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Spatiotemporal Analysis of Riverbank Erosion, Accretion, and Channel Shifting of the Bukhainagar River (1990–2020) Using geospatial Technique in Southern Bangladesh

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Abstract

Riverbank erosion, accretion, and channel shifting are critical geomorphological processes that shape the dynamics of rivers and surrounding landscapes, particularly in the region like southern Bangladesh. This study investigates the spatiotemporal dynamics of these processes along the Bukhainagar River from 1990 to 2020 using Geographic Information System (GIS) and Remote Sensing (RS) techniques. Landsat satellite imagery and supervised classification were employed to analyze changes in the river morphology over the 30-year period, with a focus on identifying erosion and accretion patterns. The study also incorporates Focus Group Discussions (FGDs) with local communities to assess both the geomorphological changes and socio-economic. The results from satellite imagery revealed significant erosion and accretion dynamics, with maximum erosion rates of 21.88 hectares per year (ha/year) from 2010–2020 and highest accretion rates of 10.31 ha/year. Overall, the net land loss over the 30 years was 177.12 ha, with an average annual erosion rate of 10.5 ha/year and an average accretion rate of 4.6 ha/year. These oscillations reflect the meandering patterns river course over time, particularly evident in the lower and middle sections. The FGDs emphasized the socio-economic impacts of these changes, such as displacement, loss of agricultural land, and economic distress owing to erosion. The findings highlight the urgent need for integrated river management strategies that combine scientific data with indigenous knowledge to address these dynamic alterations and mitigate the detrimental impacts on livelihoods and ecosystems. This study contributes to the growing body of research on river dynamics in Bangladesh, demonstrating the effectiveness of GIS and RS techniques in monitoring long-term river changes, and provides important implications for sustainable river management and climate change adaptation strategies in deltaic regions.

Introduction

Riverbank erosion, accretion, and channel shifting are fundamental geomorphological processes that significantly influence river systems globally (Das et al., 2007; Bhuiyan et al., 2017). In Bangladesh, particularly in the southern region, these processes have been intensified due to a combination of natural factors, such as hydrological variability, and anthropogenic activities, including sand extraction, deforestation, and urbanization (Ghosh et al., 2020; Naim et al., 2020; Ritu et al., 2023). The dynamic changes in river morphology have significant consequences for local ecosystems, communities, and the livelihoods that depend on stable riverbanks for agriculture, fishing, and transportation (Sinha et al., 2012; Heitmuller, 2014). In recent decades, the increasing rate of riverbank erosion has become a major environmental concern, leading to displacement of communities and loss of agricultural land. Erosion is closely linked to changes in rainfall patterns, soil characteristics, river morphology, and stream topography, all of which contribute to shifts in river channels (Nabi et al., 2016; Arefin et al., 2021; Hasan et al., 2024).

Erosion, accretion, and channel shifting are fundamental processes driving the geomorphological evolution of river systems worldwide (Das et al., 2007; Ritu et al., 2023). The morphological change of the old Brahmaputra River provides a clear grip on the causes of erosion and accretion occurrences,

which is essential for river behavior management and planning (Alam et al., 2009). Similarly, changes in the riverine landscape, ecology and surrounding environments have been extensively documented (Hasan et al., 2024). Research on riverbank erosion, especially in Bangladesh, has revealed significant socio-economic impacts, including displacement and economic loss (Chowdhury et al., 2021; Salman et al., 2023). The Bukhainagar River, located in southern Bangladesh, provides a valuable case study for understanding these river dynamics. The river has experienced significant morphological changes over the past few decades, influenced by both natural forces and human interventions. Despite its importance for transportation, agriculture, and fishing, the river is increasingly vulnerable to erosion, flooding, and other environmental stresses.

Existing studies on similar river systems, such as the Padma and Brahmaputra Rivers, have demonstrated the utility of Geographic Information Systems (GIS) and Remote Sensing (RS) in tracking changes in river morphology, including erosion and accretion (Wang et al., 2010; Janes et al., 2018 GIS and RS techniques are particularly effective for monitoring these dynamic processes, especially in large and active rivers where traditional field-based methods are challenging (Halder et al., 2023; Jabar et al., 2023; Rahman, 2023). Furthermore, recent studies have also demonstrated that integrated geospatial modeling can anticipate environmental hazards and hydro morphological changes (Jabar et al., 2023; Jaafar et al., 2023). For example, channel adjustment studies have demonstrated the considerable modifications in river channels, highlighting both the possibilities and limitations for its recovery (Surian et al., 2009). Evaluating bank erosion and channel shifting in Padma River has been represented by the GIS and RS techniques to understand these geomorphological changes (Ophra et al., 2018; Jabar et al., 2023; Jaafar et al., 2023). The importance of integrating GIS and RS technologies to monitor and analyze river changes at different scales, from local channels to larger river systems in Nepal, Bosnia, and India (Lovric et al., 2016; Gharti et al., 2024). Additionally, Jabar et al (2023) discuss the modeling of soil erosion, which may complement the erosion patterns observed in the Bukhainagar River and its neighboring regions. Likewise, the GIS-based approaches presented by Jabar et al (2023) align with the methods used to track sedimentation and morphological changes in the study of river systems. Jaafar et al. (2023) further illustrate the significance of hydraulic properties in river training works, which are relevant for understanding the dynamics of the Bukhainagar River and other similar systems.

Numerous studies have focused on mapping and monitoring erosion and accretion in major river like the Padma River, but research on smaller distributary channels such as Bukhainagar River remains limited (Billah, 2018). Besides, another study has revealed the efficiency of these technologies in exploring the physical features and developments of river systems (Rahman et al., 2021). Meanwhile, examining the RS-based satellite imagery, the braided channel of the Yellow River in China has illustrated its migrations for around forty years (Wang et al., 2016). Advanced remote sensing and modeling techniques are also useful for tracking hydrological changes and forecasting erosion dynamics in view of future climatic scenarios, according to recent studies (Mohammed et al., 2022; Mohammed et al., 2024; Sattar et al., 2024). However, several studies have shown a broad range of variance in streamflow, which is one of the principal factors of riverbank erosion in our country, river velocity along with all major rivers will be raised from 15% to 20% in the year 2050 and 2100, respectively (Chowdhury et al., 2021; Hasan et al., 2024). In

southern Bangladesh, the combined effect of riverbank erosion and accretion has led to severe socio-environmental consequences, with substantial changes observed in regions such as Mehendiganj and Char Hizla (Chowdhury et al., 2021; Salman et al., 2023; Quamar et al., 2024). Furthermore, these modeling of spatially distributed sedimentation has been applied to other regions, such as the Houran Dam H-3 (Sattar et al., 2024), and the spatial distribution of soil moisture in the Iraqi Western Desert (Mohammed et al., 2024). These modeling approaches provide valuable insights into sediment dynamics and moisture distribution that can enhance our understanding of erosion and accretion patterns in river systems.

Despite the extensive research on other major rivers such as Padma, Jamuna, and Brahmaputra, few studies have focused specifically on the geomorphological dynamics of smaller distributary channels like the Bukhainagar River. These smaller rivers that directly affect rural populations have not been sufficiently studied. Most existing research has focused on large rivers with regional-scale implications, neglecting smaller rivers that are vital to the local populations reliant on them. This work seeks to address the research gap by delivering a spatiotemporal analysis of erosion, accretion, and channel shifting in the Bukhainagar River from 1990 to 2020. The chosen timeframe includes a pivotal phase of land-use change, population growth, and heightened anthropogenic activities in southern Bangladesh (Dewan & Yamaguchi, 2009). Over these decades, substantial alterations in land use, hydrology, and climatic patterns have likely intensified the river's dynamics, leading to increased erosion and modifications in channel morphology.

This study employs GIS and RS methodologies to measure erosion and accretion rates along the river and evaluate the social repercussions of these geomorphological alterations on local populations using Focus Group Discussions (FGDs). This research enhances comprehension of river dynamics in southern Bangladesh and offers significant insights for sustainable river management and mitigation strategies. This work seeks to elucidate the geomorphological alterations in the Bukhainagar River, thereby advancing our comprehension of deltaic river systems and showcasing the effectiveness of GIS and RS techniques in managing and mitigating river-related issues. Additionally, the research incorporates an interdisciplinary approach by integrating geospatial analysis with socioeconomic evaluations, offering a comprehensive perspective on the effects of river dynamics on local populations and livelihoods.

Methodology

Study Area

The Bukhainagar River is located in southern Bangladesh, characterized by a floodplain and deltaic geomorphology, within the lower segments of the Meghna and Kirthonkhola Rivers, part of the Bengal Delta (Fig. 1). Geographically, the study area located from Barishal City to Laharhat in the Mehendiganj Upazila of Barishal, with coordinates ranging from N 22°42'27" to N 22°40'31" and E 90°24'28" to E 90°29'00". This region's geology is typified by unconsolidated Holocene sediments, making riverbanks highly susceptible to erosion. This region is highly vulnerable to riverbank erosion due to flat topography,

which is exacerbated during the monsoon season as an effect of heavy rainfall and hydrodynamics forces from the lower Meghna River (Islam et al., 2025; Khatun et al., 2025; Valentine et al., 2023).

The soils of this region are composed of alluvial sediments with clay, silt, and sand layers, which are particularly vulnerable to water induced erosion, during heavy rainfall. This region experiences a tropical monsoon climate, with rainfall significantly contributing to the erosion and accretion processes along the riverbanks. The area has witnessed notable agricultural activities, particularly paddy rice cultivation (Aus, Aman, and Boro varieties), along with crops like sugarcane, watermelons, vegetables, beans, lentils, and pods. Over 20,000 people live in the area, predominantly relying on agriculture and fishing for their livelihood. The population density (approximately 668 people/km²) further increases the vulnerability of local communities to changes in the riverbank, with many families forced to relocate due to erosion-induced displacement.

The period from 1990 to 2020 was chosen due to significant geomorphological and anthropogenic changes, including the development of agricultural land and urban growth along the riverbanks. This timeframe also marks the period of intensified climate change impacts, including increased rainfall intensity during the monsoon, which has influenced the river dynamics (Dewan & Yamaguchi, 2009; Hasan et al., 2020). The substantial expansion of paddy rice cultivation and urbanization during this time likely contributed to shifts in river dynamics, including changes in sediment transport and soil stability.

Data Collection

GIS and RS Data

Satellite imagery from Landsat was obtained for the years 1990, 2000, 2010, and 2020 to track the spatiotemporal dynamics of riverbank erosion and accretion. The imagery was processed using ArcGIS 10.8 and Google Earth Pro to analyze morphological changes in river channel. The Landsat 5 Thematic Mapper (TM) images for 1990, 2000, and 2010, and the Landsat 8 Operational Land Imager-Thermal Infrared Sensor (OLI-TIRS) image for 2020, all with a spatial resolution of 30 meters, were used for this study. (Table 1). These images were geo-referenced, atmospherically corrected, and geometrically adjusted using ground control points. Cloud-free images from the dry season (January) were specifically selected to minimize cloud cover and seasonal variations in river water levels and flood impacts. The image processing involved radiometric enhancement to improve the contrast and highlight subtle changes in land cover, facilitating better detection of erosion and accretion areas. Cloud masking was applied using the Fmask algorithm, ensuring that cloud cover did not interfere with classification results. All images were then stacked into multi-band composites and mosaicked to form a continuous image covering the study period.

Table 1
Description of Landsat images used in this study

Acquisition period	Satellite	Sensor	Spatial resolution	Cloud coverage
1990	Landsat 5	TM	30	0
2000	Landsat 5	TM	30	0
2010	Landsat 5	TM	30	0
2020	Landsat 8	OLI-TIRS	30	1

Image Analysis

The image analysis process involved three main stages: pre-processing, processing, and post-processing (Fig. 2). Landsat images from 1990, 2000, 2010, and 2020 were processed in ArcGIS 10.8 using supervised classification with the maximum likelihood algorithm to detect land cover changes, including erosion and accretion. Training samples were selected from high-resolution reference images, and a total of 1000 training points were randomly selected across the study area for each year. The land cover classes were categorized into: water bodies, vegetation, agricultural land, built-up area. The study area was clipped using the raster clip tool in ArcGIS, and the classification was performed on the extracted area of interest (AOI), corresponding to the riverbanks along the Bukhainagar River.

Analysis of Erosion and Accretion

Erosion and accretion were calculated for four distinct periods: 1990–2000, 2000–2010, 2010–2020, and the overall period of 1990–2020. The supervised classification technique was applied to the multi-band composite images for each period. The AOI was classified into the aforementioned land cover categories, and the maximum likelihood algorithm was used to accurately identify areas of erosion and accretion (Bartley et al., 2008; Pal et al., 2017; Billah, 2018; Ferrel et al., 2018; Hasan et al., 2024; Muzahid et al., 2024; Parvej et al., 2024). The river area shapefiles were generated from the classified vector images using ArcGIS 10.8 (Iqbal et al., 2014; Butt et al., 2015; Debnath et al., 2023). These shapefiles were used to calculate the extent of erosion and accretion by identifying unchanged areas over time. The amount of erosion for each period was calculated using the formula:

$$\mathbf{Erosion} = \mathbf{AreaofPreviousYear} - \mathbf{AreaofCurrentYear} (\mathbf{Eq}.1)$$

Similarly, accretion was calculated as:

$$\mathbf{Accretion} = \mathbf{AreaofCurrentYear} - \mathbf{AreaofPreviousArea} (\mathbf{Eq}.2)$$

The pixel-based supervised classification technique has been validated in previous studies (Billah, 2018; Ferrel et al., 2018) and proved effective in accurately quantifying erosion and accretion zones

Statistical Analysis

To assess the classification accuracy, the Kappa coefficient was used, providing a statistical measure of the agreement between the classified data (satellite images) and ground truth observations. The Kappa coefficient was calculated for each time period (1990, 2000, 2010, 2020) using a confusion matrix, comparing the classified results with actual land cover data. The Kappa coefficient was calculated using the formula:

$\mathbf{K} = \frac{(\mathbf{P}_{\circ} - \mathbf{P}_{\mathbf{e}})}{(1 - \mathbf{P}_{\mathbf{e}})}$ (Eq. 3)

Where, $P_{\circ}$ is the observed agreement (the proportion of correctly classified pixels). P_e is the expected agreement due to change (based on the distribution of the classes). The values of Kappa are interpreted as follows:

K ≥ 0.80: Strong agreement

0.60 ≤ K ≤ 0.80: Moderate agreement

0.40 ≤ K ≤ 0.60: Fair agreement
K ≤ 0.60: Poor agreement

Focus Group Discussions (FGDs)

To verify and enrich the quantitative findings from GIS and RS data, FGDs were conducted. Participants were selected from communities with long-term residence along the riverbanks, offering firsthand knowledge of the erosion and accretion processes. The goal was to validate the spatial findings from the satellite imagery and gain qualitative insights into the socio-economic impacts of these changes. A total of five FGDs were conducted, each with 6–10 participants like local farmers, fishermen, government officials, and community members, ranging from 25 to 70 years of age. These discussions provided detailed accounts of the economic losses, displacement, and livelihood impacts of riverbank changes, offering essential context to the geospatial analysis. Thematic analysis and coding procedures were used to analyze the data collected through voice recordings and field notes, providing a comprehensive understanding of the community's challenges and needs.

Result and Discussion

Riverbank Erosion and Accretion Dynamics

The GIS and RS analysis revealed significant changes in the morphology of the Bukhainagar River over the 30-year period from 1990 to 2020. The total riverbank erosion amounted to 315.02 hectares (ha), while accretion accounted for 137.90 ha, resulting in a net loss of 177.12 ha (Fig. 3). These

geomorphological changes significantly affect local soil stability, agricultural productivity, and livelihoods. Areas with severe erosion have lost fertile topsoil, reducing agricultural potential, while people along the riverbanks have encountered land loss, displacement, and economic hardship. Erosion over the 30 years period (1990 to 2020) showed significant temporal variation (Fig. 3). The highest erosion rate occurred between 2010 to 2020, averaging 21.88 ha/year, corresponding to a total loss of 218.79ha. This period experienced the largest crop and land loss, reflecting increased erosion dynamics, which were also accompanied by socio-economic consequences. For example, the displacement of households and agricultural losses from the eroded land were directly reported by local farmers and residents during FGDs. In contrast, from 1990 to 2000 period experienced moderate erosion of 13.28 ha/year (132.84 ha total), while the lowest rate occurred between 2000 to 2010 at 6.68 ha/year (66.78 ha total). The average erosion rate throughout these 30 years was 10.5 ha/year, with a total of 315.02 ha of land lost during that time. This fluctuation indicates dynamic channel-shifting behavior influenced by natural causes, including sediment load variations, hydrological changes, and human interventions such as land use changes and river management practices (Rahman et al., 2022; Jabar et al., 2023; Jaafar et al., 2023; Muzahid et al., 2024).

Accretion patterns exhibited similar dynamics. The highest accretion occurred between 2000 to 2010, contributing 103.05 ha at an average annual rate of 10.305 ha/year. However, the period from 2010 to 2020 experienced reduced accretion of 70.29 ha/year (Fig. 3). The average accretion rate throughout the study period was 4.60 ha/year. While accretion facilitated soil deposition in certain areas, partially rehabilitating agricultural land, it was inadequate to counterbalance the elevated erosion rates. During FGDs, many community members noted that although accretion in some parts allowed for partial soil regeneration, the ground remained unstable, leading to further challenges for agricultural use. Human activities, including embankment construction and land reclamation, have also affected these deposition patterns. These variations indicate the river shifting behavior, influenced by both natural processes such as sediment deposition and anthropogenic activities like land use and river management (Guchhait et al., 2016; Jabar et al., 2023; Jaafar et al., 2023; Langhorst et al., 2023; Mou et al., 2023).

The overall analysis highlights a dynamic interplay between erosion and accretion, with natural factors such as sediment transport and hydrological changes, as well as anthropogenic activities like land-use changes and river management strategies, influencing the river's morphology (Guchhait et al., 2016; Mou et al., 2023). While some periods, particularly the early 2000s, saw substantial accretion, the overall trend indicates a net loss of land along the river, driven by higher erosion rates in more recent years. The comprehensive investigation reveals that the Bukhainagar River exhibits a tendency toward net land loss, presenting ongoing risks to local residents. Erosion has degraded fertile soils, damaged crops, and undermined agricultural livelihoods. While accretion has benefited soil deposition in some areas, it often results in unstable ground that is unsuitable for agriculture.

Channel Shifting and Riverbank Dynamics

Rivers in humid and semi-humid regions generally through their morphological cycles in three phase such as young, mature, and old, demonstrating enhanced meandering as slopes flatten (Gazi et al.,

2020). The Bukhainagar River follows this typical pattern, exhibited significant lateral erosion and channel displacement. Over the 30 years from 1990 to 2020, the river showed substantial lateral displacement, leading to erosion and deposition along opposite banks. Superimposing, GIS and RS maps of riverbank erosion and accretion over four temporal intervals (1990–2000, 2000–2010, 2010–2020, and 1990–2020) demonstrates significant spatial variations in bank movement (Fig. 4).

The river's channel most significant shifted between 2010 and 2020, expanding and relocating westward. This resulted to severe erosion along the left bank, the degradation of agricultural land, and the evacuation of riverfront residents (Fig. 5). In the central and lower sections, increased meandering led to soil instability, compromising crop production and diminishing arable land availability. During FGDs, residents described their struggles with agricultural losses and the difficulties they faced in adapting to the rapid changes in the river's course. The decade from 2000 to 2010 experienced considerable meandering accompanied by isolated erosion and accretion, while the period from 1990 to 2000 demonstrated relative stability. The period from 2010 to 2020 saw even more pronounced changes, with the river shifting further west, causing more substantial erosion and land loss. The observed dynamics result from natural processes, including variations in sediment load and hydrological changes, alongside anthropogenic influences such as riverbank alterations and upstream land use modifications (Mou et al., 2023; Muzahid et al., 2024).

The river's meandering behavior caused soil instability, compromising crop production and reducing arable land availability. The period from 2000 to 2010 experienced moderate meandering with localized erosion and accretion, while 1990–2000 showed relative stability. These dynamics result from both natural variability (e.g., sediment load and hydrological changes) and anthropogenic factors (e.g., riverbank modifications and land-use practices) (Mou et al., 2023; Muzahid et al., 2024). Despite the river's almost straight flow in 1990, the study presents that it continues to have a strong propensity to meander, suggesting that the river has not yet reached stability and that bank erosion will persist in the future. On the other hands, the channel shifting directly affected local communities. Riverside farmers reported agricultural losses attributed to weakened banks, while relocated households faced economic and social distress. Fishing practices were also impacted as alterations in river morphology modified fish habitats affecting local livelihoods. FGDs with community members underscored these concerns, emphasizing the increasing unpredictability of river dynamics and the necessity for adaptive land-use planning.

Pattern of Erosion, Accretion, and Socio-Economic Impacts

Analysis of the Bukhainagar River over the 30-year period (1990–2020) reveals significant fluctuations in the land affected by erosion, accretion, and areas that remained unchanged. Between 1990 and 2000, erosion impacted 2.29% (13.28 ha) of the land, while accretion accounted for 1.17% (6.79 ha), and 6.54% (37.91 ha) of the land remained unchanged of total land in per year. From 2000 to 2010, erosion affected 1.21% (6.68 ha) of the land, with accretion increasing to 1.87% (10.31 ha), and 6.91% (38.03 ha) of the land remaining unchanged (Fig. 6). The most significant erosion occurred from 2010 to 2020, with 3.95% (21.88 ha) of the land eroded, 1.27% (7.01 ha) accreted, and only 4.78% (26.45 ha) of the land remained

unchanged annually (Fig. 6). These findings highlight the growing impact of erosion, particularly during the last decade, and emphasize the river unstable morphology, driven by both natural and anthropogenic factors, including deforestation, upstream water diversion, and intensified flooding (Owens, 2020; Shahariar et al., 2025).

The socio-economic impacts of erosion are significant. Erosion strips fertile topsoil, reducing agricultural productivity, while the accreted land typically requires stabilization before cultivation. Crops near eroding banks are often destroyed, resulting in property loss for households and displacing residents. FGDs revealed growing concerns among the local community about the unpredictability of erosion, with causes such as upstream water diversion, deforestation, and intensified flooding, particularly in the past decade. These findings emphasize the necessity for sustainable river management strategies, which should focus on environmental sustainability while addressing the socio-economic challenges faced by local populations. The integration of both scientific and local knowledge will be crucial for effective mitigation (Nicholls et al., 2016; Hossain et al., 2024).

Accuracy Assessment

The Kappa coefficient values suggest that the GIS and RS-based classification technique used in this study provided reliable results for assessing riverbank erosion, accretion, and channel shifting along the Bukhainagar River. The analysis across three periods (1990, 2000, 2020) showed strong agreement Kappa values ($\kappa \geq 0.80$), confirming the high reliability of the classification for long-term monitoring of river dynamics. However, the 2010 showed moderate agreement ($\kappa = 0.79$) which can be attributed to the complex river morphology and minor inconsistencies in the satellite imagery for that period (Table 2). The intricate meandering of the river and potential variations in riverbank features made it challenging to achieve the same level of agreement as in other years, suggesting that the 2010 imagery was influenced by indirect morpho dynamic variations in satellite data quality. The moderate agreement for the 2010 period highlights the need for further refinement in RS data interpretation in areas with complex river features. Such discrepancies could stem from several factors, including seasonal variations, cloud cover, or the resolution of satellite imagery during that time. To address these potential inaccuracies, ground-truthing is recommended, where field observations can complement satellite data, especially in areas with complex changing landscapes. Additionally, ensuring the selection of cloud-free imagery and utilizing higher-resolution satellite data may improve classification accuracy in future studies. So, these results indicate high reliability of the classification for long-term river monitoring, though ground-truthing and local knowledge are recommended to enhance accuracy in complex zones. The calculated Kappa coefficients for each period were as follows:

Table 2
Kappa Coefficients for Riverbank Classification (1990–2020).

Year	Kappa Coefficient (κ)	Agreement Level
1990	0.85	Strong agreement
2000	0.82	Strong agreement
2010	0.79	Moderate agreement
2020	0.80	Strong agreement

These results underscore the overall reliability of the GIS and RS classification method while recognizing the importance of addressing sources of inaccuracy through improved data quality and validation techniques.

Conclusion

From 1990 to 2020, the Bukhainagar River experienced significant morphological changes, with an average annual erosion rate of 10.5 ha and an average annual accretion rate of 4.596 ha. Initially, in 1990, the river exhibited a relatively straight course. However, over the following decades, it gradually evolved into a more meandering pattern. The 30-year period saw substantial lateral movement of the riverbanksdriven by both erosion and accretion. By 2020, the river's morphology exhibited a more meandering pattern, that indicates the dynamic nature of the system, characterized by a more meandering channel. These changes highlight the complex and unpredictable nature of the river's behavior, driven by both natural and anthropogenic influences. The results of the Kappa coefficient analysis demonstrate the reliability of GIS and RS techniques in monitoring long-term changes in riverbank erosion and accretion. The high accuracy of these techniques affirms their effectiveness of GIS and RS tools in assessing river dynamics in regions with similar geomorphological challenges. This study emphasizes the importance of integrating scientific monitoring tools with local knowledge to ensure effective river management strategies. One of the major findings of this study is the significant impact of erosion and accretion on local agriculture, soil fertility, and the livelihoods of communities along the river. Erosion has led to the degradation of fertile agricultural land, the displacement of local populations, and economic hardship, especially for farming and fishing communities. Conversely, while accretion has facilitated soil deposition in some areas, it often results in the accumulation of unstable terrain, rendering the land unsuitable for agricultural use. These findings highlight the vulnerability of local populations to river dynamics, which has been compounded by factors such as land use changes and climate change. Consequently, forthcoming river management strategies must prioritize both the preservation of river basin stability and the mitigation of social vulnerabilities. The study's results emphasize the need for holistic river management that combines environmental sustainability with the well-being of local communities. Mitigation plans should be developed collaboration with local communities, using both empirical facts and indigenous knowledge to address the impacts of erratic

river dynamics. Proactive strategies, including adaptive land-use planning, flood management, and soil conservation methods, must be implemented to mitigate the negative effects of erosion and accretion. In conclusion, the persistent alterations in the Bukhainagar River necessitate a holistic strategy that integrates technological solutions with community involvement to protect the ecosystem and enhance the welfare of local populations. By integrating environmental conservation efforts with community development, sustainable river management can be achieved sustainable river management, ensuring that future generations benefit from the river's resources without compromising the ecosystem and local livelihoods.

Declarations

Author Contribution

Md Wabidur Rahman; conceptualization, investigation, methodology, formal analysis, writing- original draft, writing- review & editing, visualization, validation.Jannatul Ferdos; conceptualization, investigation, methodology, formal analysis, software, writing- original draft, writing- review & editing, visualization, validation, supervision.Md Emdadul Haque; software, writing- original draft, writing- review & editing.

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Figures

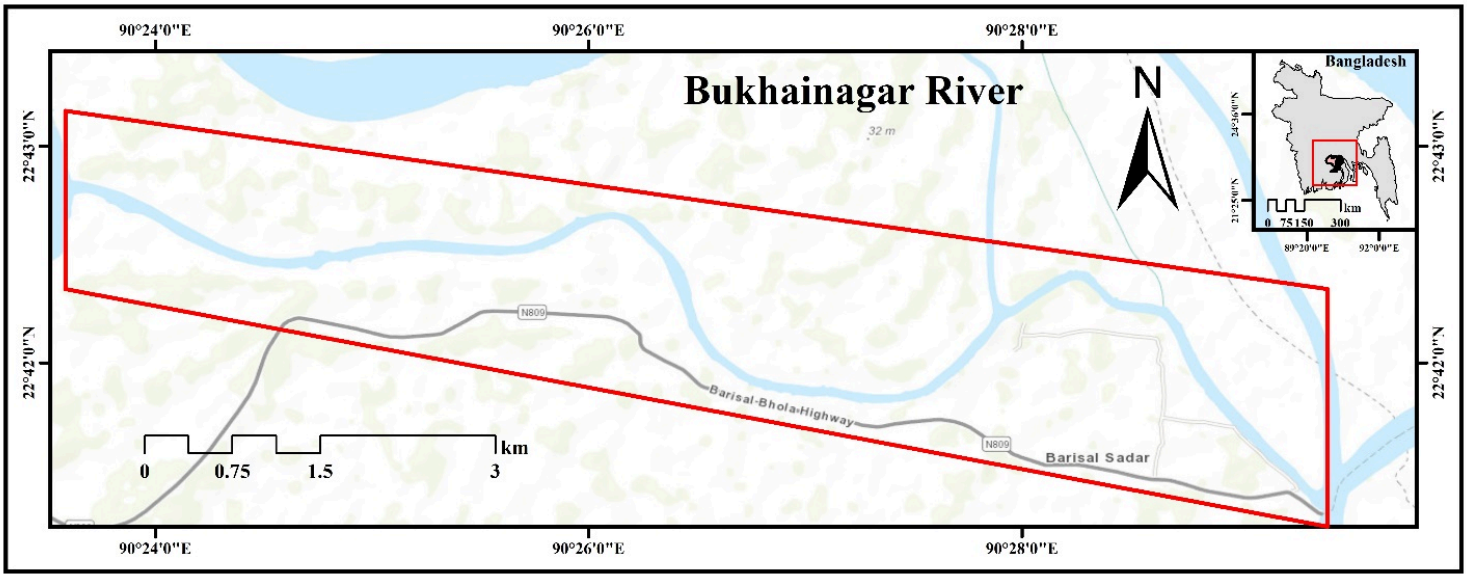


Figure 1

Map showing the study area along the Bukhainagar River in Barisal Sadar, Bangladesh. The area is delineated by the red box, highlighting the geographical location of the river and surrounding regions.

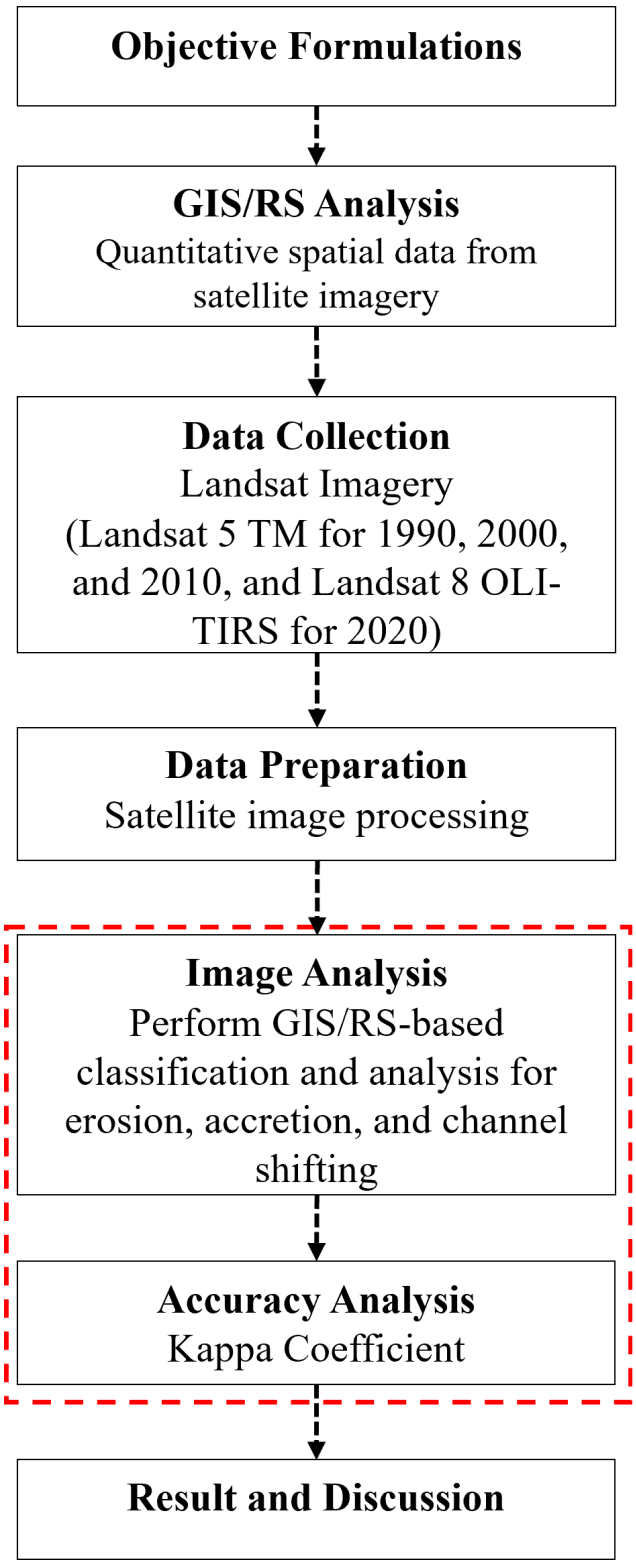


Figure 2

Methodological Flowchart for the Study: This flowchart illustrates the step-by-step methodology employed in this study, from data collection to analysis and interpretation, including GIS and RS data processing.

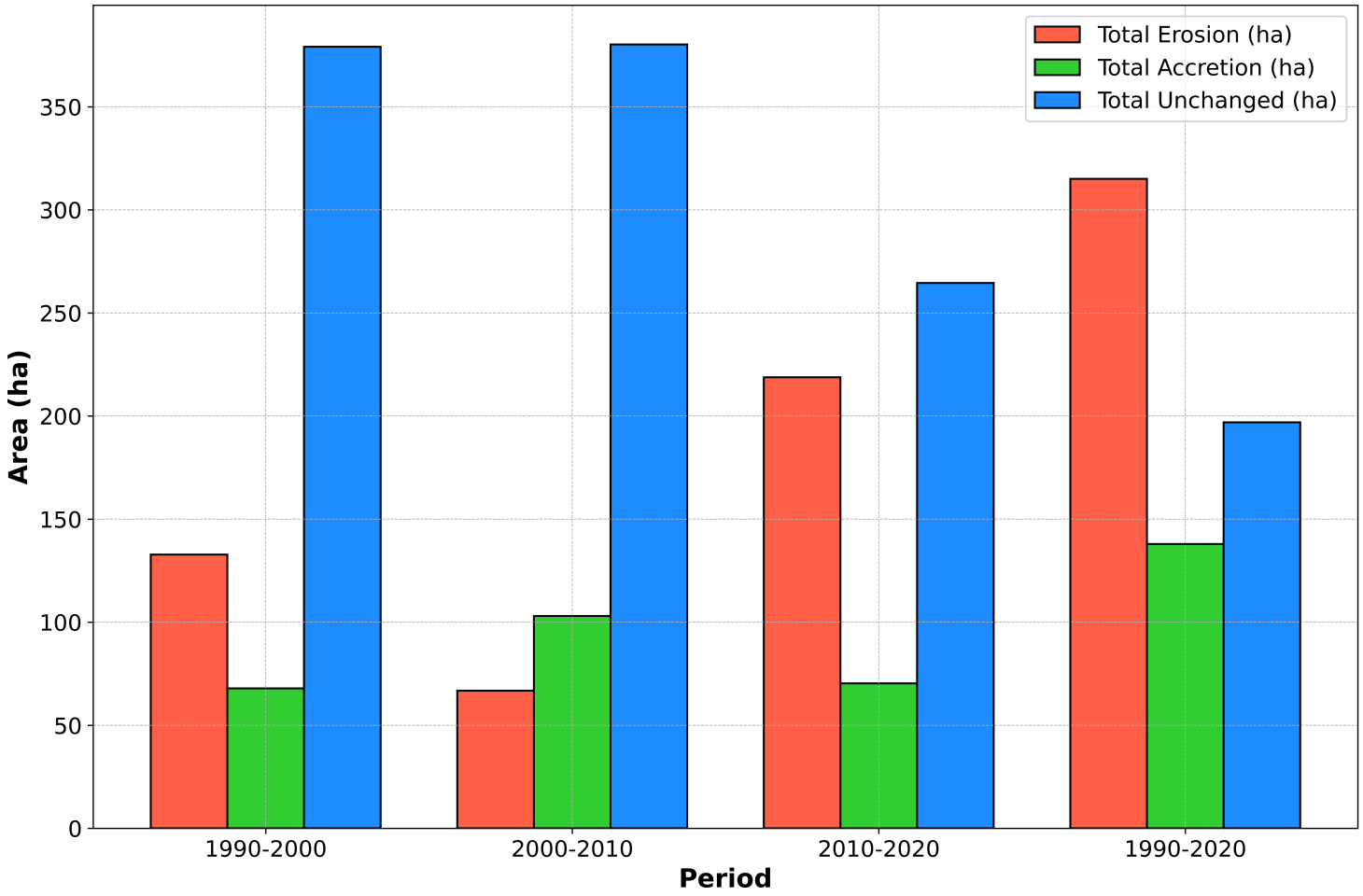


Figure 3

Combined visualization of the Bukhainagar River's geomorphological changes over specified periods. The bar chart illustrates the total erosion, accretion, and unchanged areas, with each category represented by distinct colors.

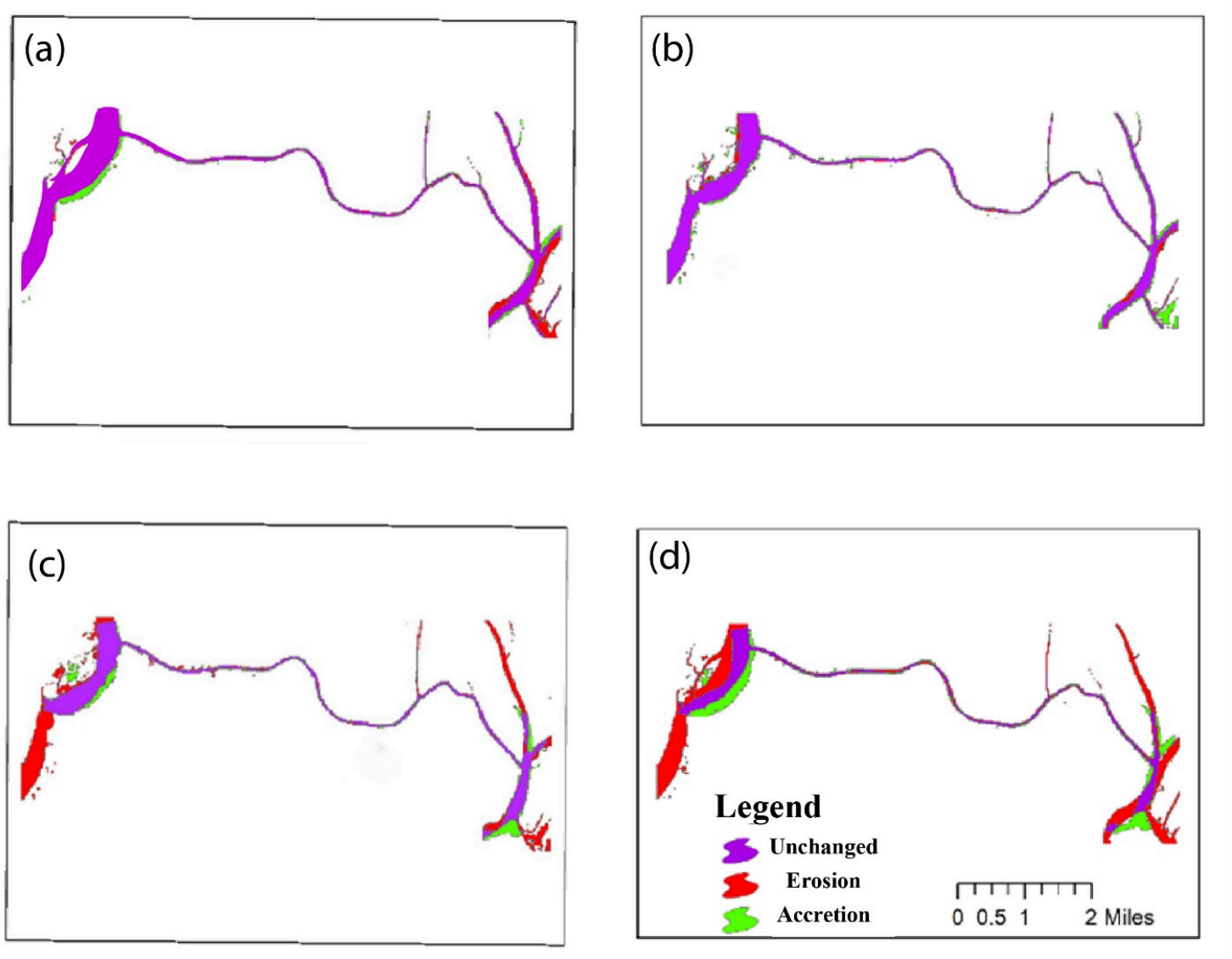


Figure 4

Temporal changes in river shoreline dynamics from 1990 to 2020. Panels (a) to (d) show the evolution of river shoreline erosion and accretion over different time periods: (a) 1990–2000, (b) 2000–2010, (c) 2010–2020, and (d) 1990–2020.

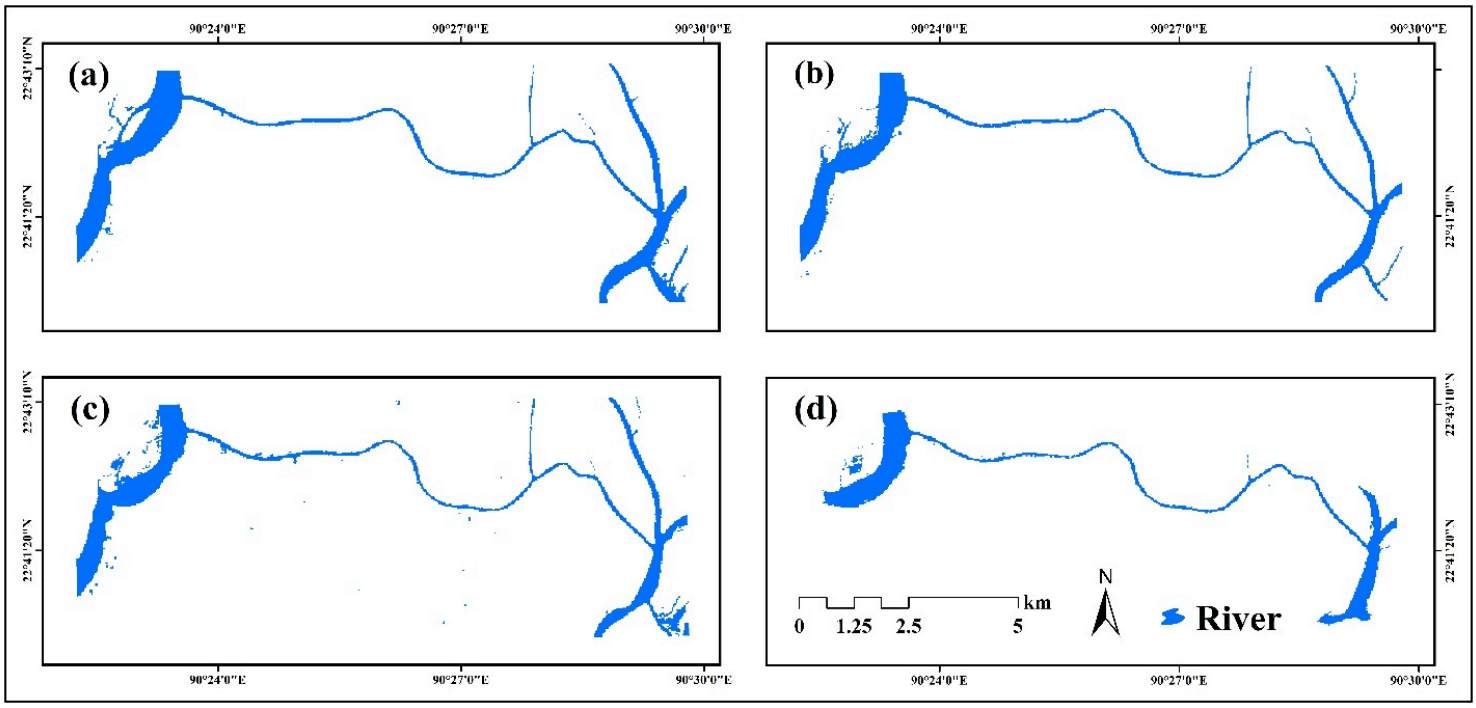


Figure 5

Temporal changes in the river course and surrounding features over 1990-2020. (a) 1990, (b) 2000, (c) 2010, and (d) 2020 show the river flow respectively.

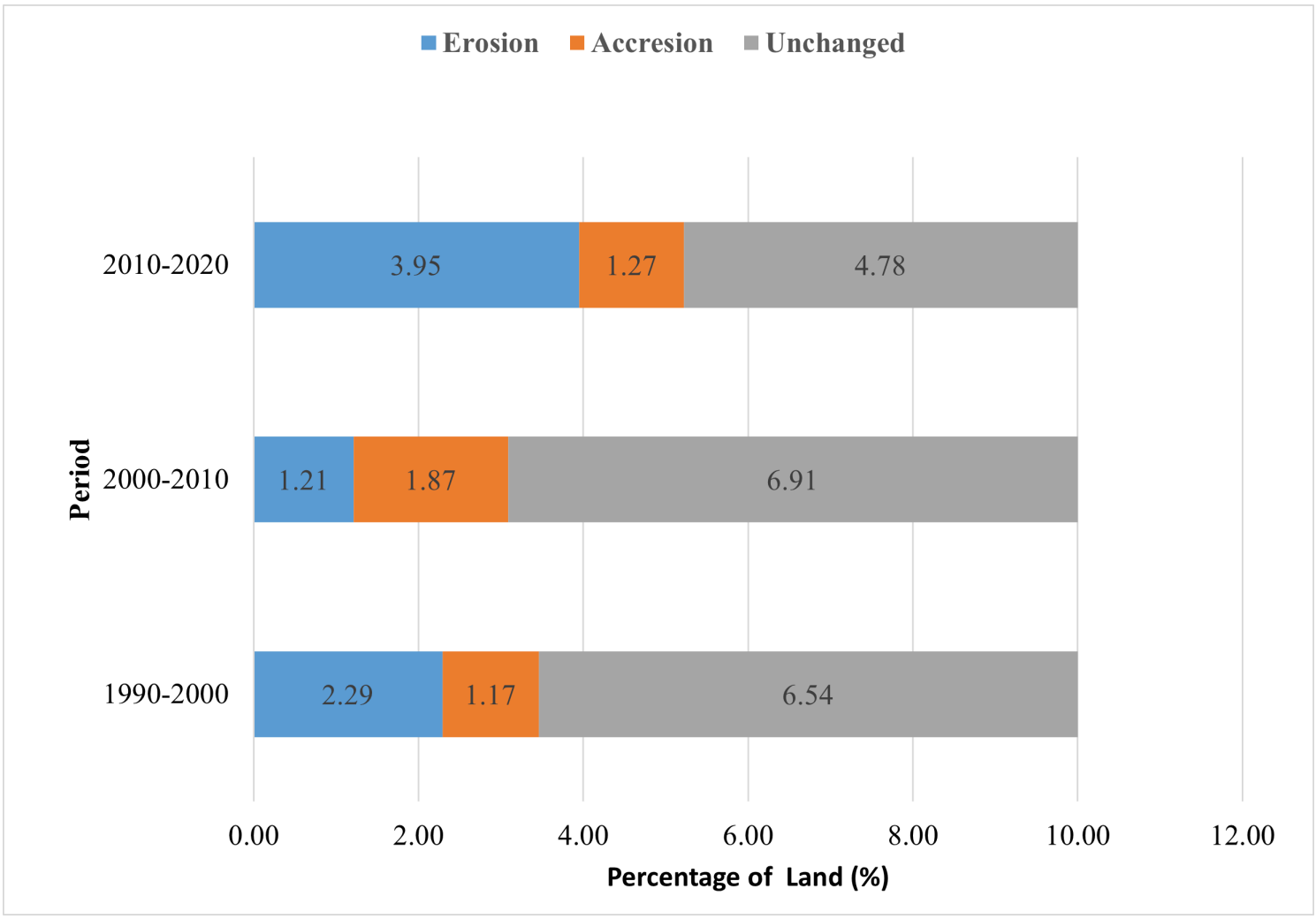


Figure 6

Average annual trends of erosion, accretion, and unchanged land areas in the Bukhainagar River (1990–2020). The graph shows the percentage of land affected by erosion, accretion, and areas that remained unchanged across three periods: 1990-2000, 2000-2010, and 2010-2020. Erosion consistently exceeded accretion, with the most significant land loss occurring between 2010 and 2020.