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Erosion and Deposition induced Land Use Changes: A Geospatial Analysis on Sangu River, Bangladesh

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Abstract

The study attempts to measure the eroded and deposited area of the Sangu River to understand the impacts of river systems on land use changes. Landsat photos of the last 28 years of the Sangu River floodplain (Anowara and Banshkhali Upazila of Chattogram) were analyzed at 5-year intervals using GIS and remote sensing techniques. ArcGIS 10.8v and ERDAS IMAGINE 2015 were used for the analysis. Results show that the total area that has been eroded and deposited during the past 28 years is 7070.70 ha and 437.87 ha, respectively. Moreover, a substantial portion of the deposited land has already been transformed for commercial uses such as shrimp cultivation which might deteriorate the soil fertility in the future and could exacerbate the salinity aggression in this area. It is expected that the study will contribute in the optimization and management of the floodplain which is crucial for the safety and welfare of the communities.

Keywords: Erosion, Accretion, Landuse Changes, Sangu River, Bangladesh

Introduction

Bangladesh is endowed with a substantial number of flowing water bodies where almost seven percent of the country’s land surface is occupied by its river system[1]. The rivers are channeled through the country in a crisscrossed pattern[2]. Presently, there are 230 rivers in Bangladesh and the total length of the rivers is almost 24000 kilometers[3]. As a deltaic tract, Bangladesh often experiences river bank erosion[4]. The land surface of Bangladesh is predominantly formed by alluvial deposits that have increased the proneness of riverbank erosion[5,6]. Furthermore, the continual shifting of channels is evident in most of the rivers due to their active fluvial geomorphic processes[7]. In a fluvial system, river bank erosion and accretion are the two principal geomorphic processes[8,9]. Bank erosion, accretion and downcutting are common occurrences for alluvial rivers, which are prevalent in Bangladesh[10]. Throughout the last few decades, riverbank erosion has been observed to happen incessantly[11]. Moreover, river bank erosion is termed as a ‘Silent disaster’ in Bangladesh because of being very unpredictable, frequent and gradual in nature[12-15]. The underlying reasons behind riverbank erosion are quite complex and incorporate different geomorphic processes[16]. Likewise, riverbank erosion is frequently instigated by excessive rainfall and the failure of a riverbank that causes intense sediment load[2]. Usually, erosion in a river bank takes place during or after a flood, therefore, influencing the size and shape of the channel through the discharge of upstream water and sediments[16,17] Erosional works of a river can also be influenced by factors like inadequate vegetation cover, hindrance in the streams, wind upsurge and boat wakes etc.[14,18]

Fluvial-morphological processes e.g. bank erosion, down-cutting, and bank accretion result in the migration of river channel which is a natural alteration process of alluvial channels of dynamic non-equilibrium[19-22]. A river often experiences erosion at the outer bank and the rate of wearing away of materials depends on their characteristics[6,23]. Contrarily, river bank accretion takes place on the inner side of the meander[24]. Shifting of the channel and creating braids are the common fluvial processes in a river. The erosional process in a river continues if the rate of bank erosion surpasses the deposition rate[25]. However, changes in the river course may affect land use and land characteristics of the surrounding areas[26-29]. In addition, the accretion of the riverbank could result in the growth of riparian vegetation, the acquisition of new alluvial land that might be used for farming and pastoral purposes[22]. The modification of alluvial channels is primarily influenced by the alteration of water and sediment inputs, tectonic events, and human actions at a range of spatio-temporal scales[6,30,31]. One of the adverse impacts of bank erosion is the loss of land[32,33]. Besides, such fluvial processes can be exaggerated by flooding events[34]. On the other hand, morphological changes in the river can also happen through development projects like the construction of embankments, dams, bridges or other bank protection measures[35,36].

There are plenty of studies[13-15,18,28,37-39] that have investigated different aspects of the Ganges, Brahmaputra-Jamuna and the Meghna. However, very few research works[40,41] are found focusing Sangu River which is still insufficient to understand the nature of this hilly river.

Because they depend on it for their lives and means of subsistence, the inhabitants of the Chattogram (formerly known as Chittagong) region view the Sangu River as being extremely vital. Nonetheless, the locals are starting to worry about the river bank's erosional activities. The river's erosion and depositional processes have altered its morphological features throughout the years, although this morphological change has not been fully studied. The area where the physical changes brought about by the fluvial processes have not been identified, even though there are several studies focused on the impact of riverbank erosion in Bangladesh. Therefore, this paper aims to quantify the eroded and deposited bank areas of the Sangu River from 1990 to 2018. Moreover, this study is an endeavor to identify the land-use changes on both sides of the Sangu River that are associated with the erosion and depositional processes. This study can help to understand the impact of fluvial processes on the land cover of the river valley which is prone to change their channel course frequently.

Materials and methods

Description of the Study Area. The Sangu River emerges in the Arakan Hills of Myanmar and enters into Bangladesh near Remarki of Thanchi Upazila of Bandarban district, and ultimately ends in the Bay of Bengal[40]. Sangu River has had a great significance in Chattogram as the river flows through three notable Upazila (sub-district) namely Banshkhali, Patiya and Satkania. Furthermore, Sangu is also connected with Karnafully, which is the major river of Chattogram district[40,42]. The banks of the Sangu River erode in different locations of Anowara, Banskhali, and Satkania. Based on the news coverage of different local newspapers it is known that the proneness of river bank erosion is higher in Anowara and Bashkhali Upazilas. Therefore, these two Upazila were selected for conducting this study. The portion of the Sangu River channel that has flowed through Anowara and Banshkhali Upazila is taken into account for the current study (Figure 1).

The northern portion of the river Channel is Anowara Upazila (Figure 1) which is geographically located between 22°07' and 22°16' north latitude and in the middle of 91°49' and 91°58' east longitudes. Anowara is surrounded by Patiya Upazila on the north,

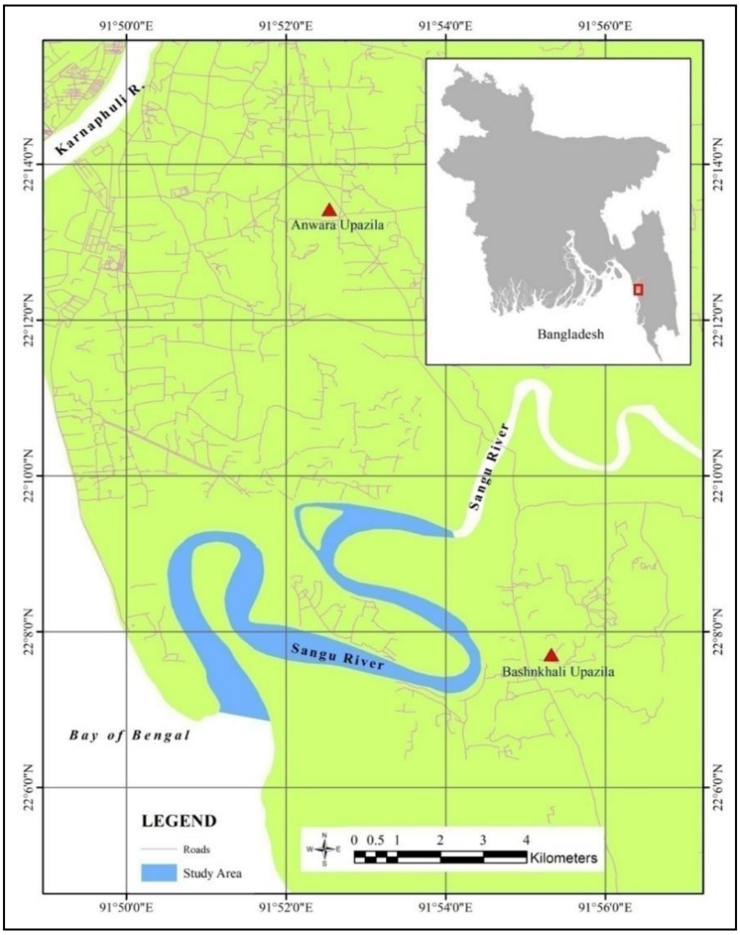

Figure 1: Location of the Study Area (Source: Redrawn from Google Maps)

Banshkhali on the south, Chandanish Upazila on the east and the Bay of Bengal on its west[43]. Anowara Upazila is endowed with 2325 acres of forest land while 20922 acres of land is under temporary farming practice. Besides, several canals are draining off this Upazila e.g. Isamoti Canal, Boropol Canal, Dhanpora Canal, Borkol Canal etc.[44]

The South and Southeastern part of Sangu river is bordered by Banshkhali Upazila, situated between 21°53' and 22°11' north latitudes and in between 91°51' and 92°03' east longitude. The area is encompassed by Anowara Upazila and Sangu stream on the north, Chakaria Upazila on the south, Lohagara and Satkania Upazila and extensive hilly region on the east, Bay of Bengal, Kutubdia channel and Kutubdia Upazila on the west[45]. The major flowing water bodies of this region are Sangu River, Jalkadar Canal, Puichhori Canal, Bamer Chhora etc.[46]

Satellite Data Collection. For the riverbank erosion and depositions, the map is collected from Google Erath 7.0v map in all-time 15-meter resolutions. The most recent high-resolution satellite photographs provided by Google Earth and NASA-GLCF (Global Land Cover Facility) Archive (uninhibitedly downloadable around the world) for Landsat TM and USGS for Landsat 8 satellite map are used to analyze the visual interpretations, land use identification and classification. Many primary and secondary data were required for this analysis. These data were gathered from various sources. Some important Satellite pictures and maps utilized for the investigation were gathered from the "Center for Environmental and Geographic Information System" (CEGIS). Total data like Landsat TM, Landsat 7 and Landsat 8 OLI-TIRS sensors have a spatial resolution of 30m and 15m. Table 1 depicts the satellite image meta data in details.

Table 1: Satellite Image Meta Data Information (Data Source: USGS earth explorer website, accessed on 26th August 2018).

Year	Image ID	Acquisition Date	Sensor	Resolution
1989	LT04_L1TP_136045_19890121_20170204_01_T1	21-01-89	Landsat 4	30m
1994	LT05_L1TP_136045_19941213_20170110_01_T1	13-12-94	Landsat 5	30m
1999	LT05_L1TP_136045_19990125_20161219_01_T1	25-01-99	Landsat 5	30m
2004	LE07_L1TP_136045_20040115_20170122_01_T1	15-01-04	Landsat 7	30m
2009	LE07_L1TP_136045_20090128_20161222_01_T1	28-01-09	Landsat 7	30m
2014	LE07_L1TP_136045_20140126_20161119_01_T1	26-01-14	Landsat 7	30m
2018	LC08_L1TP_136045_20180129_20180207_01_T1	29-01-18	Landsat 8	15m

*All the maps take in path 135 and row 46, have no cloud and in the winter season.
**UTM zone 46 Northern hemisphere projection.

Data Analysis. This paper aims to highlight the channel morphology change from 1990 to 2018 with a 5-year interval to extract the changes in channel line position due to accretion and erosion. ArcGIS 10.8v software was used to show the different yearly accretion and erosion sites of Sangu River.

A procedural framework has been employed to meticulously extract the Sangu River bank lines from satellite imagery using ArcGIS 10.8v software. The process entails a series of structured steps to ensure precision in delineating the river's boundaries. Initially, the satellite image undergoes preprocessing to enhance discernible features, followed by the application of segmentation techniques to isolate the region corresponding to the Sangu River. Subsequently, edge detection algorithms are employed to detect the edges of the Sangu River, facilitating the elimination of extraneous noise and irrelevant features. The extraction of Sangu River bank lines is conducted based on the identified edges, followed by a rigorous validation process to refine the extracted lines, predominantly through manual intervention. Finally, the shapefiles representing the Sangu River bank lines are generated. Besides, ERDAS IMAGINE 2015 was applied to detect the change of river channel due to the erosion and deposition, and subsequent changes of nearby land-uses were also identified by preparing the maps from satellite images.

Two-step methods were followed for identifying fluvial morphological changes; the first one was the identification of erosion and accretion of Sangu River from 1990-2018 and the second one was the land-use change detection between the respective years. The erosion and accretion were measured through supervised classification with maximum likelihood estimation of river area boundary.

Then, the measured eroded and accreted area of Sangu River determines the fluvio-morphological changes alongside describing the land-use changes. The remotely sensed image helped to interpret the change in the land-use and created a thematic map whereas ground truthing is also required for accuracy assessment. Investigator's observation was also helpful in finding out the major changes in the land use.

Afterwards, satellite images of the last 27 years have been gathered to distinguish the adjustments in land-use changes and morphology of the Sangu River (Figure 2). To check the accuracy of the change of land use, ground truthing has been performed by visiting the study locations several times. Overall accuracy were 85% which represented the proportion of correctly classified pixels to the total number of pixels in the datasets. Land use changes were identified similar to the findings of the satellite image analysis.

On the other hand, the statistical values were calculated in SPSS 25.0 and the outcomes were presented as tables.

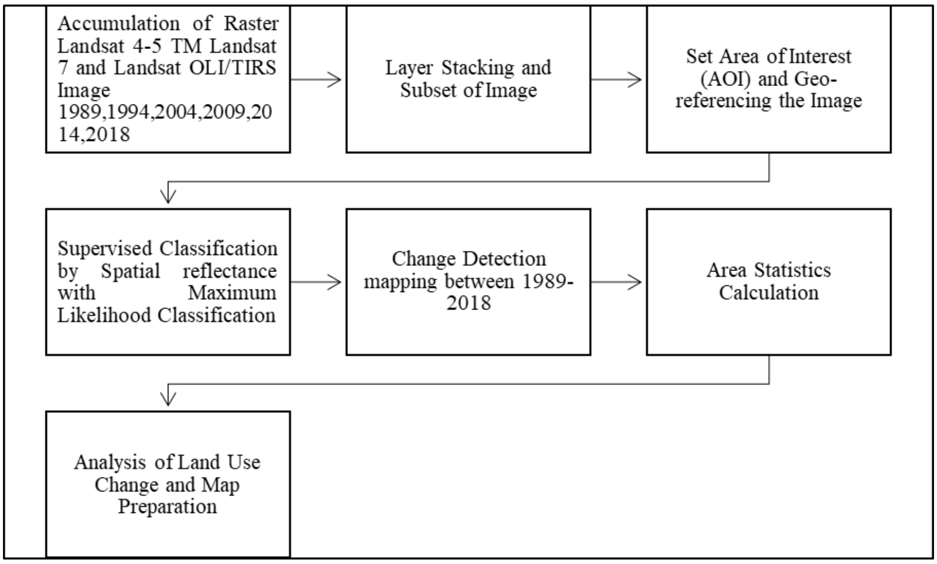

Figure 2: Steps of preparing land use change maps using remotely sensed images.

In this study, land-use of the area was assembled into six classes based on the statistical analysis and the information from the field visits, i.e., Fallow land, Settlement, River Channel, Shrimp Cultivation, Char Land and Vegetation.

Results and Discussion

Erosion and Deposition Scenario from 1990 to 2018. Erosion, transportation and sedimentation are the common morphological processes found in a river channel[50]. Such morphological works are also evident in the Sangu River. The majority of the rivers in Bangladesh are prone to erosion and every year they erode 10,000 ha of land[18,51]. The morphological process of Sangu has resulted in the massive erosion of the river banks, as identified from study sites. From the analysis of satellite images of the last 28 years (1990-2018), erosion is found to be more prominent than accretion in the Sangu River banks (Table 2).

Some parts of the main channel area are constantly being eroded, for instance, erosion is a common phenomenon in *Gohira* and some parts of the *Ratarkul*, *Juidhandi* and *Khuruskul*, while depositional works are evident near *Permesia*, *Barunchara*, *Juidhandi* area of Anowara Upazila (Figure 3). Throughout these 28 years, almost 707.68 ha of the land area was devoured by the Sangu River through incessant erosion. Nevertheless, the accretion of the same river during the indifferent period was 473.85 ha. Just within 28 years, about 234 ha of land is lost in the river channel. Many households, agricultural fields and other land uses have been erased with the elapse of time. Banks of Sangu River experienced the utmost erosion during 1994-1998; approximately 170 ha of land were eroded although the same period represents 19.67 ha of accretion in the river channel; perhaps there was high water flow during this period due to the high

Table 2: Statistical data of yearly erosion and deposition of the Sangu River

Year	Erosion Area (ha)	Accretion Area (ha)	Change Area (ha)
1990-1994	103.34	83.74	-19.60
1994-1998	170.70	19.67	-151.03
1998-2002	110.31	51.68	-58.63
2002-2006	76.30	63.27	-13.02
2006-2010	45.24	102.60	57.36
2010-2014	102.51	83.18	-19.33
2014-2018	99.28	33.71	-65.56

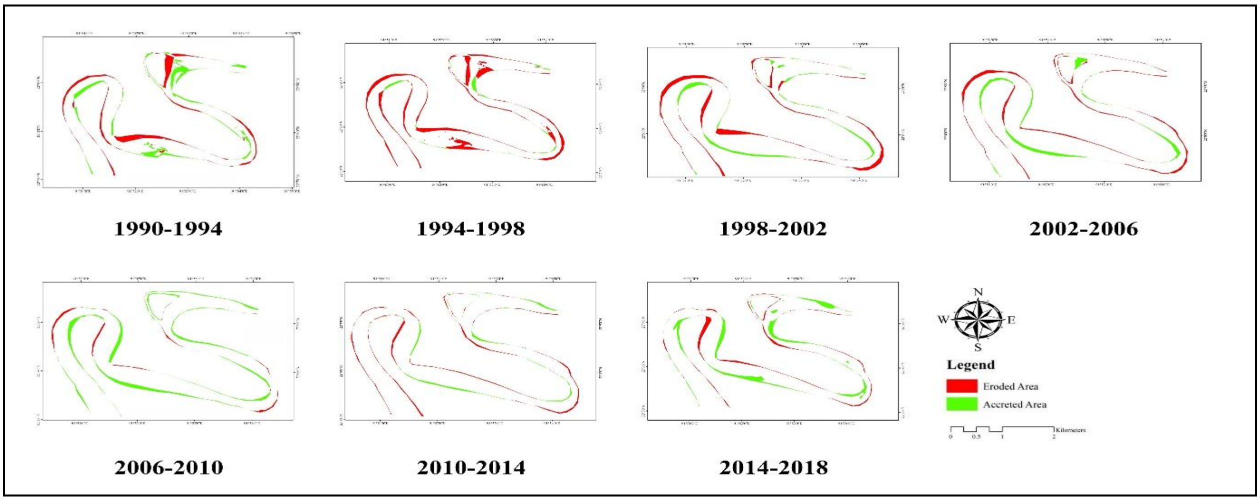

Figure 3: Erosion and Accretion at Sangu River between 1990 and 2018 (in 4 years intervals)

precipitation. In like manner, erosion is found significant from 1990 to 1994 and 2010-2014. Contrarily, about 102 ha of land was newly formed through the depositional activities during 2006-2010, which was the highest throughout the study period. However, Chattogram experienced the highest annual rainfall in 2007 between 2002-2011[49].

At the same time duration of 5 years (2006-2010), only 45.24 ha of the river banks were eroded, perhaps due to the occurrence of no flooding event at that time which made the river a bit sluggish and therefore, a substantial amount of sediments got deposited to extend the bankline towards the channel. The prominence of bank erosion rather than its deposition in the Sangu River indicates that the channel has widened with the elapse of time as it eroded both of the banks gradually at a significant pace. Within a quite similar timeframe (1973-2011), a study by Bhuiyan et al.[18] has found Padma River to have similar morphological behavior. They have propounded that except for a few years, throughout the period the erosional rate in the mighty river the Padma has outstripped the accretion rate. However, another research work has argued about more accretion in the Padma River than erosion[6].

It is comprehended from the analysis that the shape of the Sangu River channel has slightly changed throughout the chosen 28 years (Figure 3). Though not substantially, the channel has become widened in some locations while a small portion of the southeastern side seems to become narrowed. All the maps in Figure 4

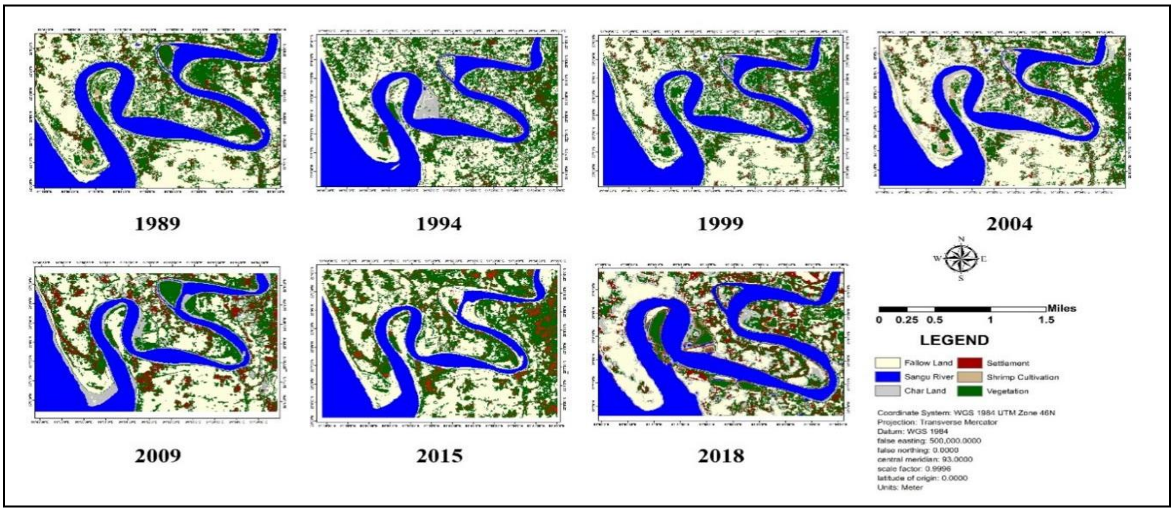

Figure 4: Land use change at Sangu River floodplain between 1989 and 2018 (in 5 years intervals)

articulately present that in different periods red color is more prominent than green, which indicates the spatial and temporal dimension of erosional activities in the Sangu River.

Yearly Sediment Budget of the River bed Area of Sangu. In the channel process, different landforms are developed by a river; channel bars or Char (Gray color in the maps) are common in the rivers of Bangladesh. Sangu River also possesses such depositional features (Figure 4). At the same time, figure 4 also depicts the loss of sediments through erosional activities of the Sangu River bank. This study has calculated the sediment budget of the Sangu River to understand the physical consequences of erosion, transportation and deposition in the channel environment. Over time, the river Sangu has consistently lost sediments (Table 3).

About 341 m^3 of sediment was eroded and moved elsewhere from this channel from 1994 to 1998. This trend of losing sediment continued until 2010 when the amount of sediment loss of the Sangu River environment went down to only 90.48 m^3, which is quite lower compared to the 1994-1998 period. A significant accretion of the area (205.21 m^3) was recorded at that time (2006-2010) that allowed loads of materials to settle down in the channel. However, after 2010 loss of sediment through erosional works became prominent in the Sangu River. Possibly the high current of this river transported the sediment faster before it settled somewhere in the channel. The substantial portion of sediment from the Sangu River travels towards its estuary and therefore, dives into the Bay of Bengal, while the river receives most of the sediment from its tributary *Dolu Khal*. As Sangu River originated from the hilly region, a large portion of the hilly sediments is also transported by this river.

Land-use Change in the Flood Plain Area of Sangu River. Due to the Sangu riverbank erosion in the chosen study sites, the land use pattern has been changing gradually (Figure 4). From the comparison and analysis of satellite images, it is found that the land uses have been changed significantly with the passage of time. Normally, a floodplain is not static or stable as it is composed of unconsolidated particles, which are eroded quickly during floods and high progressions of water, or they might be found on new layers of clay, silt and sand deposits. Because of this, the stream may change its channel and can move laterally from one side of the floodplain to the opposite side. Keeping pace with the change of river channel, lands of nearby areas have kept changing due to the influence of morphological processes, i.e. erosion and accretion (Figure 3 & 4). Out of 5178 ha area in 1989, there used to be fallow land of 1268.61 ha (24.5%), 1848.54 ha of vegetation area (35.5%), Shrimp cultivation in 201.94 ha (3.9%), 300.32 ha area of settlement (5.8%), Char Island over 388.85 ha (7.5%) and the Sangu channel stretched over 1170.22 ha (22.6%) (Table 4).

Table 3: Sediment Budget of the Sangu River during the last 28 years (1990-2018)

Year	Erosion Area(m^3)	Accretion Area (m^3)	Change Area (m^3)
1990-1994	206.68	167.48	39.20
1994-1998	341.41	39.35	302.06
1998-2002	220.63	103.37	117.26
2002-2006	152.60	126.54	26.05
2006-2010	90.48	205.21	-114.72
2010-2014	205.02	166.36	38.66
2014-2018	198.56	67.42	131.13

Table 4. Land use change in Sangu River flood plain areas throughout 28 years period (1989-2018)

Land Classes	1989		1994		1999		2004		2009		2014		2018	
	Area (Ha)	(%)	Area (Ha)	(%)	Area (Ha)	(%)	Area (Ha)	(%)	Area (Ha)	(%)	Area (Ha)	(%)	Area (Ha)	(%)
Fellow Land	1268.61	24.5	1310.03	25.3	1413.59	27.3	1445.00	27.9	1496.44	28.9	1512.00	29.2	1563.75	30.2
Vegetation	1848.54	35.70	1744.9	33.70	1682.85	32.50	1584.46	30.60	1486.08	28.70	1367.00	26.40	1392.88	26.90
Settlement	300.32	5.80	331.4	6.40	326.21	6.30	424.59	8.20	455.66	8.80	481.60	9.30	476.37	9.20
Char land	388.35	7.50	409.06	7.90	341.74	6.60	403.90	7.80	512.62	9.90	548.90	10.60	481.55	9.30
River Channel	1170.22	22.60	1128.8	21.80	1263.43	24.40	1123.60	21.70	973.46	18.80	994.20	19.20	906.15	17.50
Shrimp Cultivation	201.94	3.90	253.8	4.90	150.16	2.90	196.80	3.80	253.72	4.90	274.43	5.30	357.28	6.90

The fallow land next to the Sangu channel has gradually expanded with the passage of decades. Even though there were about 1268 Ha of unused land during 1989, it got elongated to 1563.75 ha in 2018. It represents that people have been abandoning many of their plots located close to the river. Presumably, the incessant morphological works of the river have compelled the farmers to abandon their lands, as erosion or accretion in the area would make the landscape unstable, therefore, it cannot be utilized for a specific purpose over a long period. At the same time, the vegetation cover throughout the area has shrunk substantially within just 28 years. During this period, about 456 ha of vegetation area disappeared which demonstrates a huge loss of environmental status. It has either been caused by the continual shifting of the river channel or the human intervention has resulted in the contraction of vegetation area. The gradual expansion of shrimp cultivation in the study site indicates human interference with nature. The increase of salinity in river water and nearby floodplain areas resulted in the gradual expansion of shrimp cultivation[47]. A study by Primavera (1997) mentioned that since 1990, the production of shrimp raised in aquaculture has increased at an astounding pace of 20% to 30% annually[48].

On the other hand, human settlements expanded significantly over the period (from 5.8% in 1989 to 9.2% in 2018). Contrarily, during the data collection period, many people were identified who have been compelled to change their occupation due to the river bank erosion. People who used to be farmers in the past started shrimp farming due to the loss of arable land by river bank erosion. Many people have converted their agricultural lands to shrimp projects. A study[52]also reported the loss of arable land due to river bank erosion. Furthermore, such contraction of agricultural land was also identified in the Kolubara River Basin in Serbia[53].

The riverine impact of land use is evident from the changes in the area of char land. In 1989, the char land was spread over 388.35 ha while it went up to 481.55 ha in 2018. The expansion of char land articulates the persistent accretion in the Sangu River throughout the timeline. Furthermore, as the newly formed char can accommodate people and let the inhabitants settle down in a new place, the areas under settlement have expanded over the decades (Table 4). People who have been living near the Sangu have newly occupied over 176 Ha of land by building their houses. A recent study[25] stated that bank erosion of the river significantly affects the land use and land cover of the area under the river channel. However, this study found that land use in the floodplain area could be modified through both erosion and depositional works of a river.

Conclusion

This study has unveiled the prominence of erosional works at the Sangu River channel, however, the deposition of sediments and formation of chars (bars/islands) are also identified from the study. Furthermore, the sediment budget analysis of the channel articulately presents that the Sangu has devoured a huge zone between Anowara to Banshkhali of Chattogram district in Bangladesh. Except for the exceptions (2006-2010), the rate of accretion in the river never surpassed the wearing away of its banks. In parallel to the changes of river channel due to erosion and deposition, the land use pattern in the river's flood plain has also changed significantly. Due to the consistant changes in the river channel, there were notable changes taken place in the land uses of the chosen areas, this represents a link of fluvial processes with the land use pattern. Future research is needed to integrate people's perceptions with satellite data and meteorological data analysis to understand the causes of differential erosion and deposition in different time periods and direct imapcts of erosion and depiction on the land uses and lives of inhabitants of the Sangu River floodplain.

Limitation of the Study

The study focused on only a short period, therefore, satellite data from 1989 to 2018 were taken for analysis. Moreover, there were no socio-economic tools used in this study which could have provided a better understanding of the causal impacts of fluvial processes and land use changes.

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Conflict of Interest

The authors have no known conflict of interest.

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