

Spatiotemporal Dynamics of Riverbank Erosion and Accretion of the Surma River in Sunamganj District, Bangladesh: A Remote Sensing and GIS-Based Assessment (2000–2025)

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ABSTRACT

Riverbank erosion and accretion are continuous fluvial processes that modify channel position, floodplain surfaces and adjacent land. In Bangladesh, long-term monitoring of these processes is particularly important because river systems are strongly influenced by monsoonal hydrology, sediment transport and floodplain dynamics. This study assesses the spatial and temporal dynamics of erosion and accretion along the Surma River in Sunamganj District, northeastern Bangladesh, from 2000 to 2025 using multi-temporal Landsat imagery and geographic information system (GIS) techniques. Satellite scenes were selected from the available Landsat archive with comparatively low cloud cover for the target observation periods. NDVI was used as an image-interpretation aid, followed by river-feature extraction and preparation of polygon shapefiles. Temporal river polygons were compared using GIS overlay operations, including Erase, Union and Intersect, to identify erosion, accretion and relatively unchanged areas. All area values are reported in km². The results show strong temporal variability: accretion dominated 2000–2005, erosion was more prominent during 2005–2010 and 2010–2015, a pronounced accretion signal occurred during 2015–2020, and both erosion and accretion were extensive during 2020–2025. The reported erosion values range from 0.224532 to 273.911314 km², whereas reported accretion ranges from 0.128719 to 975.462243 km² across the listed comparison periods. A confusion-matrix-based accuracy assessment produced User's Accuracy values of 92.86%, 93.62% and 91.86% and Producer's Accuracy values of 92.86%, 92.63% and 92.94% for accretion, erosion and unchanged area, respectively. Overall Accuracy was 92.80% and the Kappa coefficient was 0.891. The findings demonstrate the usefulness of multi-temporal remote sensing and GIS for monitoring riverbank change, while highlighting the need for field validation and hydrological and sedimentological observations in future work.

Keywords: riverbank erosion; accretion; Surma River; Sunamganj; Landsat; NDVI; remote sensing; GIS; channel migration; Bangladesh.

INTRODUCTION

Riverbank erosion and accretion are fundamental geomorphological processes through which alluvial rivers continuously adjust their planform and floodplain boundaries. Erosion removes bank material and land from the channel margin, whereas accretion represents deposition and the development or expansion of river-adjacent surfaces. The two processes can occur simultaneously at different locations, producing lateral migration, changes in channel width and redistribution of sediment.

Bangladesh is particularly exposed to riverbank change because of its extensive alluvial floodplains and dense river network. Riverbank erosion can reduce agricultural and homestead land and threaten transport infrastructure

and other assets. Long-term spatial monitoring is therefore useful for identifying changing erosion-prone locations and for supporting river and land-management decisions.

The Surma River is a major river system in northeastern Bangladesh and flows through the Sylhet region, including Sunamganj District. The surrounding floodplain contains extensive haor wetlands, agricultural land, settlements and interconnected water bodies. Seasonal changes in rainfall, discharge and sediment transport contribute to continuing adjustment of the river and its floodplain.

Remote sensing provides a practical way to reconstruct river boundaries over multiple dates, while GIS allows those boundaries to be compared quantitatively. Recent Bangladesh studies have demonstrated the value of Landsat-based geospatial analysis for riverbank erosion and accretion assessment, including studies using NDVI or water-related spectral indices, GIS overlay and DSAS-based bankline analysis. Recent work on the Surma River has also examined geomorphological change in relation to climate variability.

Objectives

- To delineate the Surma River boundary for selected observation years between 2000 and 2025.
- To identify spatial changes in river extent using GIS overlay techniques.
- To quantify erosion, accretion and relatively unchanged areas for the reported comparison periods.
- To examine temporal variation in riverbank shifting and the balance between erosion and accretion.
- To assess the reliability of the classified change categories using confusion-matrix-based accuracy metrics.

Study Area

The study area is located along the Surma River within Sunamganj District in northeastern Bangladesh under Sylhet Division. The area is part of the low-lying Surma–Kushiyara floodplain and includes extensive haor wetlands, agricultural land, settlements and surface-water features. Seasonal inundation is an important characteristic of the landscape, with water levels and river extent changing markedly between wet and dry periods.

Because agriculture, fisheries and river-based activities are important to local livelihoods, changes in river position can have direct environmental and socioeconomic implications. The study therefore focuses on the spatial behaviour of the river boundary and does not attempt to estimate socioeconomic losses.

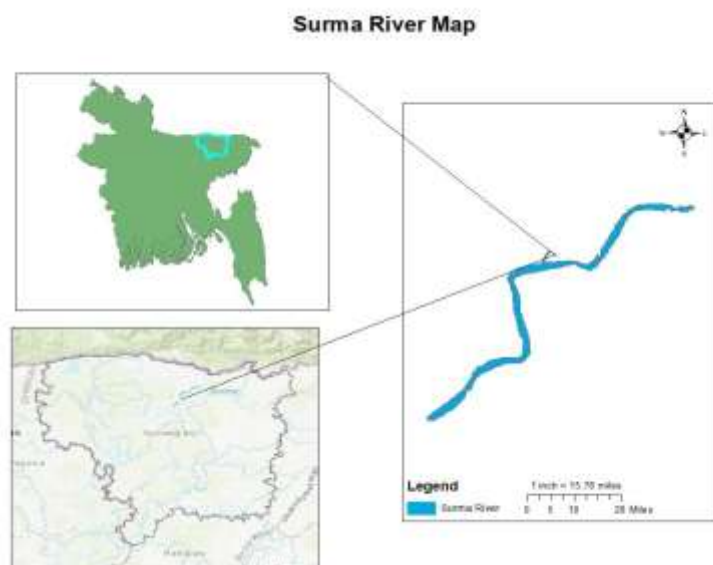


Figure 1. Location map of the Surma River study area in Sunamganj District, Bangladesh.

MATERIALS AND METHODS

Satellite Data Selection

Multi-temporal Landsat imagery was used to represent the selected observation periods from 2000 to 2025. Scenes were selected from the available archive with comparatively low cloud cover and suitable image availability for the target years. Landsat 5, Landsat 7, Landsat 8 and, where available for the recent period, Landsat 9 were considered according to sensor availability. The Landsat archive provides a consistent multi-decadal record at 30 m multispectral spatial resolution, making it suitable for long-term river-boundary monitoring.

Image selection also considered seasonal comparability where possible because river stage and floodplain inundation can alter the apparent position of a water boundary. The selected scenes were used as the basis for the river-boundary maps presented in Figures 2–7.

Image Pre-processing

The satellite scenes were prepared before spatial analysis. The workflow included image inspection, clipping to the study area, appropriate band combinations for visual interpretation, and projection into a common coordinate reference system for spatial comparison. Where Level-2 surface-reflectance products were used, the atmospheric correction incorporated in the Landsat Collection 2 processing was retained. Quality information and cloud conditions were considered during scene selection.

NDVI Calculation and River Feature Interpretation

NDVI was calculated as an image-interpretation aid using the standard expression:

$$\text{NDVI} = (\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$$

where NIR is near-infrared reflectance and Red is red-band reflectance. NDVI was used to help distinguish vegetated surfaces from non-vegetated or water-dominated areas. Because NDVI is primarily a vegetation index rather than a direct water index, river-boundary delineation was based on combined interpretation of the processed imagery and the extracted spatial features rather than on NDVI alone.

River Polygon Extraction

The river extent was delineated from the processed satellite imagery for each selected observation year. The extracted river features were converted into polygon layers and stored as vector shapefiles so that the river boundaries could be compared consistently in the GIS environment.

GIS-Based Change Detection

Temporal river polygons were compared using GIS overlay operations. Intersect was used to identify overlapping portions of the compared river polygons. Erase was used to isolate portions that were present in one temporal polygon but absent from the comparison polygon. Union was used to integrate the spatial information from the compared polygon layers and support the final change classification.

Areas present in the earlier river extent but absent in the later extent were interpreted as erosion-related change, whereas areas newly represented in the later river extent were interpreted as accretion. Overlapping portions were treated as relatively unchanged for the corresponding comparison.

Area Calculation and Units

The areas of erosion, accretion and unchanged portions were calculated from the resulting GIS polygons. Following the reviewer's request, all reported area values in this revised manuscript are explicitly expressed in square kilometres (km²). The numerical values are retained from the supplied GIS results without alteration.

Accuracy Assessment

A confusion matrix was used to evaluate the reliability of the classified change categories. The assessed classes were accretion, erosion and unchanged area. User's Accuracy and Producer's Accuracy were calculated for each class. Overall Accuracy was used to summarize the proportion of correctly classified observations, while the Kappa coefficient (κ) was used to express agreement beyond chance. Because period-specific ground-reference information was not available in the supplied materials, the accuracy assessment is reported for the classified change dataset rather than as a separate accuracy value for every individual year.

RESULTS

Spatial Pattern of Riverbank Change

The multi-temporal maps show pronounced spatial adjustment of the Surma River during the study period. The river boundary shifts from one observation period to another, producing alternating zones of erosion and accretion. At the local scale, the mapped pattern is consistent with lateral channel migration, with erosion occurring along sections where the later river boundary retreats into previously occupied land and accretion occurring where the later boundary extends into areas previously outside the mapped river extent.

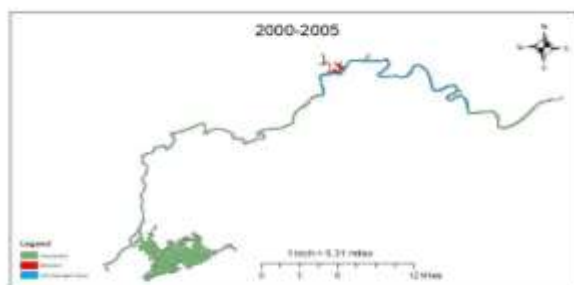


Figure 2. Spatial distribution of erosion and accretion along the Surma River during 2000–2005.

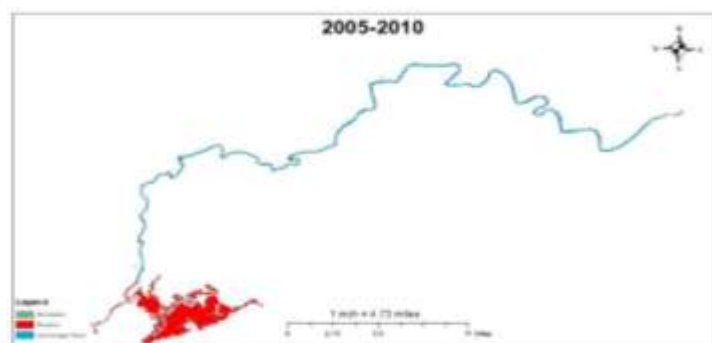


Figure 3. Spatial distribution of erosion and accretion along the Surma River during 2005–2010.

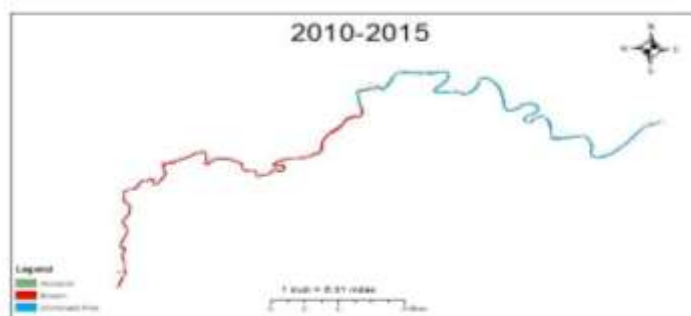


Figure 4. Spatial distribution of erosion and accretion along the Surma River during 2010–2015.

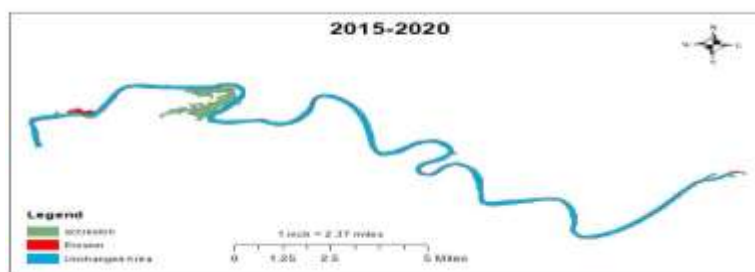


Figure 5. Spatial distribution of erosion and accretion along the Surma River during 2015–2020.

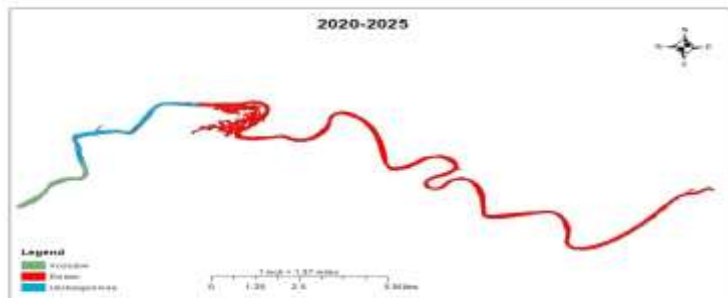


Figure 6. Spatial distribution of erosion and accretion along the Surma River during 2020–2025.

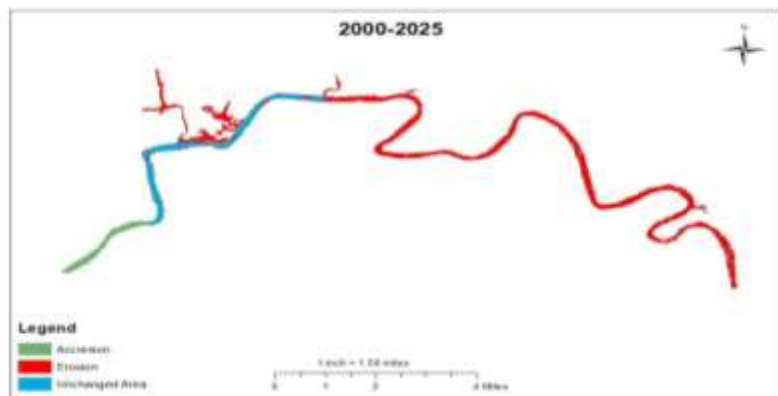


Figure 7. Overall spatial distribution of river change along the Surma River during 2000–2025.

Quantitative Assessment

Period	Erosion (km ²)	Accretion (km ²)	Unchanged Area (km ²)
2000–2005	0.947521	40.205123	6.498489
2005–2010	30.740423	2.962346	15.963188
2010–2015	9.788445	0.128719	9.137089
2015–2020	0.224532	968.039589	9.041277
2020–2025	273.911314	975.462243	1.618623
2000–2020	5.747317	273.831244	1.698693

Table 1. GIS-derived erosion, accretion and unchanged-area values for the reported comparison periods. All areas are in km².

The quantitative results indicate strong temporal variability. During 2000–2005, accretion (40.205123 km²) was substantially greater than erosion (0.947521 km²). During 2005–2010, erosion increased to 30.740423 km² while accretion decreased to 2.962346 km². During 2010–2015, erosion remained higher than accretion. The 2015–2020 interval shows a pronounced reported accretion value of 968.039589 km² alongside a low erosion value of 0.224532 km². During 2020–2025, both erosion and accretion were extensive, at 273.911314 km² and 975.462243 km², respectively. The 2000–2020 row is retained exactly as supplied in the original GIS results.

Because the reported 2015–2020 and 2020–2025 accretion values are very large relative to the other periods, they should be interpreted as the mapped polygon areas generated by the stated GIS workflow. They should not be interpreted as annual rates. Any future refinement should re-check the underlying polygon topology, projection and area-field calculation.

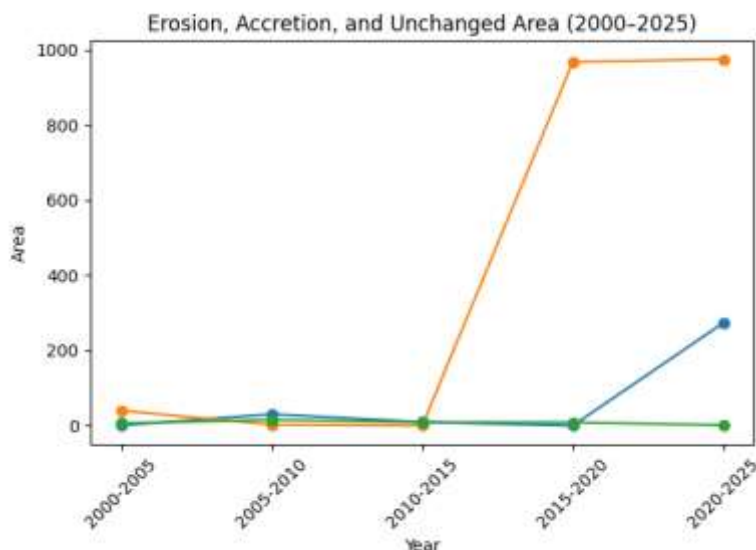


Figure 8. Temporal variation of the reported erosion, accretion and unchanged-area values, 2000–2025.

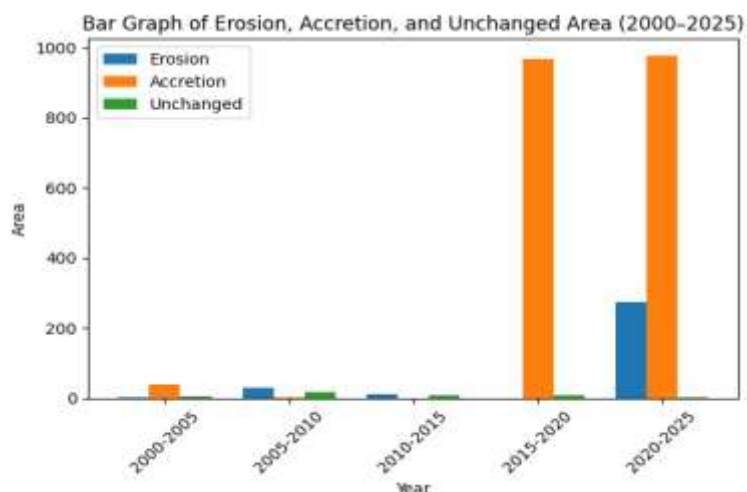


Figure 9. Comparison of the reported erosion, accretion and unchanged-area values by period.

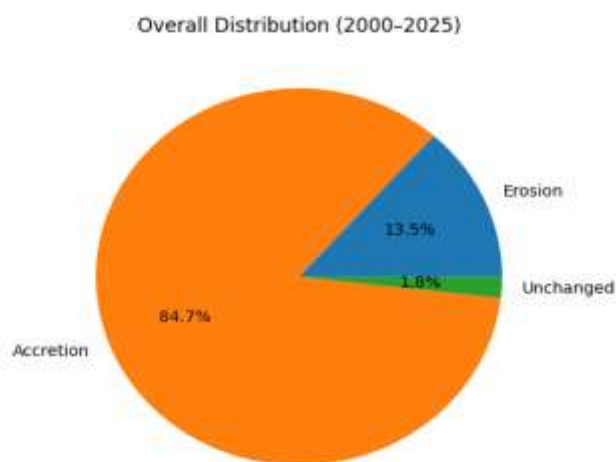


Figure 10. Overall distribution of the reported erosion, accretion and unchanged-area values, 2000–2025.

Accuracy Assessment

Land Use Class	User's Accuracy (%)	Producer's Accuracy (%)	Overall Accuracy (%)	Kappa Statistics (κ)
Accretion	92.86	92.86	—	—
Erosion	93.62	92.63	—	—
Unchanged Area	91.86	92.94	—	—
Overall / Dataset	—	—	92.80	0.891

Table 2. Confusion-matrix-based accuracy assessment of the classified river-change categories. Overall Accuracy and Kappa are dataset-level metrics.

The accuracy assessment indicates strong agreement between the classified categories and the reference information used for validation. User's Accuracy ranged from 91.86% to 93.62%, while Producer's Accuracy ranged from 92.63% to 92.94%. The Overall Accuracy of 92.80% and Kappa coefficient of 0.891 indicate a high level of classification agreement. These metrics provide quantitative support for the mapped change categories, although additional independent field observations would strengthen validation.

DISCUSSION

Temporal Variability

The results show that the Surma River does not follow a single directional trend through the entire 2000–2025 period. Instead, the mapped balance between erosion and accretion changes between observation intervals. Such alternation is expected in dynamic alluvial rivers because erosion and deposition can occur simultaneously at different channel reaches as the flow field and sediment-transport conditions change.

Hydrological and Sedimentological Controls

Discharge, flow velocity, sediment supply, bank material and channel geometry are important controls on riverbank response. Research on the Surma River has also documented relationships between geomorphological behaviour and climatic and hydrological variability. However, the present dataset does not include continuous discharge, suspended-sediment concentration, sediment load or flow-velocity measurements. Accordingly, these factors are discussed as plausible controls rather than as quantitatively demonstrated causes of any particular mapped change.

Climate Variability and Seasonal Conditions

Rainfall and seasonal runoff can modify river stage and sediment transport, while differences in satellite acquisition conditions can alter the apparent water boundary. Although comparatively low-cloud-cover imagery and seasonal comparability were considered during image selection, the observation dates are not identical and therefore cannot completely remove stage-related uncertainty. Future analysis should pair image dates with rainfall, water-level and discharge records to separate true geomorphological change from short-term hydrological variability.

Potential Upstream and Anthropogenic Influences

Upstream interventions, embankments, bank protection, dredging, sand extraction and other human modifications can influence sediment routing and local channel geometry. Recent geospatial studies of Bangladesh's major rivers have highlighted the importance of both natural hydrodynamics and localized human interventions in explaining spatially variable bankline behaviour. The present study does not contain sufficient spatially explicit information to attribute any particular erosion or accretion zone to a specific intervention. Such attribution should therefore be treated as a research need rather than a confirmed finding.

Comparison with Recent Bangladesh Studies

The observed alternation of erosion and accretion is consistent with recent multi-temporal remote-sensing studies of Bangladeshi rivers. Recent work on the major rivers of Bangladesh found distinct erosion and accretion patterns among the Ganges, Padma, Jamuna and Meghna, while studies of the Arial Khan and Padma rivers similarly demonstrate strong spatial and temporal variability. The present study contributes a focused 2000–2025 assessment for the Surma River in Sunamganj, an area where long-term riverbank monitoring is particularly relevant to the floodplain and harbor environment.

Study Limitations

- The analysis is based primarily on multi-temporal satellite imagery and GIS-derived river polygons. Differences in spatial resolution, image quality, cloud conditions, georegistration and digitization can introduce positional uncertainty.
- Satellite images represent river conditions at specific acquisition dates. Differences in river stage and seasonal inundation can influence the apparent river boundary even when the underlying channel has not changed to the same extent.
- Systematic field-based GPS or ground-truth observations were not available for all observation periods. The confusion-matrix accuracy assessment therefore provides useful quantitative validation, but independent field validation would strengthen the evidence.
- Continuous hydrological and sedimentological observations, including discharge, water level, sediment concentration and sediment load, were not incorporated. Consequently, the physical causes of individual erosion and accretion episodes cannot be established quantitatively.
- The effects of specific upstream interventions, bank-protection structures, dredging, sand mining, land-use change and climate variability were not independently modelled.
- The reported area values, especially the very large accretion values in 2015–2020 and 2020–2025, should be rechecked against the original GIS polygon topology, projected coordinate system and area-calculation settings before any rate-based interpretation is attempted.

CONCLUSION

This study assessed the spatiotemporal dynamics of riverbank erosion and accretion along the Surma River in Sunamganj District from 2000 to 2025 using multi-temporal Landsat imagery, NDVI-assisted interpretation and GIS overlay analysis. River boundaries were extracted as polygons and compared using Intersect, Erase and Union operations to identify erosion, accretion and relatively unchanged areas.

The results reveal pronounced temporal variability. Accretion dominated the 2000–2005 interval, erosion was more prominent during 2005–2015, a pronounced accretion signal was reported for 2015–2020, and both erosion and accretion were extensive during 2020–2025. The mapped pattern indicates continuing lateral adjustment of the river and spatial redistribution of river-adjacent land.

The confusion-matrix-based accuracy assessment produced an Overall Accuracy of 92.80% and a Kappa coefficient of 0.891, with User's and Producer's Accuracy values above 91% for all three classes. These results support the usefulness of the remote-sensing and GIS workflow for long-term river monitoring.

The study provides a spatial baseline for monitoring riverbank change in the Surma River corridor. Future work should integrate field surveys, discharge and water-level records, sediment measurements, rainfall data, higher-resolution imagery and explicit assessment of human interventions to improve causal interpretation and predictive river-management applications.

RECOMMENDATIONS

- Repeat Landsat and higher-resolution satellite monitoring at regular intervals to identify emerging erosion-prone reaches.
- Integrate riverbank-change maps with settlement, agricultural-land and infrastructure layers for local risk planning.
- Combine future remote-sensing analysis with discharge, water level, sediment load, rainfall and channel-geometry measurements.

- Where possible, establish field validation points or GPS-surveyed banklines to independently assess positional accuracy.
- Investigate the influence of upstream water-management and local engineering interventions before assigning causal explanations to individual erosion or accretion zones.

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