MORPHOLOGICAL CHANGES AND BAR DYNAMICS OF THE JAMUNA RIVER: A STUDY OF THE JAMALPUR TO MANIKGANJ REACH

Isfar Liva*[1], Tosnim AI Raji[2] and Fariha I Mou[3]

[1] *Student, Military Institute of Science and Technology, Bangladesh, e-mail: isfarliva.mist.cwre@gmail.com*
[2] *Student, Military Institute of Science and Technology, Bangladesh, e-mail: tosnimalraji50.mist@gmail.com*
[3] *Lecturer, Institute of Water and Flood Management, Bangladesh University of Engineering and Technology, Bangladesh, e-mail: farihaislam@iwfm.buet.ac.bd*

***Corresponding Author**

ABSTRACT

The Jamuna River holds immense significance for Bangladesh, serving as a vital pathway that transports a substantial volume of sediment from the Himalayas to the Bay of Bengal. Because of the interaction of several elements, including hydrology, sediment transport, bank erosion, channel migration, and bar development, the river is extremely braided, unstable, and changes its path regularly. The river widens as a result of these forces every year, forming intricate patterns of channels and bars. This study aimed to analyze the morphological behavior of the Jamuna River in Bangladesh starting from Jamalpur district to Manikganj district using Landsat images for a period of 20 years ranging from 2001 to 2021. This stretch of the river is about 210 km long covering an area of about 2100 sqkm. The bar development phenomenon was also analyzed in this study for the previously mentioned reach.

The study used Landsat images with a spatial resolution of 30 meters to extract the river boundary and bar area for each year. The images were pre-processed using ArcGIS tools and techniques. The erosion and deposition areas were calculated by overlaying the river boundary polygons for different years.

The results indicated that the river experienced significant erosion along both banks of the river while deposition occurred in some places during the study period. The river lost about 465.79 Km^2 of land due to erosion whereas gained only 168.96 Km^2 of land due to deposition in the past two decades. The net loss of land was 296.83 Km^2, which is equivalent to about 14.38% of the study area. The analysis also showed that at this reach, the Jamuna River's bar area increased considerably between 2001 and 2021, growing from 161.02 km^2 to 661.91 km^2, or nearly four times, in that period. The bars occupied about 7.80% of the study area in 2001 and about 32.08% in 2021.

The increase in bar area indicates that the Jamuna River has become more braided and sediment-laden over time. The possible causes of this morphological behavior are the high sediment load, the low gradient, the monsoon floods, the human interventions, and the climate change effects. The implications of this behavior are the loss of agricultural land, the displacement of population, the disruption of navigation, and the degradation of aquatic habitats. The study suggests some recommendations for future research and management such as monitoring the river dynamics using remote sensing and GIS, developing a numerical model to simulate the morphological processes, implementing appropriate erosion control measures, and enhancing the resilience of the communities living along the river.

Keywords*: Morphological Changes, Jamuna, Bars, Landsat*

1. INTRODUCTION

Jamuna River is one of the three main rivers of Bangladesh, and the lower stream of the Brahmaputra River. It originates in Tibet as Yarlung Tsangpo, and flows through India and southwest into Bangladesh. It joins the Padma River near Goalundo Ghat, and then flows into the Bay of Bengal as the Meghna River. Jamuna River is a classic example of a braided river, which means it has a network of interlacing channels with numerous sandbars enclosed between them. The sandbars, known as chars, do not occupy a permanent position. The river deposits them in one year, very often to be destroyed later, and redeposits them in the next rainy season. This process of bank and deposit erosion together with redeposition has been going on continuously, making it difficult to precisely demarcate the boundary between different districts (Rahman, 2022).

Jamuna River covers more than 7 percent of Bangladesh's area, and has a total length of 240 km. It is a vital source of fresh water for millions of people living along its banks. However, it also poses serious challenges for the country's development and environment. The river is highly susceptible to channel migration and avulsion, which means it can break off from its main channel and flow into another direction. This can cause flooding, loss of land, damage to infrastructure, and displacement of people (Chowdhury, 2012).

One of the most vulnerable areas along Jamuna River is between Jamalpur and Manikganj districts in Bangladesh. This area has been experiencing severe erosion due to high sediment load from upstream tributaries such as Teesta and Mahananda rivers. The erosion rate is estimated to be around 0.5 meter per year on average, with higher rates during the rainy season (June-September). The erosion has resulted in loss of croplands, forests, wetlands, fisheries, and settlements along the river banks. The erosion has also increased the risk of flooding during heavy rains or cyclones (Alam & Ahamed, 2023)

The government and local authorities have been implementing various measures to mitigate the effects of erosion on Jamuna River system in this area. Some of these measures include constructing embankments or bunds along the river banks to prevent further erosion, planting trees or creating buffer zones along the river banks to reduce sedimentation, restoring or creating artificial islands or chars to stabilize the river channels, developing drainage systems or canals to divert excess water away from the river banks, promoting alternative livelihoods or income-generating activities for people living near the river raising awareness among people about the importance of protecting Jamuna River system. These measures have shown some positive results in reducing erosion and improving environmental conditions in this area.

However, they also face some challenges such as lack of adequate funds or resources for implementing these measures, lack of coordination or cooperation among different stakeholders such as government agencies, NGOs, communities, etc., lack of proper monitoring or evaluation system for assessing these measures' effectiveness, lack of public participation or involvement in planning or implementing these measures etc. Therefore, there is a need for more comprehensive and sustainable solutions that can address both the causes and consequences of erosion on Jamuna River system in this area.

The objective of this study is to investigate the morphological changes and bar dynamics of the Jamuna River in the Jamalpur to Manikganj reach as Jamuna River is a precious resource that supports life in Bangladesh. It also faces many threats from human activities that affect its natural dynamics. By understanding its history and present situation, we can better appreciate its value and potential for development while also protecting its environment for future generations. The study will contribute to the scientific knowledge and practical applications of river dynamics and geomorphology in Bangladesh.

2. METHODOLOGY

The effectiveness of remote sensing and GIS approaches for researching river morphology has been shown by a number of studies (Hossain, Jahan, & Yehan, 2014); (Shibly & Kalimur, 2021); (Enamul, Sayedur, Zahedur, & Muslem, 2021). This study specifically focuses on analyzing 20 years of satellite images to detect changes in the morphology of the Jamuna River, including land erosion and accretion as well as the shifting nature of the river banks from 2001 to 2021.

2.1 Study Area

The study area of this study is the Jamuna River from Jamalpur to Manikganj districts in Bangladesh. This area covers about 210 km of the river course, from the confluence of the Jamuna and Padma rivers near Goalundo Ghat to the confluence of the Jamuna and Meghna rivers near Chandpur. The study area is bounded by the districts of Sirajganj, Pabna, Mymensingh, Tangail, and Dhaka on one side, and the districts of Kurigram, Rajshahi, and Khulna on the other side. The study area is shown in **Figure 1**.

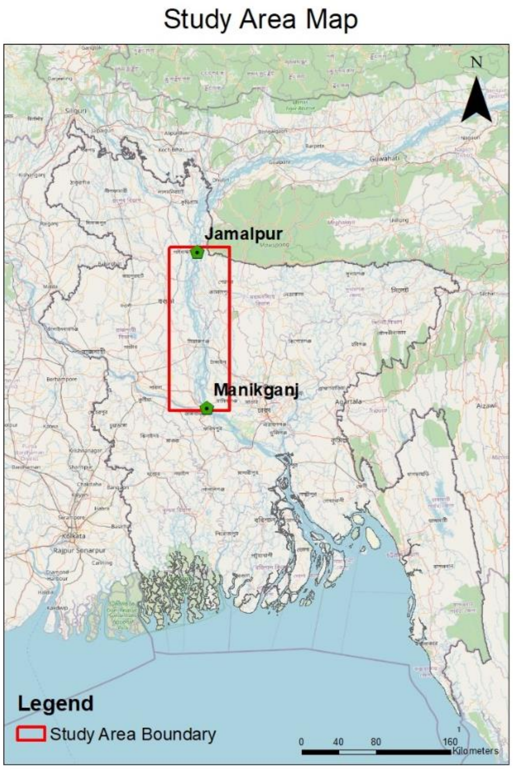

Figure 1: Study area map of Jamuna River from Jamalpur to Manikganj districts in Bangladesh.

The study area is selected because it is one of the most vulnerable and eroded regions along the river, due to high sediment load from upstream tributaries such as Teesta and Mahananda rivers. The study area also has a high population density and socio-economic importance, as it supports livelihoods of millions of people who depend on fishing, agriculture, transportation, and tourism. The study area also has a rich cultural and historical heritage, as it is home to many ancient temples, monuments, and festivals.

The study area is characterized by a complex geomorphological pattern of braided channels with numerous sandbars enclosed between them. These sandbars are known as chars or islands, and they do not occupy a permanent position. The river deposits them in one year, very often to be destroyed later, and redeposits them in the next rainy season. This process of bank and deposit erosion together with redeposition has been going on continuously for centuries, making it difficult to precisely demarcate the boundary between different districts or even between different parts of the same district. The breaking of a char or the emergence of a new one is also a cause of much violence and litigation among local communities.

2.2 Data Collection

Earth surface imagery is gathered by a number of public domain earth observation satellites, including Meteosat, Corona, Landsat, Modis, Sentinel, Aster, and Modis. Of them, Landsat is one of the most popular and offers raster images that are open-source. NASA's Landsat Mission is a collaborative effort between NASA and the United States Geological Survey (USGS) to gather and disseminate satellite imagery for a range of uses, such as environmental tracking and analyzing changes in land usage. A broad collection of panchromatic and multispectral imagery at different temporal and spatial resolutions is provided by the software. Landsat imagery has been used in several studies to examine patterns of river bank erosion and accretion, morphological transition and change in land cover such as **(Halder & Chowdhury, 2021)**; **(Gazi, Hossain, & Uddin, 2020)** etc.

The methodology of this study was based on the use of Landsat images with a spatial resolution of 30m x 30m to extract the river boundary and bar area for each year. The images were acquired from 2001 to 2021, covering a total span of 210 km along the Jamuna River in Bangladesh.

2.2.1 Data Preprocessing

The images were pre-processed using ArcGIS tools and techniques, such as image classification, band composition, cloud masking etc. The river boundary was delineated by digitizing the banklines manually for observing the planform of the river and bankline shifting phenomena over the decades. The bar areas were also digitized and then calculated by using ArcGIS tool for calculating geometry of features. The erosion and deposition areas were estimated by subtracting the cross-cutting areas from the original river boundary area for each year. The results were then assessed using statistical analysis.

2.2.1.1 Digitization of River Banklines and Bar Areas

River bank line digitization is the process of converting the river bank line from a map or satellite imagery to a digital format that can be utilized for additional research. Since it enables precise erosion and bank shifting pattern measurement of riverbanks over time, it is a crucial stage in the research of river bank erosion and accretion. River bank erosion and accretion have been studied using digitalized river bank lines in a number of research. For instance, a study to examine the changes in Deduru Oya River of Sri Lanka was performed by digitizing river bank lines using high-resolution satellite images (Basnayaka, et al., 2022).

In this study, the river bank lines were manually traced as part of the digitization procedure. The banklines has been saved in the GIS program as a vector layer once it has been digitized. The patterns of erosion and accretion can then be studied, as well as the changes in the river bank over time, using this layer. Some examples of the digitized banklines in Jamuna River reach starting from Jamalpur up to Manikganj districts have been illustrated in the figures below (**Figure 2** and **Figure 3**):

Banklines Digitized from Satellite Image of 2001

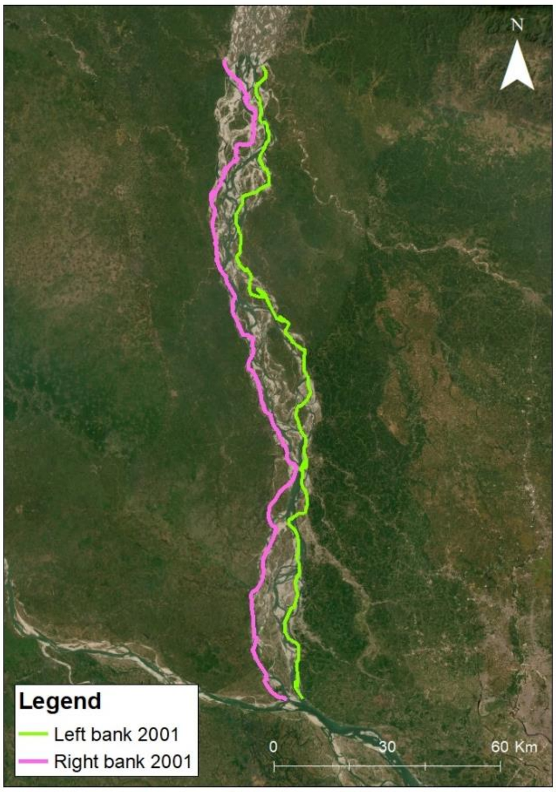

Figure 2: Banklines in 2001

Banklines Digitized from Satellite Image of 2021

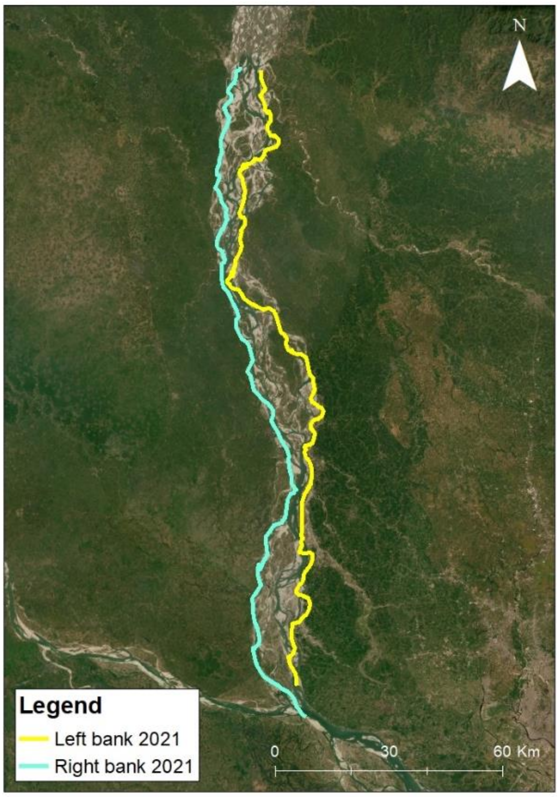

Figure 3: Banklines in 2021

Similarly. some examples of the digitized bar areas in Jamuna River reach starting from Jamalpur up to Manikganj districts have been illustrated in the figures below (**Figure 4** and **Figure 5**):

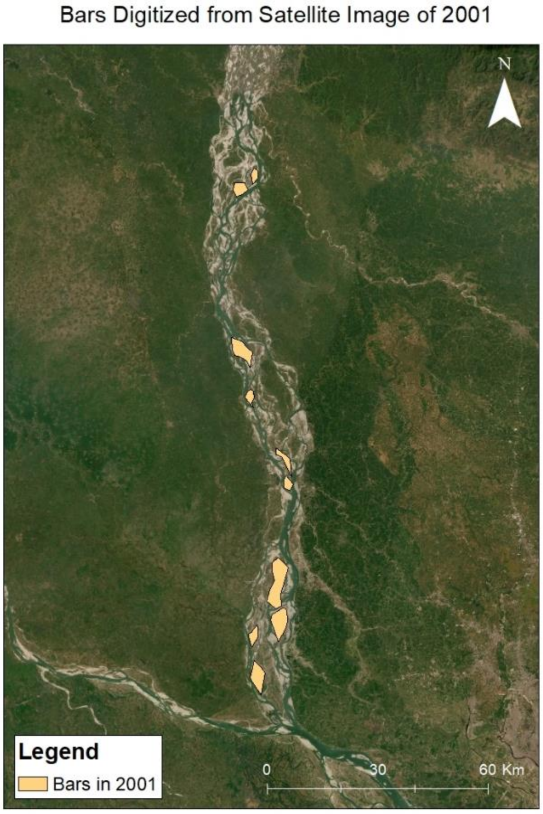

Figure 4: Bars in 2001

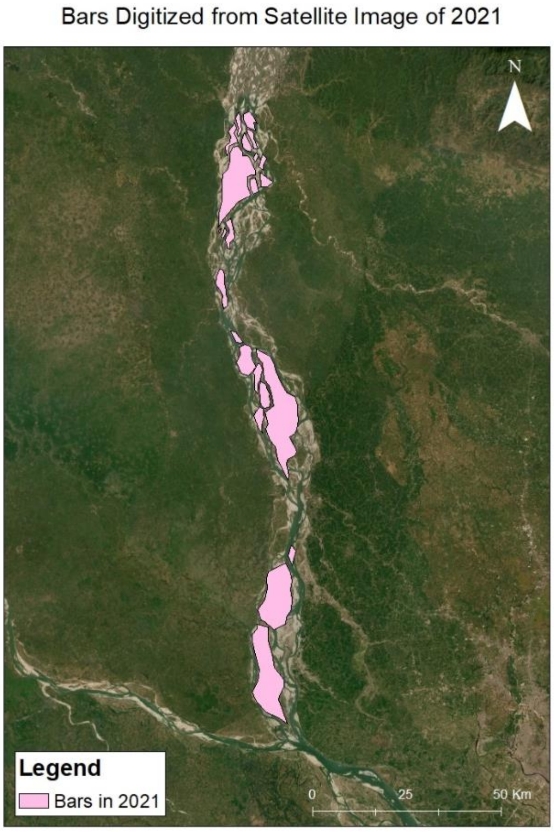

Figure 5: Bars in 2021

2.2.1.2 Investigation of Erosion and Accretion

An essential component of studies on riverbank erosion and accretion is the area method, which is used to determine the rate of river net erosion and accretion. It is one of the popular methods for identifying changes in land cover and use. In order to detect changes in the riverbank, this method computes the cross-cutting areas of banklines that have been digitized for various years and compares the areas over time.

The area-based approach has been used in multiple studies to identify the extent of river accretion and erosion such as examining changes in land cover and use along the Dharla River in India (Shubro & Raju, 2018) and determination of erosion and accretion rates of multiple Indian rivers (e.g., Muriganga, Bidya, Harinbhanga, Raimangal, Hooghly, Saptamukhi, Gomdi, Matla, Thakuran, Kalindi, Gosaba) of Indian Sundarbans (Bera & Maiti, 2019). The findings from these investigations demonstrated the efficacy of the area-based method in identifying modifications to land cover and use, including rates of river accretion and erosion. In order to comprehend riverbank erosion processes and create efficient management plans to lessen the effects of erosion, the method can offer precise and trustworthy information on changes in the riverbank over time.

To investigate the erosion and accretion phenomena of the study area, the intersecting area between the years has been measured using the intersect tool. To analyze the erosion and deposition along the banks, the shift in banklines has been observed. The shift in banklines for both banks of the study reach has been demonstrated in the figures in the following section.

3. RESULTS AND ANALYSIS

The erosion and deposition phenomena of the study reach from over past 20 years (2001 to 2021) can be visualized from the figures below (**Figure 6** and **Figure 7**):

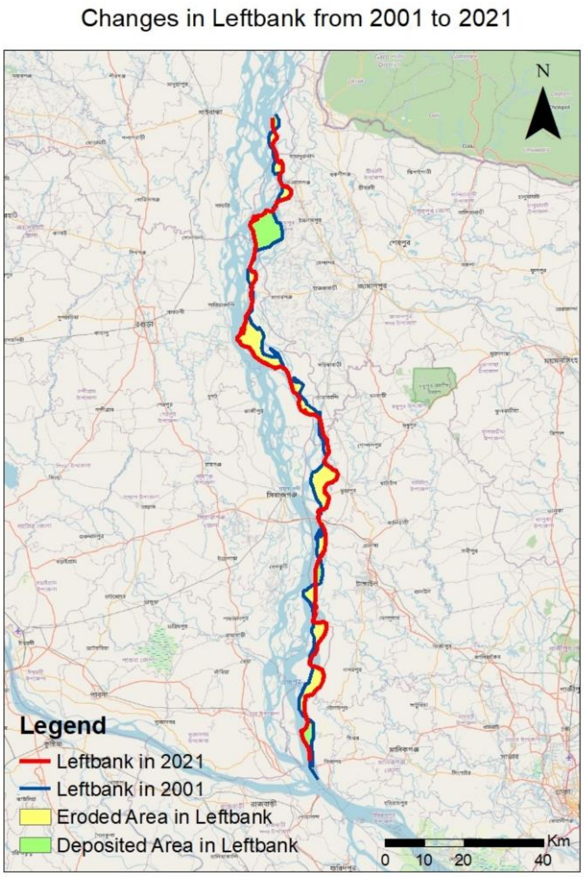

Figure 6: Bankline Shifting and Changes of Landform in Leftbank from 2001 to 2021

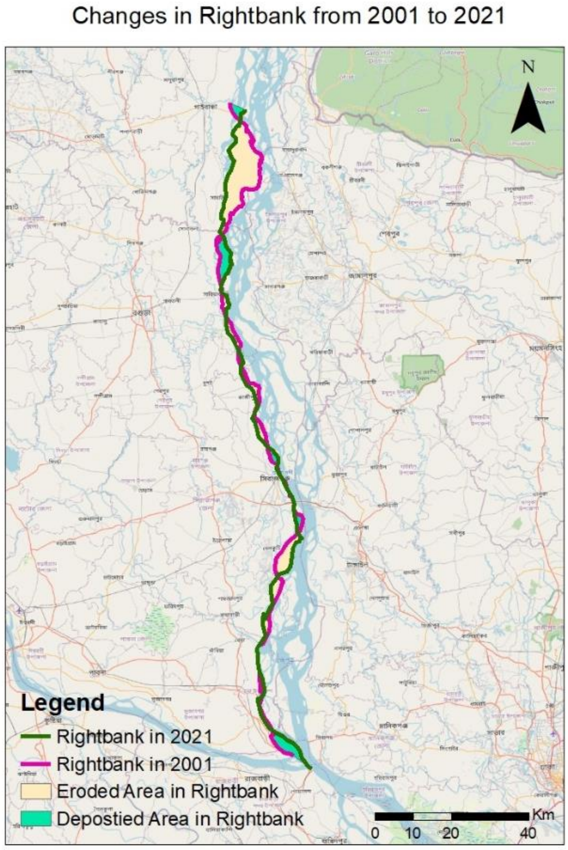

Figure 7: Bankline Shifting and Changes of Landform in Rightbank from 2001 to 2021

The amount of area eroded and deposited along the banks of the study area were calculated for a qualitative analysis. The result showed net erosion in both of the banks after subtracting the total deposited area from the total eroded area. The outputs of the analysis have been shown in the following tables (**Table 1** and **Table 2**).

Table 1: Summary of Erosion Accretion over 20 years (From 2001 to 2021) in Jamuna River

	Value in Km^2
Total Study Area	2063.60
Net Eroded Area in Leftbank	138.25
Net Eroded Area in Rightbank	158.58
Total Loss	**296.83**
Total Loss in Percentage (%)	**14.38 (%)**

The findings showed that during the study period, the river underwent considerable erosion along both of its banks while deposition took place in certain locations. Over the previous 20 years, the river has gained only 168.96 km^2 due to deposition, while it has lost roughly 465.79 km^2 due to erosion. A total of 296.83 km^2 of land were lost, or approximately 14.38% of the study area.

Table 2: Summary of Bar Dynamics of Jamuna River in last 20 years (From 2001 to 2021)

	Total Bar Area in 2001	**Total Bar Area in 2021**
Value in Km^2	161.02	661.91
Value in Percentage (%)	7.80 (%)	32.08 (%)

The analysis also revealed that the bar area of the Jamuna River at this reach grew significantly between 2001 and 2021, expanding from 161.02 km^2 to 661.91 km^2, or nearly four times, during that time. In 2001, the bars covered roughly 7.80% of the study area; in 2021, they covered roughly 32.08%. This indicates the loss of conveyance capacity and navigability of the river reach over the past two decades due to abrupt sedimentation within the channel.

4. CONCLUSIONS AND RECOMMENDATIONS

The aim of this study was to investigate the morphological changes and bar dynamics of the Jamuna River in the Jamalpur to Manikganj reach in Bangladesh from 2001 to 2021. The study hypothesized that erosion would be more dominant than deposition in this area due to high sediment load from upstream tributaries and frequent channel migration. The study also hypothesized that bar area would increase over time due to sediment accumulation in some places along the river.

The study used remote sensing and GIS techniques to analyze changes in morphology over time (from 2001 to 2021). The study collected raw satellite images of different years over the past two decades from 2001 to 2021 from the USGS website. The images were pre-processed and digitized for analyzing the bankilne shifting, erosion-accretion phenomena at both banks and bar dynamics of the study area. The land accretion and erosion were calculated by using an area method.

These results suggest that the Jamuna River system is undergoing major changes in morphology due to natural processes such as erosion and deposition. These changes have significant impacts on the river's water quality, biodiversity, socio-economic conditions, etc., as discussed in other sections of this paper.

Some limitations of this study include that the use of satellite images as proxies for river morphology may introduce errors or uncertainties due to atmospheric conditions, sensor characteristics, image processing methods, etc.; the use of fixed time intervals for erosion and deposition calculations may not capture temporal variations or dynamics due to seasonal or interannual fluctuations and the use of fixed spatial boundaries for river segments may not reflect actual changes or boundaries due to channel migration or reconfiguration.

For future research or practice, it is recommended to use more frequent or updated satellite images with higher spatial resolution or spectral bands for better monitoring or assessment of river morphology; to use more advanced methods or models for erosion and deposition estimation that account for temporal variations or dynamics; and to use more flexible spatial boundaries for river segments that reflect actual changes or boundaries due to channel migration or reconfiguration.

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