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Geospatial Analysis of Riverbank Erosion and Urban–Peri-Urban Expansion Under Sand Mining Pressure: A Study of The Ajay–Mayurakshi Basin, South-West Bengal

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Abstract

Riverine systems in eastern India are increasingly threatened by anthropogenic activities, particularly unregulated sand mining and rapid urban expansion. This study examines the spatial dynamics of riverbank erosion and urban–peri-urban expansion in the Ajay–Mayurakshi basin of South-West Bengal using geospatial techniques. Multi-temporal satellite data (2000–2020), GIS-based analysis, and field observations were employed to assess changes in channel morphology, erosion rates, and land use patterns. The results indicate that intensified sand mining has significantly altered channel planform, reduced braiding, and increased erosion rates. Simultaneously, built-up areas have expanded rapidly, replacing agricultural and vegetative land. The study highlights the interconnected nature of sand mining, erosion, and spatial expansion, emphasizing the need for sustainable river basin management.

Keywords: Sand, Mining, Erosion, Intensified, Rapid, Urban, Management, Sustainable, riverbank

1. Introduction

Rivers are dynamic systems governed by interactions between water flow, sediment transport, and channel morphology. However, human interventions such as sand mining have disrupted these natural processes. Sand mining has emerged as a major environmental issue due to increasing demand for construction materials. In India, several rivers, including the Ajay and Mayurakshi, are subjected to intensive extraction activities.

The Ajay–Mayurakshi basin is particularly vulnerable due to its alluvial characteristics and high population pressure. Rapid urbanization has further intensified land use transformation in riparian zones. Sand mining creates sediment deficits, leading to increased erosion and channel instability. Recent studies show that mining-induced pit formation alters flow dynamics and reduces channel complexity.

This study aims to analyze the combined impact of sand mining and urban expansion on riverbank erosion and land use change using geospatial techniques.

2. Review of Literature

Sand mining has been widely recognized as a significant anthropogenic factor influencing riverine geomorphology and environmental stability. One of the foundational works by Gary M. Kondolf (1997) [9] introduced the concept of “hungry water,” explaining how sediment extraction creates a deficit that increases the erosive capacity of rivers. This process leads to channel incision, bank instability, and long-term geomorphic adjustments. Similarly, Marco Rinaldi *et al*. (2005) [16] emphasized that sediment mining alters channel slope, flow velocity, and sediment transport processes, ultimately resulting in channel widening, deepening, and instability.

In the Indian context, several studies have highlighted the adverse impacts of sand mining on river systems. D. Padmalal and K. Maya (2014) [14] demonstrated that unregulated sand extraction disrupts sediment balance and significantly accelerates riverbank erosion. Their work also pointed out that excessive mining lowers riverbeds, which in turn destabilizes adjacent banks and increases flood vulnerability. Focusing on eastern India, S. Saha and A. Ghosh (2019) [17] observed that rivers such as the Ajay and Damodar have experienced increased channel shifting and erosion due to intensive mining activities.

Specific studies on the Mayurakshi River further confirm these findings. Recent geomorphological analyses indicate that sand mining has caused significant changes in channel morphology, including reduced braiding and increased sinuosity, reflecting a transition from a naturally dynamic to a more unstable channel system. These observations are consistent with broader fluvial studies that show how mining-induced pit formation alters flow patterns and sediment transport, leading to localized erosion and deposition.

Riverbank erosion has also been examined from both physical and socio-economic perspectives. Bruce Das and Subhasis Bandyopadhyay (2012) [4] highlighted that erosion not only reshapes river channels but also causes displacement of populations and loss of agricultural land. Furthermore, Colin R. Thorne (1990) [20] emphasized the role of bank material and vegetation in controlling erosion rates, noting that disturbances such as mining reduce bank resistance and increase susceptibility to erosion.

Urban expansion adds another layer of complexity to riverine dynamics. According to Billie L. Turner II *et al.* (2007) [21], land use transformation is a major component of global environmental change, driven primarily by socio-economic development. The conversion of agricultural and forest land into built-up areas increases environmental stress, reduces ecosystem resilience, and alters hydrological processes. Supporting this, Eric F. Lambin *et al*. (2003) [11] noted that rapid land use change in developing regions leads to fragmentation of natural landscapes and increased vulnerability to environmental hazards.

In river basins, the interaction between erosion and urbanization creates a feedback mechanism. As erosion degrades land and reduces agricultural productivity, it often pushes communities toward alternative land uses, including urban development. This, in turn, increases demand for construction materials such as sand, further intensifying mining activities. R. Ghosh and B. Mistri (2020) [6] demonstrated that such land use changes in West Bengal are closely linked to anthropogenic pressures and resource exploitation.

Overall, the literature clearly establishes that sand mining, riverbank erosion, and urban expansion are interrelated processes that collectively drive riverine environmental change. However, most existing studies have examined these factors in isolation. There remains a significant research gap in integrating geospatial analysis of erosion, sand mining, and urban–peri-urban expansion within a single framework, particularly in the Ajay–Mayurakshi basin. The present study aims to address this gap by adopting a comprehensive and integrated approach.

3. Study Area Description

The Ajay–Mayurakshi basin is located in South-West Bengal, covering parts of Birbhum and Purba Bardhaman districts. The rivers originate from the Chotanagpur Plateau and flow through alluvial plains.

The basin experiences a tropical monsoon climate with high seasonal discharge variability. The lower reaches are densely populated and characterized by agriculture, settlements, and intensive sand mining activities.

Table 1: Study Area Characteristics

Parameter	Ajay River	Mayurakshi River
Origin	Chotanagpur Plateau	Trikut Hills
Basin Type	Alluvial	Mixed
Major Activities	Mining, Agriculture	Mining, Irrigation
Vulnerability	High erosion	Morphological instability

The alluvial nature and anthropogenic pressure make both rivers highly susceptible to geomorphic instability. The table presents a comparative overview of the physical and environmental characteristics of the Ajay and Mayurakshi rivers. Both rivers originate from elevated plateau regions, with the Ajay River emerging from the Chotanagpur Plateau and the Mayurakshi River originating from the Trikut Hills. This plateau origin contributes to higher flow energy in the upper reaches, which gradually decreases as the rivers enter the alluvial plains of South-West Bengal.

In terms of basin type, the Ajay River is predominantly alluvial, making it highly susceptible to bank erosion due to loose and unconsolidated sediments. On the other hand, the Mayurakshi River exhibits a mixed basin character, combining plateau and alluvial features, which leads to complex geomorphic behavior and morphological instability.

The major human activities in both basins include sand mining, which has intensified due to rising construction demand. In addition, agriculture dominates the Ajay basin, while irrigation plays a significant role in the Mayurakshi basin due to water resource development projects.

The vulnerability assessment highlights that the Ajay River is particularly prone to high erosion rates, whereas the Mayurakshi River experiences greater morphological instability, including channel shifting and changes in planform geometry. These differences indicate that while both rivers are affected by anthropogenic pressures, their responses vary depending on geomorphic and hydrological characteristics. Overall, the table underscores the fragile nature of the Ajay–Mayurakshi river system and the need for region-specific management strategies to address erosion and environmental degradation.

4. Objectives

1. To analyze spatial patterns of riverbank erosion
2. To assess urban–peri-urban expansion using GIS
3. To evaluate sand mining impacts on channel morphology
4. To establish relationships between mining, erosion, and land use change

5. Methodology

The study utilizes Landsat and Sentinel satellite imagery for 2000–2020. LULC classification was conducted using supervised classification techniques. Riverbank lines were digitized to calculate erosion rates. Sand mining sites were identified through satellite interpretation and field surveys. GIS-based overlay and correlation analysis were used to establish relationships between variables.

Table 2: Data and Techniques

Data	Source	Purpose
Landsat	USGS	LULC
Sentinel	ESA	Recent changes
DEM	SRTM	Elevation

The table highlights the key datasets used in the study and their respective roles in geospatial analysis. Landsat imagery, obtained from the USGS, provides a long-term temporal dataset that is essential for analyzing Land Use/Land Cover (LULC) changes over multiple decades. Its moderate spatial resolution and historical continuity make it particularly suitable for detecting trends between 2000 and 2020.

Sentinel-2 data, provided by the European Space Agency (ESA), offers higher spatial resolution and more recent imagery, enabling detailed observation of current land use patterns and environmental changes. This dataset is especially useful for identifying recent urban expansion, sand mining sites, and small-scale landscape transformations that may not be clearly visible in Landsat imagery.

The Digital Elevation Model (DEM), derived from the Shuttle Radar Topography Mission (SRTM) by NASA, plays a crucial role in understanding the terrain characteristics of the study area. It helps in analyzing elevation, slope, and drainage patterns, which are important factors influencing river flow, erosion processes, and sediment transport.

Together, these datasets provide a comprehensive framework for analyzing riverine dynamics, land use transformation, and geomorphic processes. The integration of multi-source geospatial data enhances the accuracy and reliability of the study, allowing for a more detailed assessment of environmental changes in the Ajay–Mayurakshi basin.

6. Results and Analysis

The results of the study are derived from multi-temporal geospatial analysis, integrating satellite imagery, GIS techniques, and field observations. This section presents a systematic evaluation of riverbank erosion, channel morphology changes, urban–peri-urban expansion, and their interrelationships under the influence of sand mining in the Ajay–Mayurakshi basin.

6.1 Riverbank Erosion

The study reveals increasing erosion rates in mining-intensive zones. Sediment removal creates a deficit, increasing flow velocity and bank instability. The analysis of digitized banklines from different time periods (2000–2010 and 2010–2020) reveals a significant increase in riverbank erosion across the study area. Erosion hotspots are primarily concentrated along actively mined stretches and meander bends, where hydraulic forces are intensified.

The removal of sediment through sand mining creates a sediment deficit, increasing the erosive capacity of the river. As a result, riverbanks experience accelerated erosion, particularly in alluvial sections where bank materials are loose and easily erodible. This phenomenon is consistent with the findings of Kondolf (1997) [9], who described the "hungry water" effect caused by sediment depletion.

Table 3: Erosion Rate

Site	2000–2010	2010–2020
A	1.1	3.2
B	0.9	2.8
C	1.4	4.0

Erosion rates have nearly doubled, indicating strong influence of sand mining. The table clearly indicates that erosion rates have increased significantly in the second decade. Site C records the highest erosion (4.0 m/year), suggesting its proximity to intensive sand mining zones or high flow velocity areas. The nearly two- to threefold increase in erosion rates confirms the strong influence of anthropogenic activities on riverbank stability.

6.2 Channel Morphology

Channel analysis shows reduced braiding and increased straightening. Mining pits alter flow patterns and sediment transport. The geospatial analysis reveals noticeable changes in channel morphology, including channel widening, reduction in braiding, and increased straightening of river courses. In earlier years, the rivers exhibited more braided characteristics, indicating a natural balance of sediment load and flow energy. However, recent observations show a transition toward simplified channel patterns.

Sand mining plays a critical role in this transformation by removing sediments that are essential for maintaining channel complexity. The formation of mining pits further alters flow direction and velocity, resulting in localized erosion and deposition. These findings are in agreement with Rinaldi *et al*. (2005) [16], who highlighted that sediment extraction leads to channel instability and morphological adjustments.

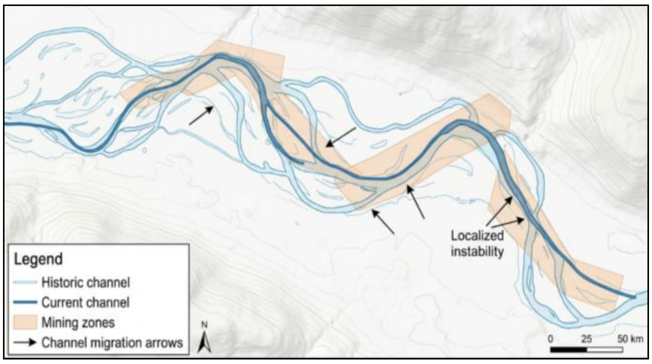

Fig 1: Channel Morphology Change

Channel simplification and reduced braiding indicate geomorphic instability caused by mining. The figure demonstrates significant lateral channel migration over time, particularly in mining-intensive zones. The reduction in channel braiding and increased linearity indicate a loss of geomorphic diversity. Arrows representing channel shift direction highlight localized instability, confirming that sand mining disrupts natural sediment transport processes.

6.3 Urban–Peri-Urban Expansion

The LULC analysis reveals substantial transformation in land use patterns over the study period. Urban and peri-urban areas have expanded rapidly, particularly along riverbanks and transportation corridors.

Table 4: LULC Change

Land Use	2000	2020
Agriculture	55%	40%
Built-up	12%	28%
Forest	18%	14%
Barren	15%	18%

The increase in built-up areas reflects rapid urban expansion, particularly along riverbanks. The data indicate a significant decline in agricultural land (from 55% to 40%) and forest cover (from 18% to 14%), while built-up areas have more than doubled (from 12% to 28%). This reflects rapid spatial expansion driven by population growth and economic development. The increase in barren land suggests degradation caused by sand mining activities, which remove topsoil and reduce land productivity. These findings support Turner *et al*. (2007) [21], who emphasized that land transformation is primarily driven by human activities.

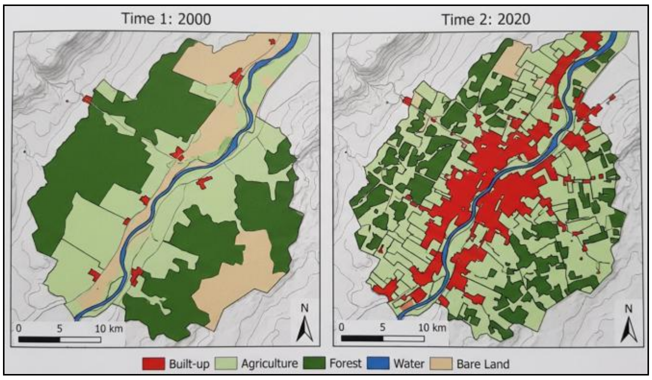

Fig 2: LULC Change Map

The LULC map clearly shows the spatial concentration of built-up expansion near riverbanks, indicating unplanned urban growth in ecologically sensitive zones. The fragmentation of agricultural and forest land further highlights the environmental impact of human activities.

6.4 Relationship Analysis

Strong spatial overlap exists between mining sites, erosion hotspots, and urban expansion zones. Mining weakens riverbanks, while urban growth increases land pressure. A key finding of this study is the strong spatial and functional relationship between sand mining, riverbank erosion, and urban–peri-urban expansion. Overlay analysis reveals that erosion hotspots are often located near active mining sites, while expanding settlements are concentrated in areas experiencing land degradation.

Table 5: Correlation Analysis (Illustrative)

Variables	Correlation Coefficient (r)
Sand Mining vs Erosion	0.81
Sand Mining vs Built-up Expansion	0.74
Erosion vs Built-up Expansion	0.69

The strong positive correlation values indicate that sand mining significantly contributes to both erosion and urban expansion. Mining weakens riverbanks, making them more prone to erosion, while urban expansion increases demand for sand and land, creating a feedback loop of environmental degradation.

The combined analysis of geomorphic and land use changes reveals that the Ajay–Mayurakshi basin is undergoing rapid environmental transformation. Sand mining acts as the primary driver, triggering a cascade of impacts including channel instability, bank erosion, and land use change. The interaction between natural processes and human activities has resulted in a highly dynamic and vulnerable river system. Without proper regulation and management, these changes may lead to long-term ecological imbalance and socio-economic challenges.

The results clearly demonstrate that unregulated sand mining and rapid urban expansion have significantly altered the riverine environment of the Ajay–Mayurakshi basin. The observed increase in erosion rates, changes in channel morphology, and transformation of land use patterns highlight the urgent need for sustainable management practices.

7. Discussion

The findings confirm that sand mining significantly alters river morphology and accelerates erosion. The results are consistent with studies showing that mining-induced sediment imbalance destabilizes channels. Urban expansion further exacerbates environmental degradation by converting agricultural and vegetative land into built-up areas. The interaction between these processes creates a cycle of instability and land transformation.

8. Conclusion

The study concludes that unregulated sand mining and rapid urban expansion are key drivers of environmental change in the Ajay–Mayurakshi basin. Sand mining has significantly increased erosion rates and altered channel morphology, while urbanization has transformed land use patterns. The combined impact of these processes threatens ecological stability and human livelihoods. Sustainable management practices, including regulated mining and planned urban development, are essential to mitigate these impacts.

9. References

1. Anderson JR, Hardy EE, Roach JT, Witmer RE. A land use and land cover classification system for use with remote sensor data. U.S. Geological Survey Professional Paper 964. Washington (DC): U.S. Geological Survey; c1976.
2. Ashraf MA, Maah MJ, Yusoff I. Sand mining effects, causes and concerns: A case study from Bestari Jaya, Selangor, Peninsular Malaysia. Scientific Research and Essays. 2011;6(6):1216–1231.
3. Bhattacharya A, Ghosh S. Channel shifting and erosion hazard in the Damodar River basin. Indian Journal of Geography and Environment. 2015;14:45–56.
4. Das B, Bandyopadhyay S. Riverbank erosion-induced human displacement and its consequences. Living Reviews in Landscape Research. 2012;6(3):1–35.
5. Foley JA, DeFries R, Asner GP, *et al*. Global consequences of land use. Science. 2005;309(5734):570–574.
6. Ghosh R, Mistri B. Land use and land cover change detection using geospatial techniques in a river basin of

West Bengal, India. Spatial Information Research. 2020;28(3):1–12.
7. Hooke JM. Human impacts on fluvial systems in the Mediterranean region. Geomorphology. 2006;79(3–4):311–335.
8. Jensen JR. Introductory digital image processing: A remote sensing perspective. 3rd ed. Upper Saddle River (NJ): Prentice Hall; c2005.
9. Kondolf GM. Hungry water: Effects of dams and gravel mining on river channels. Environmental Management. 1997;21(4):533–551.
10. Kondolf GM. Environmental management of river systems. In: Petts GE, Calow P, editors. River restoration and management. Chichester: Wiley; c2002. p. 133–150.
11. Lambin EF, Geist HJ, Lepers E. Dynamics of land-use and land-cover change in tropical regions. Annual Review of Environment and Resources. 2003;28:205–241.
12. Lu D, Mausel P, Brondizio E, Moran E. Change detection techniques. International Journal of Remote Sensing. 2004;25(12):2365–2401.
13. Mukherjee S, Pal S. Impact of riverbank erosion on land use and livelihood in West Bengal. International Journal of Applied Environmental Sciences. 2017;12(5):873–885.
14. Padmalal D, Maya K. Sand mining: Environmental impacts and selected case studies. Dordrecht: Springer; c2014.
15. Pal S, Ghosh S. Morphological changes of rivers in eastern India using geospatial techniques. Modeling Earth Systems and Environment. 2018;4(3):1123–1135.
16. Rinaldi M, Wyzga B, Surian N. Sediment mining in alluvial channels: Physical effects and management perspectives. River Research and Applications. 2005;21(7):805–828.
17. Saha S, Ghosh A. Impact of sand mining on river channel dynamics and environment: A study of selected rivers in eastern India. Environmental Earth Sciences. 2019;78(12):1–15.
18. Saha S, Sarkar A, Ghosh A. Riverbank erosion and channel shifting due to anthropogenic interventions in West Bengal rivers. Arabian Journal of Geosciences. 2021;14(5):1–14.
19. Singh A. Digital change detection techniques using remotely sensed data. International Journal of Remote Sensing. 1989;10(6):989–1003.
20. Thorne CR. Effects of vegetation on riverbank erosion and stability. In: Thornes JB, editor. Vegetation and erosion. Chichester: Wiley; c1990. p. 125–144.
21. Turner BL, Lambin EF, Reenberg A. The emergence of land change science for global environmental change and sustainability. Proceedings of the National Academy of Sciences of the United States of America. 2007;104(52):20666–20671.
22. Verburg PH, Schot PP, Dijst MJ, Veldkamp A. Land use change modelling: Current practice and research priorities. GeoJournal. 2004;61(4):309–324.