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Spatiotemporal Changes of Channel Morphology of Gorai - Madhumati River Using Multi-Temporal Satellite Images

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Abstract

Gorai-Madhumati, one of the distributaries of the Ganges River system, is one of the most dynamic rivers in Bangladesh. Morphological development of the river along with frequent channel shifting within the catchment area is regular events in this system. These events, however, threaten engineering projects, resulting in various socio-economic and environmental problems. As a result, the primary goal of this study is to use multi-temporal Landsat image data and GIS to examine the spatiotemporal changes in channel morphology in the reach of the Gorai-Madhumati River, Bangladesh, between 2006 and 2022. The analysis of time series satellite images confirmed that the morphology of the river channel changed dramatically in parallel with changes in total flow area throughout the study period. In 2006, total flow area was 51.27 km^2 where it was 61.79 km^2 in 2022. In the observed sections of the river, the migration trend has regularly shifted and occurred in the NW and NE directions. Throughout the study period, total accretion was greater than net percentage erosion on both river banks. River discharge, bar accretion, and erosion history indicate that the Gorai-Madhumati River will cease to exist in its current flowing condition unless attention and proper river management are paid.

Keywords: *Gorai- Madhumati, Morphology, GIS, Landsat, Flow Area*

1 Introduction

River bank shifting usually comes with an event in which one bank forms while the opposite erodes. This event, along with channel movement, is a frequent occurrence and a continuous dynamic process in Bangladesh. Over the past few decades, global warming and climate change have modified rainfall patterns in the river basin area, causing flooding, water flow and discharge changes, and riverbank erosion, accretion, and bank line shift. Since riverbanks are mostly clay and sand, they erode every monsoon(Gazi et al., 2020). River erosion changes river morphology and affects social and environmental situations, hindering national growth. Thus, studying river dynamics, altering bank lines, bank erosion, and channel migration patterns might lessen consequences. Furthermore, time-series and spatial analyses of river channel changes are crucial for solving rivers' geomorphological, erosional, and management issues(Mohamad et al., 2018). However, Remote sensing, GIS, and modeling are important tools for spatial analysis, notably for change assessment, surface phenomenon evaluation, and forecasting of river dynamics(Rahman, 2023).

A Ganges River distributary, Gorai-Madhumati, has frequent channel shifts due to morphological evolution. Gorai-Madhumati is crucial to Bangladesh's southwest river system and is subject to massive natural and man-made changes. Sediment has clogged the Gorai River since the 1980s.Ganges downstream water flow reduced significantly after 1975's Farakka Barrage building in India. The Farakka Barrage expedited this process and caused massive sedimentation. Upstream water flow is reducing and depositing massive sediments on the river channel. Thus, river morphology changes and causes the Gorai River to be dredged regularly(Gazi et al., 2020).Several studies into the Gorai-Madhumati river system's hydrodynamics, morphological response, and bend development have been conducted(Bomer et al., 2019; Gazi et al., 2020; Hasan et al., 2015).Most of the above research were short-term or localized. To the knowledge of the author, no study has been found to study the recent river dynamics and spatial trends of Gorai-Madhumati River. The Gorai-Madhumati River, one of the Southwest's main water sources, can produce a massive salinity intrusion if its river dynamics are not studied(Kushtia, 2017).This factor motivates the current study, which is based on appropriate time and spatial scales and utilizes recent data to analyze the river dynamics of the Gorai-Madhumati in Bangladesh. Nonetheless, there were three particular objectives of the study: (i) to observe the Gorai-Madhumati River's spatiotemporal changes of flow area from 2006 to 2022; (ii) to assess the riverbank erosion ,accretion and river shifting, and (iii) to locate the vulnerable area of bank line shifting.

2 Study Area

The Gorai-Madhumati River is one of the longest rivers in Bangladesh. In the upper areas, it is named Gorai, and the name changes to Madhumati in the lower reaches(Ahmed & Islam, 2003). In the southwest of Bangladesh, the districts of Pabna, Chuadanga, Kushtia, Rajbari, Faridpur, Gopalgonj, Jessore, Jhenaidah, Magura, Norail, Pirojpur, Borguna, Bagerhat, Khulna, and Sathkhira are all included in the 199 km long catchment area of the Gorai-Madhumati River.

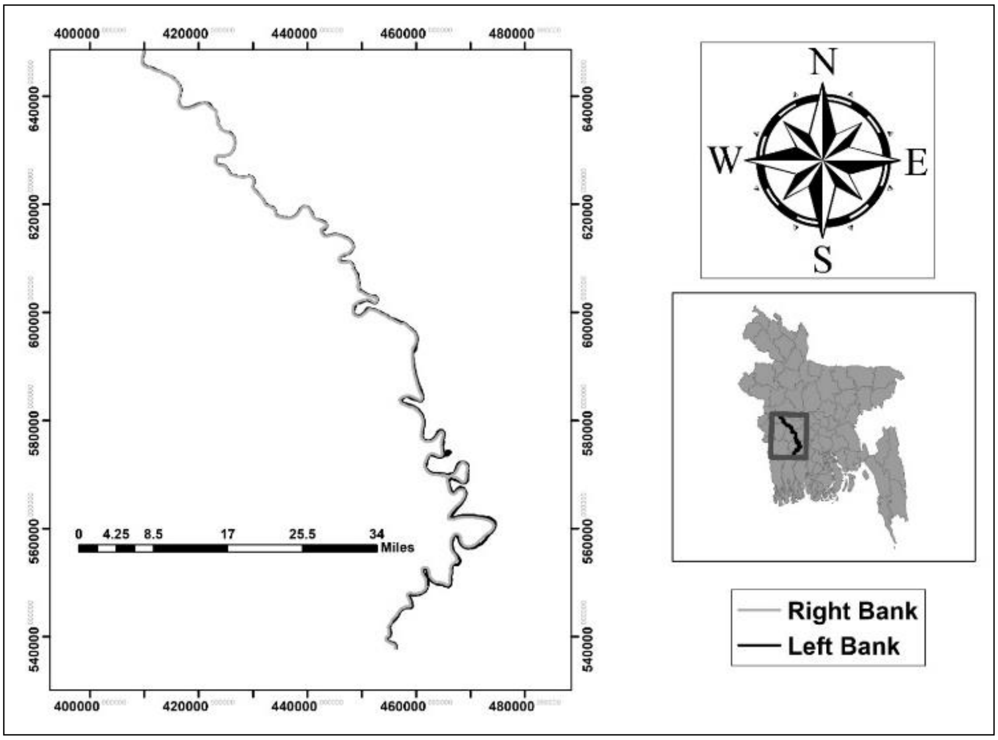

Figure 1. Study Area

3 Methodology

Landsat 5 (TM) and Landsat 8 (TOA) were used to assess the flow area change and the bank line shifting for Gorai-Madhumati River. Landsat imageries were collected from United States Geological Survey (USGS). Landsat 5 imageries were used for 2006, 2009, and 2011 while Landsat 8 imageries were used for the rest years. The initial plan was to use images at a constant interval of three years. As Landsat 7 has scan line error, the imageries from Landsat 7 (for 2012) were avoided to reduce the error and with the openly accessible satellite data, the time interval was slightly altered. In order to minimize cloud cover when selecting the imagery, the dry season of the particular year (February) was taken into consideration. This was done because all of the images were based on optical remote sensing. (Fig. 1) describes the methodology used for the whole study.

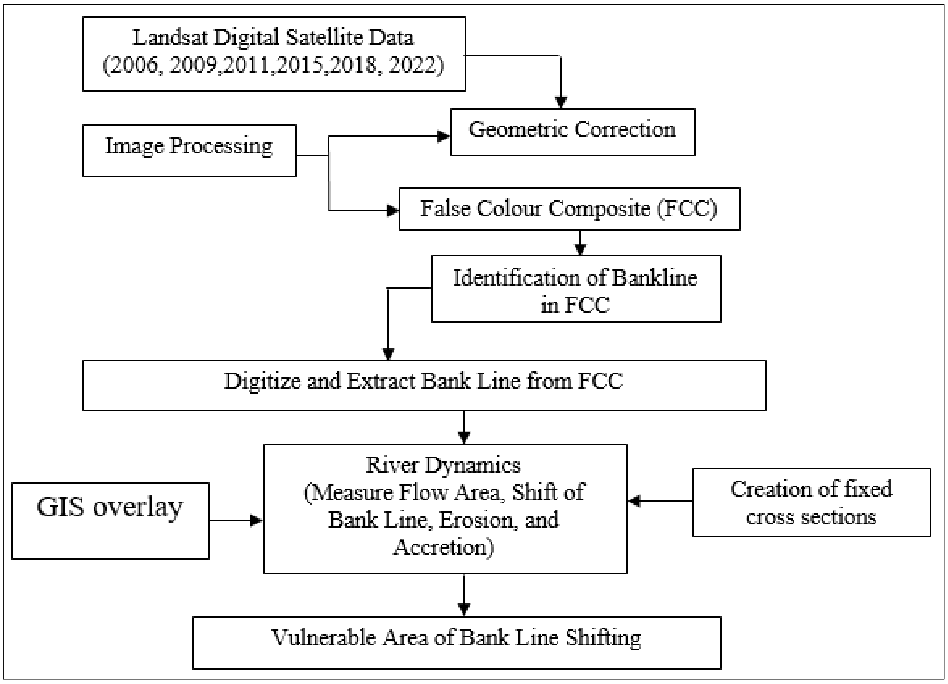

Figure 2. Methodology

4 Result and Discussions

4.1 Spatiotemporal Change in Flow Area

There was no apparent trend to the Gorai- Madhumati's flow area. Compared to 2011 (when it was at its lowest), the flow area was greatest in 2022 (Fig. 3). There was an increase in flow area during the first three years, followed by a decrease in 2011. After that, it went up in 2015 and down in 2018, back to where it started. It is possible that ongoing dredging work in the Gorai-Madhumati River would be responsible for indicating the maximum flow area in 2022. (Fig. 4 (a)) showed the change of flow area for different years.

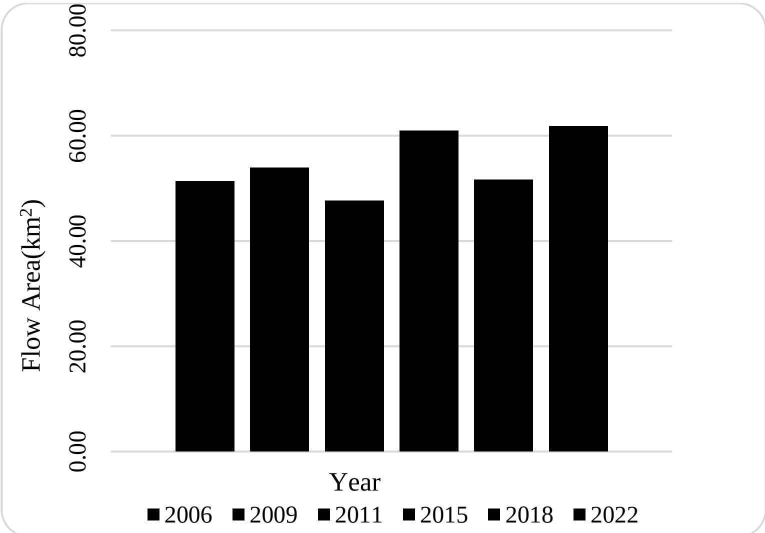

Figure 3. Flow area change for different years

4.2 Assessment of Erosion and Accretion

Through observation of the shifting of bank lines over the course of time, the current study came to the conclusion that bank lines were susceptible to both erosion and accretion. Between 2006 and 2018, the left bank of the river experienced more accretion than erosion, except the years 2018–2022. The highest annual accretion rate was 7.02 square kilometers per year. There is no discernible pattern of erosion and accretion on the right bank. From 2006 to 2011, a greater amount of accretion is seen, whereas other years show a greater amount of erosion. In addition, the study reveals that the river's course has always been shifted northwesterly, with the exception of the years 2018–2022 (Table 1). Perhaps the ongoing dredging operations prompted this modification.

Table 1. Assessment of Bank Erosion, Accretion and River Shifting

Time Span	Left Bank		Right Bank		River Shifting
	Erosion (Km$^{2)}$	Accretion (Km^2)	Erosion (Km^2)	Accretion (Km^2)	
2006_2009	2.31857	21.064376	3.641964	19.590734	N-W
2009_2011	3.576151	7.592965	3.569093	5.207906	N-W
2011_2015	7.448416	7.730953	15.893445	4.58008	N-W
2015_2018	4.326583	16.359438	6.617823	5.254662	N-W
2018_2022	14.447463	4.54674	11.458717	5.097063	N-E

From (Fig. 4(b) and 4 (c)), the shifting of both channels can be seen. Erosion and accretion mainly happened in the bend of the river as Gorai-Madhumati is a meandering river. Except for the period between 2011 and 2015, all other time periods had net change in the left bank. Over this time period, the net change in the left bank has been rather little. However, the right bank always experienced net change. However, throughout the time period of 2006 to 2022, the accretion was the governing factor for bank line shifting.

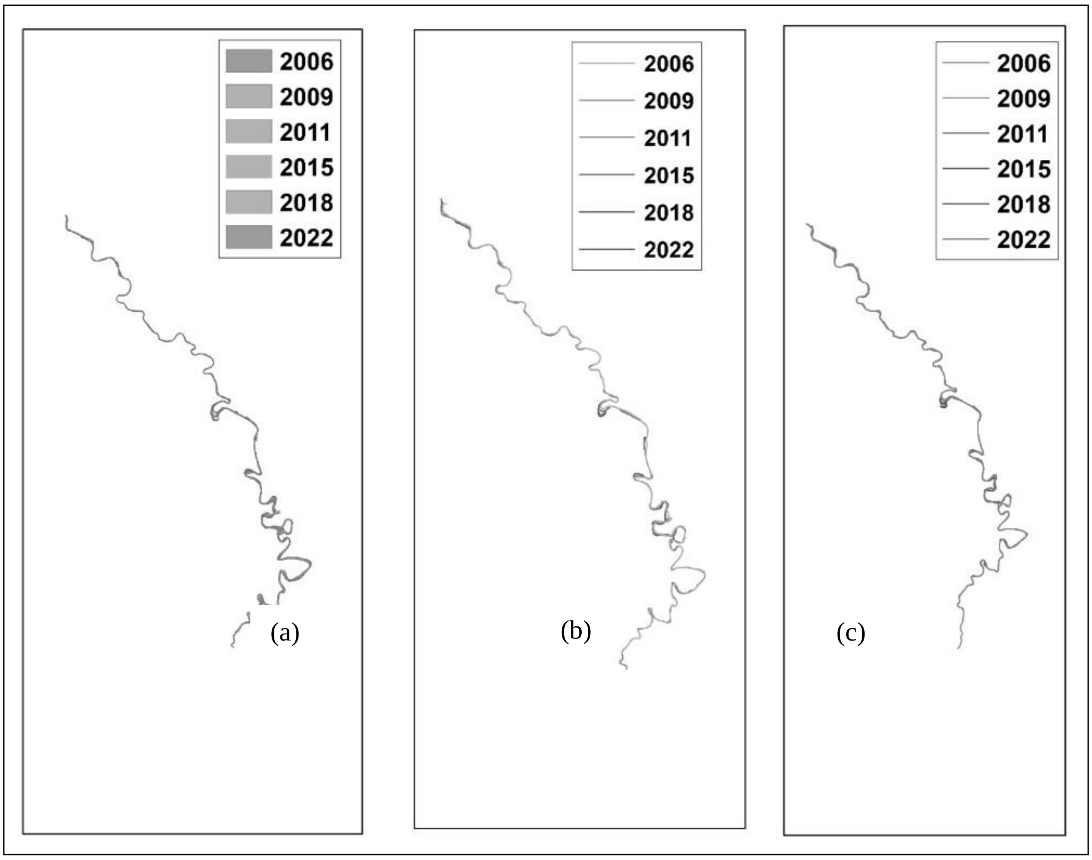

Figure 4. (a) Spatiotemporal changes in flow area, (b) Changes in left bank for different years, (c) Changes in right bank for different years

4.3 Location of Vulnerable Area of Bank Line Shifting

The intensity of horizontal erosion and accretion, as well as the locations most prone for bank shifting, can be determined by measuring river width along selected cross-sections. The taken two cross sections (Fig. 5 (a)) shows maximum width change for different years.

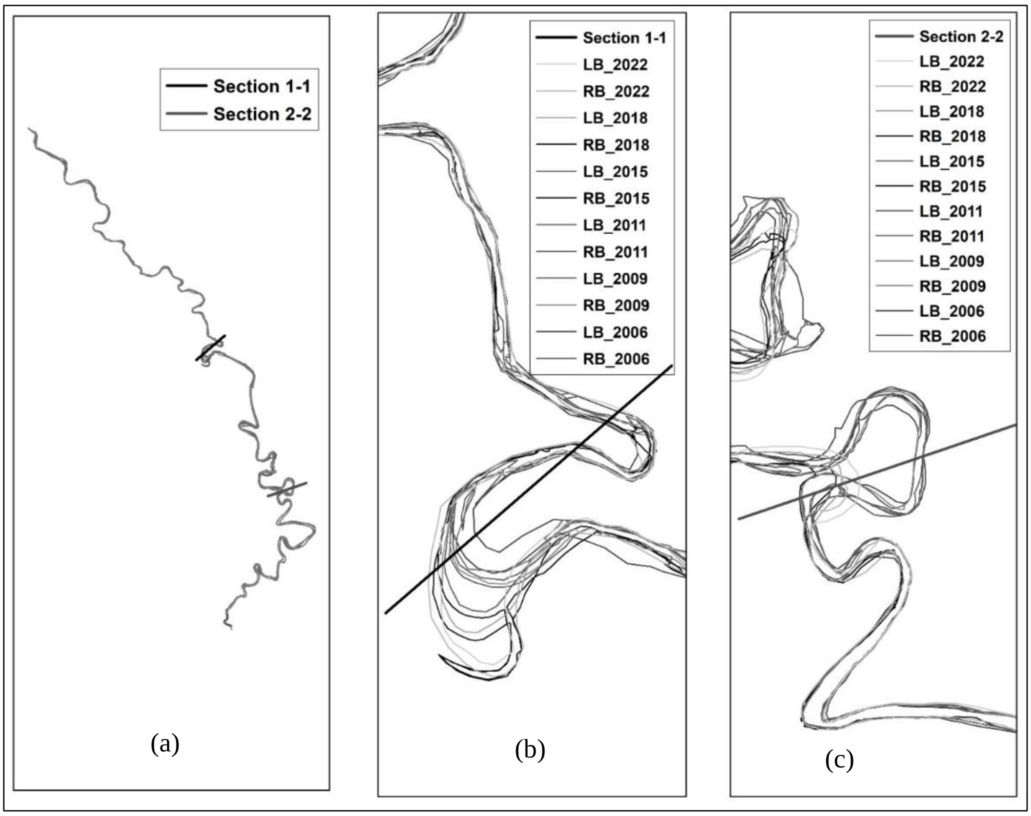

Figure 5. (a) Vulnerable cross sections, (b) Section 1-1, (c) Section 2-2

In section 1-1 (Fig 5(b), the width drastically changed from 2006 to 2009. The breadth was cut down to roughly two thirds of what it had been in 2006 (Table 2). After 2009, it began to gradually return to its previous width. In addition, the pace of width regaining is faster than in other parts of the river, and it reached its highest point over the span of 2015-2018, when it averaged 30 m/year. On the other hand, the accretion rate in this particular region is significantly higher than that of the other location. Between the years 2011 and 2015, it averaged out to just about 5 km2 every year. The nearly identical phenomenon applies to section 2-2. The only unusual occurrence that occurred in the second part was "meandering cutoff," which happened after the year 2015. Due to massive sedimentation, the channel became a braided channel and the width of the channel was increased to almost 4065m in 2015. After that, the meandering channel of the river was replaced by the main channel, and the primary flow of the river was altered.

Table 2. Width Change in Section 1-1 and 2-2

Year	Channel Width	
	Section 1-1	Section 2-2
2006	473.6 m	309.23 m
2009	124.68 m	613.06 m
2011	126.79 m	575.15 m
2015	192.26 m	4065 m
2018	288.50 m	227.99 m
2022	293.47 m	485.55 m

5 Conclusions

Using multi-sensor, multi-spectral, and multi-date Landsat satellite imagery and geospatial analysis, this study examined the Gorai-Madhumati River's dynamics spatially and temporally. This study used GIS to monitor and analyze river dynamics at the 199-km Gorai-Madhumati River reach, including bank line shifting, erosion and accretion patterns, river width, and shifting-prone areas. Over 2006–2022, the Gorai-Madhumati River was highly active. The flow area fluctuated in an unpredictable manner, and it reached its maximum in the year 2022. The flow area was shifting while maintaining a tendency that was practically sinusoidal: a decrease followed by an increase, and so on throughout the entirety of the time period. The left bank experienced more accretion than the erosion while right bank experienced almost same erosion and accretion for the whole time period. The maximum accretion rate was 7.02 km^2/year which occurred to left bank. Maximum width change happened for section 1-1 and 2-2 which makes them vulnerable to bank shifting. Geo-hazards along river banks are exacerbated by river morphometric change, which includes bank erosion and channel alteration as geomorphological features. Furthermore, this study showed that remote sensing and GIS can detect river morphological changes. Thus, this study will help policymakers comprehend the river's space–time features and create an inclusive management and action plan to address river dynamics issues. It also helps create Gorai-Madhumati River safety engineering, management, and adaption policies. This study's data, along with climate, land use/land cover, flood, and river discharge data, will aid long-term dredging plan.

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