, slope instability, river sediment quality, bedrock characteristics, relief-slope characteristics, and hydraulic conditions, are highly affected by erosion. Soil erosion controlling factors like soil erosion processes, runoff and sediment yield characteristics, soil characteristics, and the prediction and prevention of soil erosion. However, for the Brahmaputra River, erosion is caused by excessive river discharge (**Figure 5**) and prolonged flooding. Moreover, anthropogenic factors also affect river bank erosion. Field observation in the study area indicates that some anthropogenic factors include: (i) clearing of vegetation along the river banks; (ii) unwise sand extraction for construction purposes, which are influencing the river erosion.

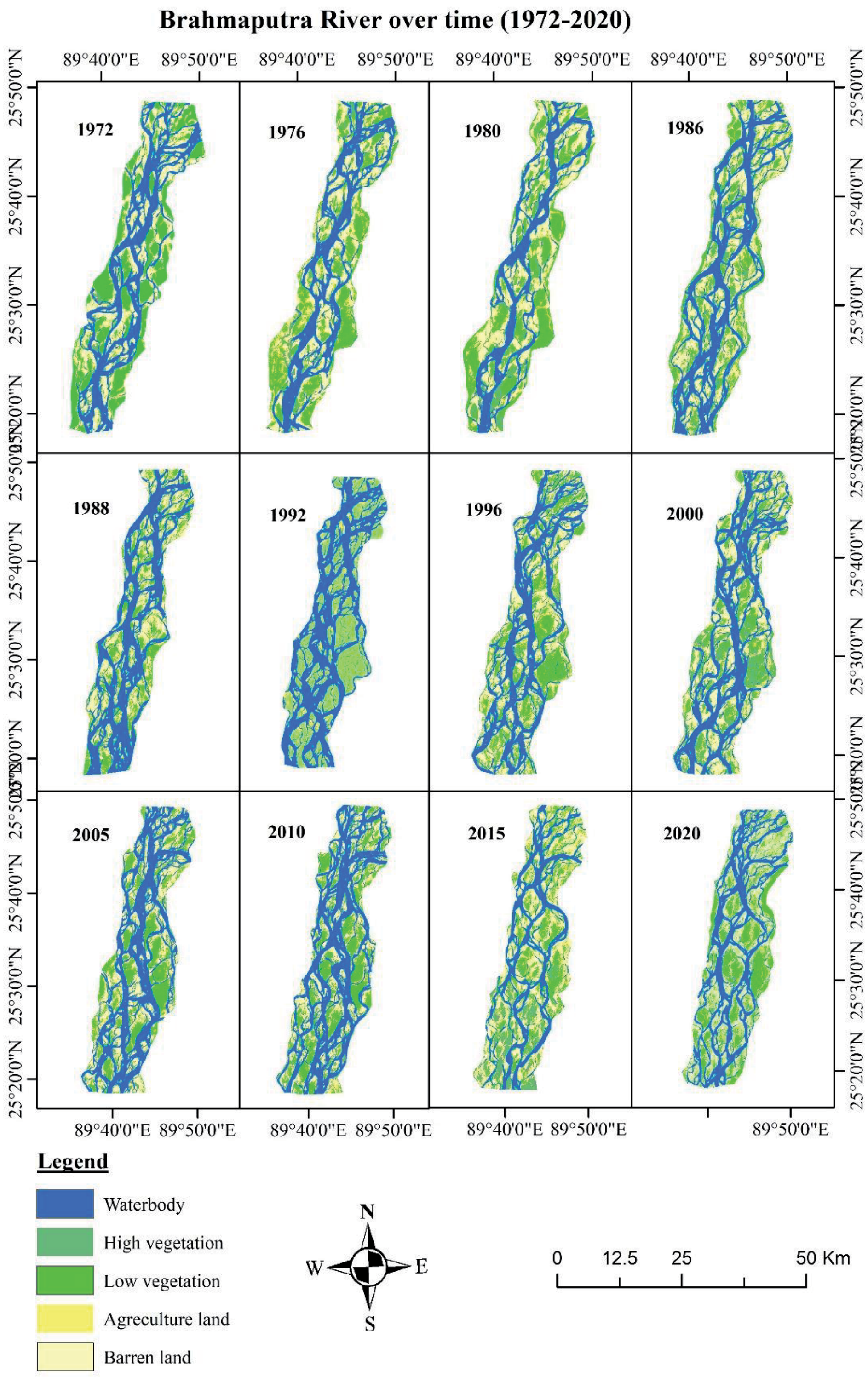


Fig. 3 Maps showing the braided channel shifting of the Brahmaputra River over time (1972-2020)

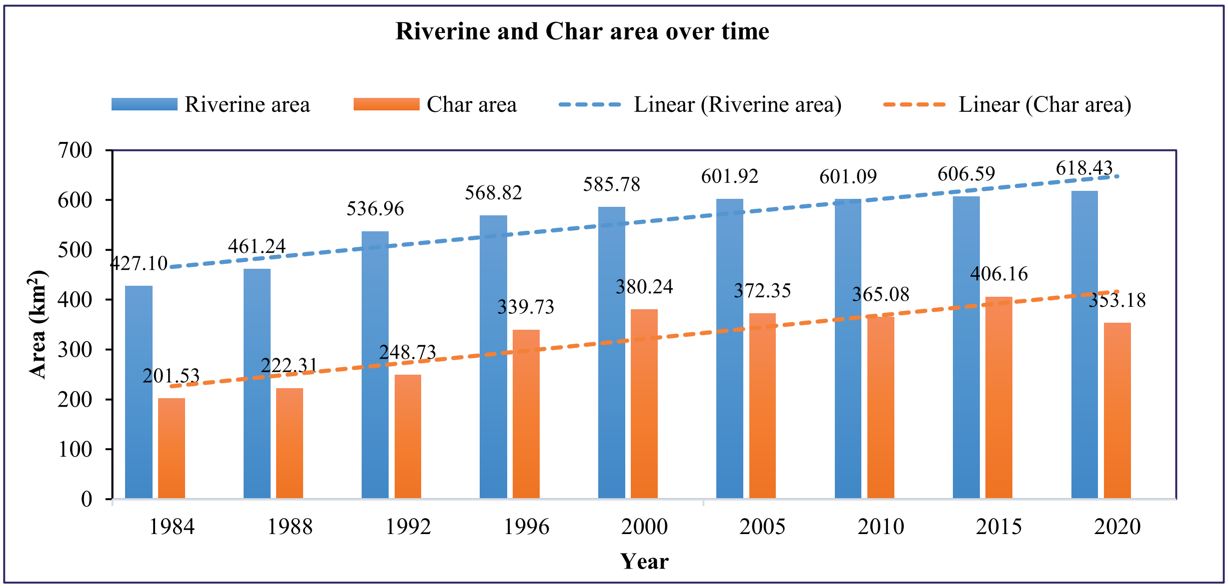


Fig. 4 Total Riverine area vs. char area for the year from 1984 to 2020 of Brahmaputra River

River erosion and society:

Human beings and River relationships have a great historical perspective; evenly, human civilization also developed on the bank of rivers. Human interaction with the river for multipurpose, which can affect the well-being of life (Aher et al., 2012). Since human development issues (physical and social) directly and indirectly depend on the river, shifting the river channel can change livelihood. River erosion causes damage to the existing land and vegetated cover, negatively impacting the environment. Populations move due to river erosion and generally migrate in various ways.

The victim people by river erosion intend to live nearby places of their previous location, expecting their lost land to be recovered and visible on char/island. This happens often, and people have built their char houses but are unhappy that the newly emerged chars last some years. The time series (Fig. 4) is a good understanding of reality. Certain peoples also have their livelihoods on the river as fishers. Some victims move safely (a few kilometers) from their previous places.

Both groups have built their new homes by acquiring new land that is either farmland or green vegetation. This activity has a direct negative impact on agricultural production and the environmental balance. Some affected people leave their parental land and start their new unknown destination, including the slums of large cities. Among this group, some migrate near the districts hoping for a better life. However, river erosion negatively impacts human development issues (annual income, food, and nutrition, poverty, population density, literacy rates, growth centers, etc.). It causes mental impairment in victims because of numerous causes. Once the landlord or rich people with huge farmland fall into poverty due to sudden loss of land ownership through river erosion, the misery of river eroded/displaced people cannot be described in a word. Sometimes they have no food, shelter, or even a place to keep their staff. Sometimes homeless people make their home next to the road or part of the road or float. The displaced have no purchasing capacity, even chocolate for their children. Due to poverty and other logistic support, children drop out of school. The life of char people is also critical for their means of living. Most of them do not have their land and cultivate another land based on sharing production. They also nurse livestock, although most of these are not of their own. They generally benefited in part from it.

The char of the river area is very unstable, as seen in **Fig. 5**. The study area has constantly flooded due to floods a few times every year that also cause devastation to the inhabitants. During the monsoon, there is an enormous discharge every year, and the water level rises to 20 m from the mean sea level (**Fig. 7**). Due to navigation problems, upstream releases overflow the bank, causing severe bank erosion. The chars submerged during a flood caused hell to the char people. They survive using different techniques as they adapt, including building shelter at a certain height with their livestock. In some cases, they would have to leave their home as the flood continues longer with a high magnitude. It is observed that during the 1988 and 1998 floods, many people in the charred area had to leave everything except their own life, as an entire char was carried away by the current of water.

Our analyses show that both banks have been eroded continuously from 1972 to till date, even though its rate ceased after 2005. It happens due to braided nature and loose silty and clayey soil in the bank. We figure out the relationship between river erosion and some development issues like literacy, population density, and land vs. riverine area of Kurigram district (Fig. 8). It is found that these three development indicators are consistence with river erosion. Severely eroded river area like Rajibpur has less literacy rate, population density, and existing land area. Almost two-third area of this Upazilla now captures by rivers. However, protective measures should be taken to stop river erosion, including civil engineering structures like green, masonry walls or embankments with geotextile.

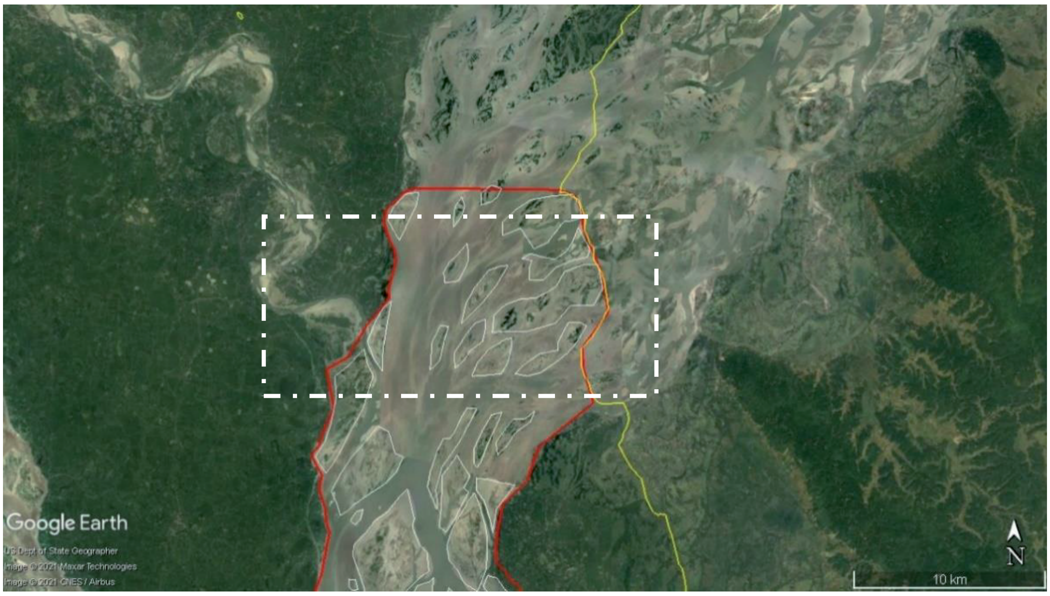
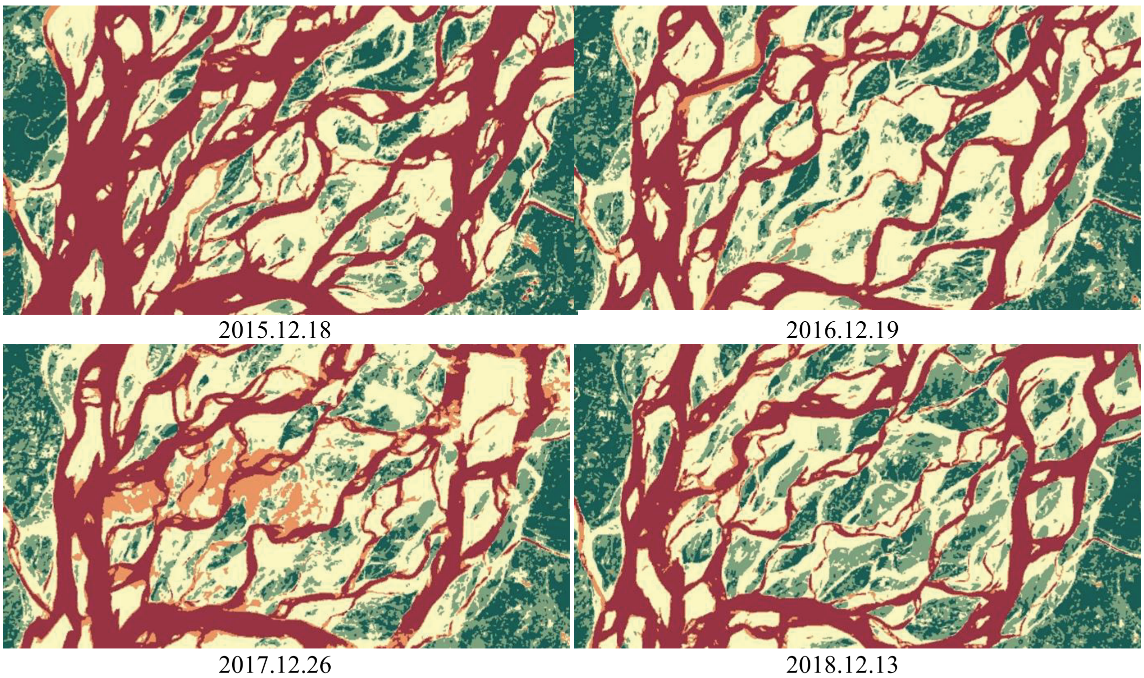


Fig. 5 Basal erosional feature of upper Brahmaputra River



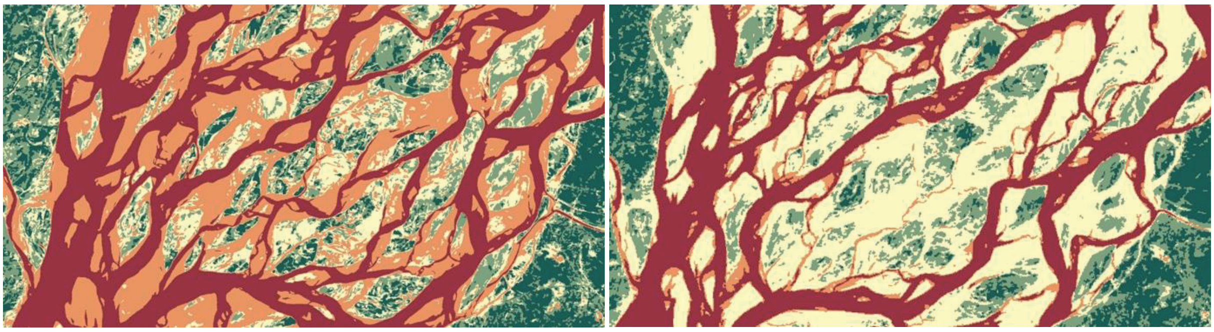


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Fig. 6 Landviewer maps showing the channel's elements of the Brahmaputra River for the years a) 2015, b) 2016, c) 2017, d)2018, and e)2020.

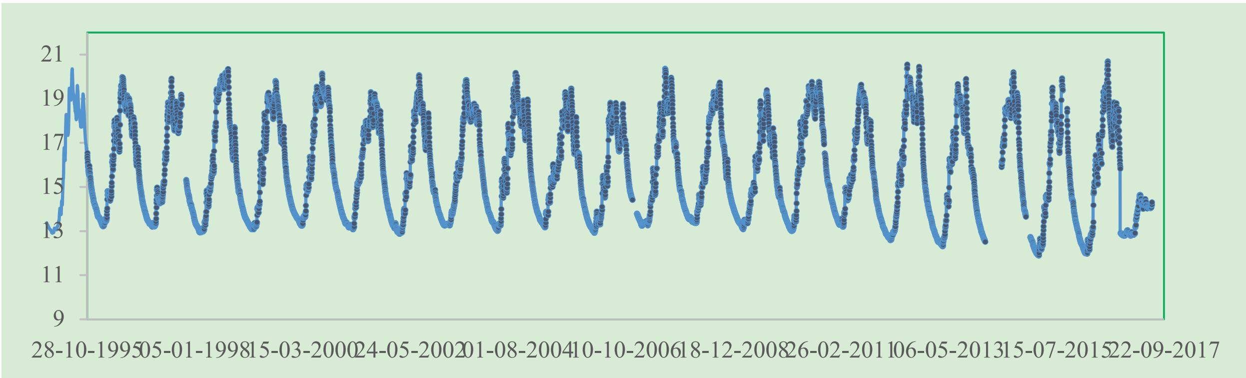

Fig. 7 Water level fluctuation of the Brahmaputra River from 1995 to 2017 record at Bahdurabad Point (WDB, 2019).

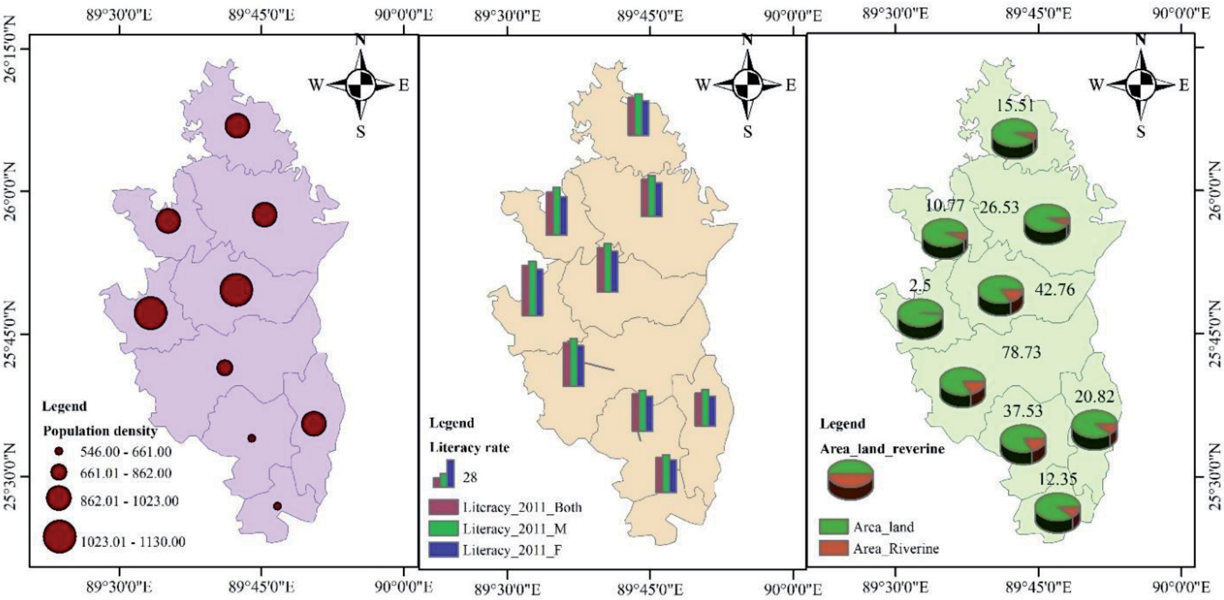

Fig. 8 generalized population density statistics, b) literacy rate, and c) land vs. riverine area of different Upazillas of Kurigram District to show a correlation with the river erosion effect.

Conclusion

The extensive river channel expansion of the Brahmaputra River in the AOI was caused by river erosion of 198 sq. km of land area over the last 50 years. River erosion was vigorous up to 2005 and ceased little then. Char area also increased as the river area increased until 2015. However, recent imagery indicates that a significant basal erosion in the upstream region might be caused naturally or have any anthropogenic effect. The natural cause would be less sediment input from the upstream, whereas human interference is the unwise sand extraction from the river bed for construction. Moreover, river erosion has direct influences on population density and education. To overcome river erosion, proper river training is needed.

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