



RESEARCH ARTICLE

EVALUATING THE ENVIRONMENTAL CONSEQUENCES OF LAND USE AND LAND COVER CHANGES IN THE RAPIDLY GROWING INDUSTRIAL TOWN OF RANIGANJ, WEST BENGAL

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ABSTRACT

Land use and land cover (LULC) changes are critical indicators of environmental transformations driven by both natural and anthropogenic factors. This study examines LULC transitions in Raniganj, West Bengal, from 2000 to 2020, a region historically impacted by extensive coal mining and industrial expansion. Using remote sensing data from Landsat 5 TM (2000) and Landsat 8 OLI (2020), along with Geographic Information System (GIS)-based analysis, this research quantifies spatial and temporal changes in major land categories, including vegetation, agricultural land, built-up areas, water bodies, and opencast mining zones. The study reveals significant declines in vegetation (-6.349%) and increases in built-up areas (+5.039%) and mining activities (+1.082%), primarily driven by urbanization, industrialization, and resource extraction. A transition matrix analysis highlights the conversion of agricultural land to built-up areas and opencast mining, leading to environmental degradation and socio-economic shifts. Accuracy assessment using an error matrix and Kappa coefficient (0.62) confirms the reliability of classification results. The findings underscore the need for sustainable land management policies to mitigate the adverse effects of industrial expansion and ensure balanced development.

KEYWORDS

Land use and land cover change, remote sensing, Raniganj, industrialization, mining, urbanization

1. INTRODUCTION

Land is a fundamental natural resource that undergoes continuous transformation due to both natural and anthropogenic factors. Over the past few decades, global economic expansion and rapid population growth have significantly altered land use and land cover (LULC) patterns, reshaping ecosystems and landscapes (Debnath et al., 2022). The increasing urbanization and industrialization in many regions have intensified pressures on land resources, leading to widespread changes in land utilization and ecological balance. Land use refers to the various ways humans utilize land for economic, industrial, residential, and recreational purposes. Unlike land cover, which describes the physical characteristics of the Earth's surface, land use encompasses human-driven modifications that may not always be apparent from remote sensing observations (U.S. Environmental Protection Agency, 2022). In many cases, publicly and privately owned lands serve vastly different purposes public lands may be conserved for wilderness, while private lands are more often used for commercial or residential development. This dynamic interaction between land use and land cover is particularly evident in regions experiencing rapid economic development, such as mining and industrial towns.

1.1 Land Use and Land Cover Change: A Review

LULC transformation is a critical phenomenon that reflects the evolving relationship between human activities and the environment. Studies indicate that unregulated urban expansion, agricultural intensification, and industrialization have significantly altered land cover across the world (Khan et al., 2015). In India, the rapid expansion of built-up areas, often at the expense of forests and agricultural land, has been a consistent trend (Balamurugan, 2015). The application of Geographic Information

Systems (GIS) and remote sensing technologies has enhanced our ability to monitor these changes, providing valuable insights into their spatial and temporal dynamics (Nath et al., 2023). Several studies have explored the impact of industrialization on LULC in India's rapidly developing towns (e.g., Das et al., 2020). Research highlights the role of mining and urbanization in reducing vegetation cover, increasing built-up areas, and altering hydrological patterns. Despite the availability of such studies, there remains a need for localized, case-specific analyses that quantify land use transitions and assess their environmental and socio-economic impacts in industrial hubs such as Raniganj.

1.2 The Case of Raniganj: Research Gap and Justification

Raniganj, West Bengal, holds historical significance as the birthplace of coal mining in India, with the British East India Company initiating extraction in 1774. Situated in the Gondwana coalfields, this region has experienced extensive LULC changes over the decades. Prior to mining, Raniganj was covered by dense forests known as "Jungle Mahal" (Patra et al., 2022). However, continued coal extraction has led to significant environmental degradation, including deforestation, soil erosion, and biodiversity loss. The rapid expansion of mining and urban settlements has disrupted traditional land use patterns, necessitating a systematic analysis of these transitions. While previous studies have assessed the environmental effects of mining on a broad scale, there remains a lack of research focusing on the temporal progression and spatial extent of LULC changes in Raniganj. Most studies have either been qualitative or limited in their spatial analysis. A detailed examination of land use transitions, combined with an assessment of the underlying socio-economic and environmental drivers, is crucial for understanding the long-term sustainability of land resources in the region. Furthermore, limited research has quantified the relationship between industrial expansion and

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LULC change using transition matrices and GIS-based modeling approaches.

1.3 Objectives and Hypothesis

This study aims to bridge the existing research gap by providing a comprehensive analysis of LULC changes in Raniganj from 2000 to 2020. The objectives of this study are:

- To quantify the spatial extent and temporal progression of LULC changes in Raniganj over two decades.
- To identify the major drivers influencing these changes, particularly industrialization, urbanization, and population growth.
- To assess the environmental and social implications of LULC transitions, including habitat loss, land degradation, and displacement.
- To provide policy recommendations for sustainable land management and urban planning in industrial regions.

The study hypothesizes that the rate of LULC change in Raniganj is directly proportional to the intensity of industrial activities. By employing GIS-based analysis and transition matrices, this research seeks to provide empirical evidence supporting this hypothesis, offering insights for policymakers, urban planners, and environmental conservationists.

2. METHODOLOGY

2.1 Data Sources

To analyze land use and land cover (LULC) changes in Raniganj town from 2000 to 2020, satellite images were obtained from Landsat 5 TM (2000) and Landsat 8 OLI (2020) through the USGS Earth Explorer, with a spatial resolution of 30 meters. The images were acquired during the post-monsoon season (October–December) to minimize cloud cover and seasonal vegetation effects, and the projection system used was WGS 84, UTM Zone 45N.

2.2 Processing and Analysis

The pre-processing of satellite images involved several steps, including radiometric and atmospheric correction using FLAASH (Fast Line-of-Sight Atmospheric Analysis of Hypercubes) and Dark Object Subtraction (DOS) to remove distortions and haze. Geometric correction was performed by co-registering images with Ground Control Points (GCPs), ensuring an RMS error of less than 0.5 pixels. Additionally, cloud masking was applied using the CFMask algorithm to eliminate cloud and shadow pixels. The LULC classification followed a supervised classification approach using the Maximum Likelihood Classifier (MLC), with 200 training samples per class collected from ground truth data, Google Earth imagery, and historical maps. The study identified five major LULC classes: water bodies (lakes, ponds, rivers), vegetation (forests, plantations, grasslands), agricultural land (cultivated land, croplands), built-up areas (urban and rural settlements, roads), and opencast mining (active mines, overburden dumps). Accuracy assessment was conducted using an error matrix generated from 580 ground truth validation points collected from high-resolution Google Earth images and field surveys, with overall accuracy, producer's accuracy, user's accuracy, and the Kappa coefficient computed.

This methodological framework ensured a reliable analysis of LULC changes over the study period. To analyze temporal changes in land use and land cover (LULC) in Raniganj from 2000 to 2020, a post-classification comparison (PCC) technique was employed. Classified maps from 2000 and 2020 were compared pixel-by-pixel to identify transitions between different LULC categories. A change matrix was generated to quantify the gains, losses, and persistence of each land cover type, while a land cover transition matrix was computed to highlight conversion patterns, such as the transformation of agricultural land into built-up areas.

2.3 Study Area

Raniganj, located in the Paschim Bardhaman district of West Bengal, India, is known for its extensive coal reserves. It spans 1,530 km² across West Bengal and Jharkhand, positioned at 23.6291°N latitude and 87.0924°E longitude. The region features an undulating landscape with elevations ranging from 65 to 75 meters above sea level. It experiences a subhumid tropical climate, receiving an average annual rainfall of 995 mm and maintaining an average temperature of 25°C, with seasonal extremes reaching 40°C in summer and 10°C in winter. The area's soil has low nutrient levels, particularly along coal-rich zones. Major rivers such as the Ajay, Barakar, and Damodar flow through the region. Raniganj hosts two major coal seam groups: the Barakar formation, containing twelve seams, and the Raniganj formation, with eleven seams. The Raniganj seams are high in moisture and volatility, while the Barakar seams produce high-quality metallurgical coke with lower moisture content. Due to its superior quality, Raniganj coal remains in high demand. The coalfield supports a population of approximately 1.2 million, with mining serving as the primary economic driver, supplemented by manufacturing and agriculture. Geologically, the region is part of the Gondwana formation, composed of nearly 7 km thick lacustrine and fluvial deposits, dating back to the Proterozoic era. Mining in Raniganj dates back to 1774, with board-and-pillar, depillaring, and caving being the predominant extraction methods. The extent of subsidence depends on factors such as seam thickness, depth, and extraction width. Thinner overburden leads to greater surface subsidence, often resulting in fissures and mine fires. Depillaring, particularly in built-up areas, necessitates sand stowing to minimize ground collapse. However, due to financial constraints, small-scale underground and opencast mining operations have become prevalent. Underground mining has led to increased instances of land subsidence, particularly in urban areas such as Raniganj and Jamuria. According to the West Bengal Asansol Durgapur Development Authority (ADDA) and the Land Use and Development Control Plan (LUDCP), over 8.7 km² of land in the Asansol-Durgapur Subdivision is classified as unstable due to mining activities, with 5.73 km² in urban areas and 2.97 km² in rural zones. While certain restricted development zones remain unaffected, densely populated regions continue to face significant subsidence risks.

3. RESULTS

3.1 Land Use and Land Cover (LULC) Transitions (2000–2020)

The analysis of LULC transitions in Raniganj from 2000 to 2020 highlights significant landscape changes due to urbanization, industrialization, and mining activities. Table 1 presents a **land use transition matrix**, showing the percentage of each land category that transitioned into other forms over the two decades.

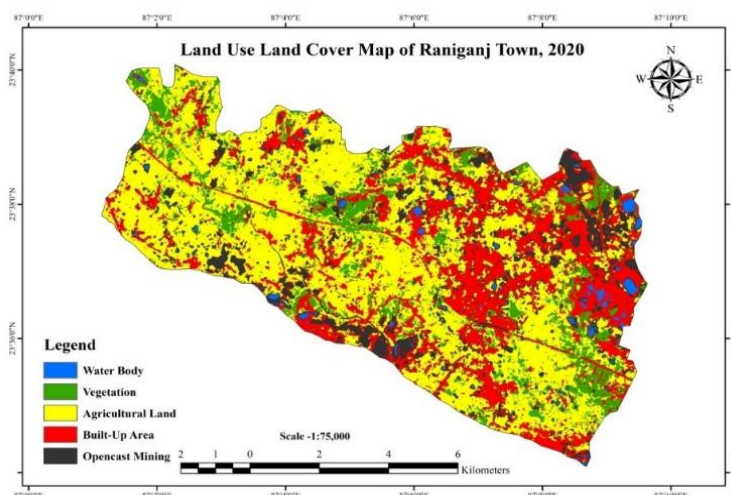


Figure 1

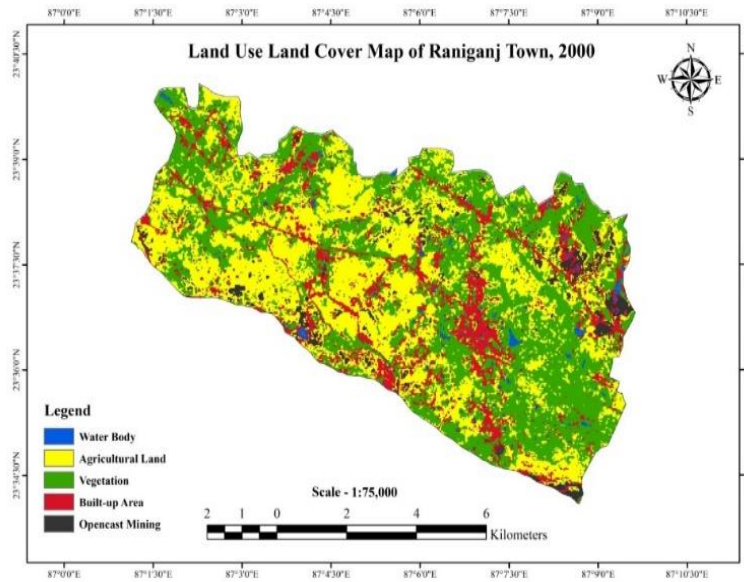


Figure 2

Table 1: Land Use and Land Cover Transition Matrix (2000–2020)						
From → To	Water Body	Vegetation	Agricultural Land	Built-up Area	Opencast Mining	Total (2000)
Water Body	0.003%	0.075%	0.076%	0.025%	0.006%	0.185%
Vegetation	0.066%	1.738%	6.036%	2.779%	0.716%	11.335%
Agricultural Land	0.270%	2.732%	74.280%	3.570%	2.241%	83.093%
Built-up Area	0.012%	0.264%	1.168%	1.107%	0.175%	2.726%
Opencast Mining	0.031%	0.177%	1.564%	0.284%	0.605%	2.661%
Total (2020)	0.382%	4.986%	83.124%	7.765%	3.743%	100%

(Values represent percentage change in total area)

Note: This table gives a complete picture of land use transformation in Raniganj from 2000 to 2020.

3.1.1 Key Observations from Table 1

Agricultural land remains dominant (83.124%), but a portion has been lost to built-up areas and mining. Vegetation cover decreased significantly (-6.349%), primarily due to urban expansion and agricultural encroachment. Built-up areas expanded significantly

(+5.039%), reflecting rapid urbanization and infrastructure development. Opencast mining increased (+1.082%), replacing former agricultural and vegetated land. Water bodies saw a minor increase (+0.197%), possibly due to conservation measures or artificial reservoirs created by mining activities. (See Table 1 and Figure 1 & 2)

Table 2: Comparison of Land Use and Land Cover Changes (2000–2020)				
Land Use Category	Area in 2000 (%)	Area in 2020 (%)	Change (%)	Observation
Water Body	0.185%	0.382%	+0.197%	Slight increase, possibly due to better water conservation or flooding.
Vegetation	11.335%	4.986%	-6.349%	Significant decline, likely due to urbanization and agricultural expansion.
Agricultural Land	83.093%	83.124%	+0.031%	Minimal change, but some areas converted to built-up and mining land.
Built-up Area	2.726%	7.765%	+5.039%	Rapid urbanization leading to increased settlements and infrastructure.
Opencast Mining	2.661%	3.743%	+1.082%	Expansion of mining activities, reducing vegetation and agricultural land.
Water Body	0.185%	0.382%	+0.197%	Slight increase, possibly due to better water conservation or flooding.

3.1.2 Key Insights from Table 2

Vegetation loss (-6.349%) is the most significant change, largely due to agricultural and urban expansion. Built-up areas have nearly tripled (+5.039%), indicating rapid urbanization and infrastructure growth.

Mining activities have increased (+1.082%), converting former agricultural land into industrial zones. Water bodies expanded slightly (+0.197%), which may be due to mining-induced artificial ponds or conservation efforts.

Table 3: Accuracy Assessment Table							
Classes	Water Body	Vegetation	Agricultural Land	Built-up Area	Opencast Mining	Total	User Accuracy (%)
Water Body	4	1	0	0	0	5	80.0
Vegetation	1	50	20	8	3	82	60.98
Agricultural Land	2	12	420	15	6	455	92.31
Built-up Area	0	4	10	28	1	43	65.12
Opencast Mining	0	1	5	2	7	15	46.67
Total	7	68	435	53	17	580	-

Accuracy Metrics						
Metric	Water Body	Vegetation	Agricultural Land	Built-up Area	Opencast Mining	Overall Accuracy
Producer's Accuracy (%)	57.14	73.53	96.55	52.83	41.18	85.6%

Kappa Coefficient: 0.62

3.1.3 Accuracy Assessment Summary

Table 3 evaluates the accuracy of LULC classification using **User's Accuracy**, **Producer's Accuracy**, **Overall Accuracy**, and **Kappa Coefficient**. **Agricultural Land** shows the highest classification accuracy with **92.31% User Accuracy** and **96.55% Producer Accuracy**, indicating reliable identification. **Vegetation** and **Built-up Areas** have moderate

accuracy, while **Opencast Mining** exhibits the lowest accuracy (**User: 46.67%**, **Producer: 41.18%**), suggesting misclassification. The **overall accuracy is 85.6%**, with a **Kappa coefficient of 0.62**, indicating a substantial agreement between classified and reference data.

3.2 Temporal Trends in LULC Changes

Table 4: LULC Changes in Raniganj (2000–2020)	
LULC Class	Change (%) (2000–2020)
Vegetation	-6.35%
Agricultural Land	+0.03%
Built-up Areas	+5.03%
Opencast Mining	+1.08%
Water Bodies	+0.20%

Note: This table summarizes the overall LULC changes from 2000 to 2020, highlighting major transformations such as vegetation decline, urban expansion, and mining growth in Raniganj.

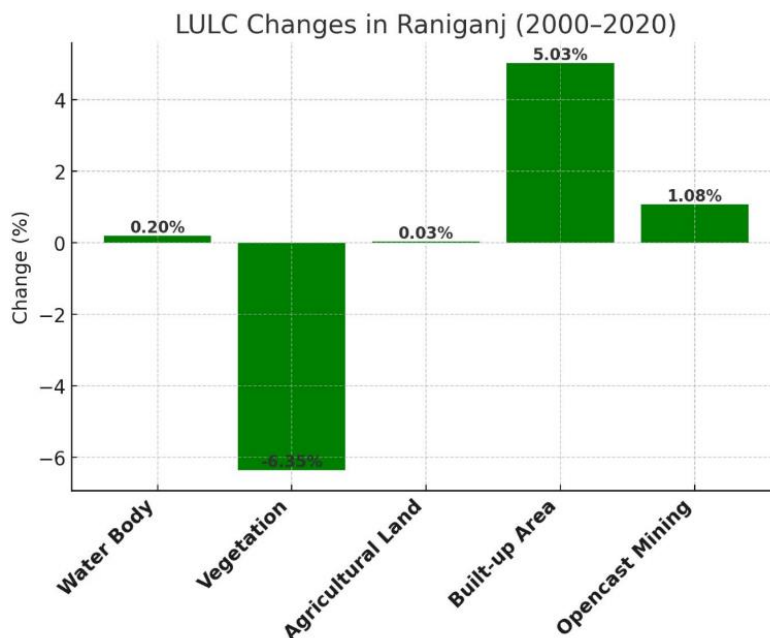


Figure 3: Net Change Of Lulc From 2000 To 2020 In Percentage

3.3 LULC Changes from 2000 to 2020

The analysis of land use and land cover (LULC) changes in Raniganj from 2000 to 2020 reveals significant transformations. Over this period, vegetation cover declined by a total of **-6.35%**, indicating continuous deforestation, though the rate of loss slowed in the latter decade. Built-up areas expanded consistently, with an overall increase of **+5.03%**, reflecting rapid urbanization. Opencast mining showed steady growth,

contributing to a **+1.08%** increase, likely due to ongoing coal extraction activities. Water bodies experienced a slight but continuous increase of **+0.20%**, while agricultural land demonstrated a marginal net gain of **+0.03%**, suggesting some level of reclamation or conversion dynamics. The overall trend highlights urban expansion, vegetation loss, and mining-induced land transformation as dominant processes shaping the landscape of Raniganj over the two decades. (See Table 4 & Fig 3)

3.4 Spatial Analysis of LULC Changes

3.4.1 A spatial assessment of LULC changes identifies key transformation hotspots:

Urban Growth Areas: Rapid expansion of **Raniganj, Kajora, Amritnagar, and Ballampur** into former agricultural zones.

Mining Expansion Zones: Significant land conversion in **Sonepur-Bazari, Jhanjra, and Mangalpur**, causing vegetation and agricultural losses.

Deforestation Zones: Major reductions in **vegetation cover in southern and western Raniganj**, driven by land clearance for urbanization.

3.5 Environmental and Socio-Economic Implications

3.5.1 Environmental Consequences

Loss of biodiversity and green cover, reducing ecosystem stability. **Increased land degradation** due to mining, leading to soil erosion and groundwater depletion. **Changes in water availability**, with mining affecting groundwater levels while artificial reservoirs provide new water sources.

3.5.2 Socio-Economic Impacts

Urban expansion has led to infrastructural stress, with increased housing and transportation demands. **Mining expansion has created employment but also displaced communities**, necessitating better land rehabilitation policies. **Decline in vegetation affects local livelihoods**, particularly those reliant on agriculture and forest-based resources.

4. DISCUSSION

The findings of this study align with previous research on land use and land cover (LULC) changes in industrial and mining regions, particularly in India. The observed increase in built-up areas and mining zones, along with the decline in vegetation and agricultural land in Raniganj, corresponds with trends reported in similar studies. For instance, some researcher highlighted the rapid expansion of coal mining activities in the Raniganj Coalfield and its impact on deforestation and land degradation (Maiti and Agarwal, 2005). Likewise, a group researcher found a significant reduction in forest cover and cropland in coal mining areas of Jharkhand, reinforcing the broader pattern of environmental changes caused by extractive industries (Singh et al., 2018). The decline in vegetation and agricultural land observed in this study is also consistent with the findings of who documented substantial LULC changes due to urbanization and industrialization in various parts of India (Rawat and Kumar, 2015). The increasing built-up area in Raniganj follows similar trends reported by some researchers in mining regions, where unplanned urban growth was a direct consequence of industrial expansion (Mondal et al., 2020). Moreover, some researcher emphasized that coal mining significantly contributes to landscape alteration, soil degradation, and biodiversity loss, all of which are evident in our study's findings (Mandal and Banerjee, 2021). Furthermore, the implications of LULC changes on environmental sustainability have been widely discussed in earlier studies. In a study, researcher reported that unregulated mining and urban sprawl lead to severe land degradation, water pollution, and socio-economic challenges (Sahu and Dash, 2011). Our results reinforce these conclusions by demonstrating a clear reduction in vegetative cover and increased land disturbance in mining and industrial areas. Additionally, the transformation of land use patterns observed in Raniganj is in agreement with global studies, such as those by who emphasized the role of human activities in altering landscapes through industrial and infrastructural developments (Lambin et al., 2001). While the results are consistent with previous research, this study further contributes to the literature by utilizing recent remote sensing data (2000–2020) to assess long-term trends in LULC changes in Raniganj. The integration of GIS and satellite imagery offers a more detailed and updated analysis, reinforcing past studies while providing new insights into current land transformation patterns. The study also underscores the urgent need for sustainable land management strategies, echoing the recommendations of who stressed the importance of policy interventions in mitigating the environmental consequences of mining activities (Gupta and Sarangi, 2022). Overall, our findings confirm that rapid industrial expansion, urbanization, and mining activities are key drivers of LULC changes, leading to significant environmental and socio-economic consequences. These results highlight the need for further research into sustainable land-use policies, reclamation initiatives, and afforestation programs to counteract the adverse effects of such transformations. Future studies should focus on integrating advanced machine learning techniques and high-resolution satellite imagery to improve classification accuracy and

monitor long-term LULC dynamics in greater detail.

5. CONCLUSION

This study highlights the significant land use and land cover (LULC) changes in Raniganj, West Bengal, over the past two decades (2000–2020), driven primarily by industrialization, urban expansion, and coal mining activities. The analysis reveals a notable decline in vegetation and agricultural land, coupled with an increase in built-up areas and mining zones. These shifts indicate the growing impact of human activities on the region's landscape, leading to environmental degradation, loss of biodiversity, and socio-economic transformations. The findings underscore the urgent need for sustainable land management strategies to balance economic development with ecological conservation. Policymakers and stakeholders should implement measures such as afforestation programs, land reclamation initiatives, and stricter environmental regulations to mitigate the adverse effects of rapid land transformation. Future research should incorporate high-resolution satellite imagery and advanced machine learning techniques to improve classification accuracy and monitor long-term LULC dynamics more effectively. By adopting a sustainable approach, it is possible to ensure that industrial progress does not come at the cost of environmental sustainability and community well-being.

RECOMMENDATIONS FOR SUSTAINABLE LAND MANAGEMENT

- **Afforestation and Reforestation Initiatives:** To counteract vegetation loss and soil erosion.
- **Sustainable Urban Planning:** Policies to manage urban sprawl and protect agricultural zones.
- **Mine Rehabilitation Strategies:** Mandating ecological restoration and soil remediation.
- **Periodic LULC Monitoring:** Conduct assessments every 5 years to track land use trends.

FUTURE RESEARCH DIRECTIONS

- Evaluating **socio-economic impacts of LULC changes** on livelihoods and migration.
- Modeling **future LULC scenarios** to predict environmental impacts.
- Examining **land governance and policy interventions** to enhance sustainable land use planning.

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DECLARATIONS

Statements and Declarations: We confirm that each of the mentioned authors has read and approved the work, and that no other individuals have met the requirements to be included as authors. We also certify that we have all approved the author order as stated in the manuscript.

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REFERENCES

- Balamurugan, G., 2015. Urban growth effects for land use changes leading to natural hazards in parts of Mumbai metro city, India. *Disaster Advances*, Pp. 8.
- Banerjee, D., 2014. Acid drainage potential from coal mine wastes: Environmental assessment through static and kinetic tests, 11 (5), Pp. 1365–1378.
- Debnath, J., Sahariah, D., Lahon, D., Nath, N., Chand, K., Meraj, G., Farooq, M., Kumar, P., Kanga, S., and Singh, S.K., 2022. Geospatial modeling to assess the past and future land use-land cover changes in the Brahmaputra Valley, NE India, for sustainable land resource management. *Environmental Science and Pollution Research*, 30

- (49), Pp. 106997–107020. <https://doi.org/10.1007/s11356-022-24248-2>
- Dhar, S.B., and Dutta, M., 2020. Changing Land use Pattern in the Raniganj Coal Belt and Its Sustainable Management: A Case Study of Mangalpur Opencast Colliery. *Current World Environment, Special Issue (1)*. <https://doi.org/10.12944/CWE.15.Special-Issue1.05>
- Ghosh, S., 2002. The Raniganj Coal Basin: An example of an Indian Gondwana rift. 147 (1–2), Pp. 155–176.
- Karmakar. H.N., and Das, P.K., 2012. Impact of mining on ground and surface water. International mine water association. https://www.imwa.info/docs/imwa_1991/IMWA1991_Karmakar_187.pdf.
- Khan, E., Firdaus, F., Hussain, N., and Ali, M., 2015. Agricultural Land Transformation: A Case Study on Rajbari Pourashava, Rajabari. *Social Sciences*.
- Mishra, N., and Das, N., 2020. Coal mining and local environment: A study in talcher coalfield of India. 10 (1). <https://doi.org/10.1177/1178622117728913>.
- Mondal, R., and Mistri, B., 2022. Changing Pattern of Land Use Land Cover Due to Sonapur–Bazari Open Cast Coal Mine and Its Impact on Surrounding Area, West Bengal, India. *Journal of the Indian Society of Remote Sensing*, 50 (9), Pp. 1651–1665. <https://doi.org/10.1007/s12524-022-01559-y>
- Mondol, S., Chakravarty, D., Bandyopadhyay, J., Maiti, K.K., 2016. Identification of land subsidence and management Using Cadastral Techniques, Mining Area of Raniganj, Barddhaman District, India. 6 (2), Pp. 52–62.
- Nath, N., Sahariah, D., Meraj, G., Debnath, J., Kumar, P., Lahon, D., Chand, K., Farooq, M., Chandan, P., Singh, S.K., and Kanga, S., 2023. Land Use and Land Cover Change Monitoring and Prediction of a UNESCO World Heritage Site: Kaziranga Eco-Sensitive Zone Using Cellular Automata-Markov Model. *Land*, 12 (1), Pp. 151. <https://doi.org/10.3390/land12010151>
- Patra, T., Dutta, D., Kundu, A., Kumar, M., Hossain, S.S., and Chattoraj, K.K., 2022. Evolution of Opencast Mines in the Raniganj Coalfield (India): An Assessment through Multi-temporal Satellite Data. *Journal of the Geological Society of India*, 98 (3), Pp. 387–394. <https://doi.org/10.1007/s12594-022-1990-5>
- Prokop, P., 2020. Remote sensing of severely degraded land: Detection of long-term land-use changes using high-resolution satellite images on the Meghalaya Plateau, northeast India. 20. <https://doi.org/10.1016/j.rsase.2020.100432>
- Sarkar, A., 2019. A Geoinformatics Approach to Assess Land Use Dynamic and Landscape Fragmentation Due to Opencast Coal Mining in Raniganj Coalfield, India. *International Journal of Research in Advent Technology*, 7 (1), Pp. 307–325. <https://doi.org/10.32622/ijrat.71201910>
- Singh, R.P., Yadav, R.N., 1995. Prediction of subsidence due to coal mining in Raniganj coalfield, West Bengal, India. 39 (1–2), Pp. 103–111.
- Singh, R.P., Yadav, R.N., 1995a. Subsidence due to coal mining in India Series of Proceedings and Reports. 234, Pp. 207–214.
- U.S. Environmental Protection Agency (last). 2022. EPA's Report on the Environment (ROE) (Land in the ROE). <https://www.epa.gov/report-environment/land-use>

