"Geospatial Insights: A Review of GIS Applications in Assessing Environmental Impacts of Coal Mining in East Jaintia Hills, Meghalaya"

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Abstract: The district of East Jaintia Hills of Meghalaya, India, is abundant in coal deposits, and coal mining plays a significant role in the region's economy. However, unregulated mining practices have led to intense environmental destruction, including deforestation, water pollution, soil erosion, and loss of biodiversity. Geographic Information System (GIS) technology has proven its worth significantly in environmental management by providing spatial data analysis and decision-making support for the assessment and mitigation of these impacts. This paper reviews the role of GIS in assessing the environmental impacts of coal mining in East Jaintia Hills, focusing on the identification, monitoring, and management of the environmental consequences of mining activities. Using case studies, the paper reassesses to illustrate the implementation of the application of GIS in mapping land cover changes, monitoring air and water quality, and modeling potential future impacts. Furthermore, it emphasizes the importance of integrating GIS with other environmental management tools to develop sustainable mining practices that reconcile economic advancement with environmental responsibility.

Keywords: Geographic Information System, Environmental Impact Assessment, Coal Mining, East Jaintia Hills, Meghalaya, Land Use Change, Water Pollution, Soil Erosion, Sustainable Development.

1. Introduction

East Jaintia Hills, located in the northeastern state of Meghalaya, India, is known for its abundant coal reserves, primarily mined through unscientific and illegal methods. The extensive mining activities, though economically beneficial, have triggered critical environmental difficulties. These include soil degradation, water contamination, deforestation, and a loss of biodiversity, all of which pose a significant threat to the region's ecological balance and the health of local communities. The absence of effective management plans and the shortfall in proper regulatory measures has exacerbated these issues.

To mitigate these challenges, Geographic Information Systems (GIS) have gained recognition as a powerful tool for assessing, monitoring, and mitigating the environmental impacts of coal mining. GIS enables the visualization, analysis, and interpretation of spatial data to provide insights into how mining activities affect the landscape and environment. This paper reviews and discusses the deployment of GIS application in

environmental impact assessment (EIA) in East Jaintia Hills, focusing on the mapping of environmental degradation, tracking changes in land use, and reinforcing environmentally responsible mining.

The investigation of environmental implications caused by coal mining is a critical aspect of sustainable resource management, especially in ecologically sensitive regions such as the East Jaintia Hills district of Meghalaya, India. Geographic Information Systems (GIS) have emerged as a powerful tool for evaluating these impacts, offering a spatially explicit approach to understanding the distribution and intensity of environmental degradation. In the case of East Jaintia Hills, where unregulated coal mining activities have led to significant ecological disturbances, GIS provides an invaluable platform to assess and monitor the multifaceted impacts on land use, water quality, vegetation, and biodiversity. This research delves into the use of GIS and investigates its application in evaluating these environmental impacts, focusing on its application in the region, the methodologies used, and its potential to inform policy and management strategies for more sustainable mining practices.

2. **Research Objectives**

For an overview paper on GIS applications in Assessment of Environmental Impact on Coal Mining Sites in East Jaintia Hills District of Meghalaya, outlined here are some proposed research aims and objectives:

Aim: To critically review the applications of Geographic Information System (GIS) in assessing the environmental impacts of coal mining in the East Jaintia Hills district of Meghalaya, focusing on land degradation, water quality, biodiversity, and health outcomes.

Objectives:

1. To analyze the role of GIS in mapping and monitoring environmental changes in coal mining regions of East Jaintia Hills, with an emphasis on land use/land cover changes and deforestation.

2. To review the integration of GIS with other environmental assessment tools (such as remote sensing and environmental modeling) for effective monitoring and management of coal mining impacts in the region.

3. To assess the use of GIS in evaluating water quality and the impacts on local water bodies, such as rivers and streams, due to coal mining activities in East Jaintia Hills.

4. To examine the application of GIS in understanding the socio-economic impacts of coal mining, including effects on local communities, health, and biodiversity in the region.

5. To review the challenges and limitations of using GIS for environmental impact assessments in coal mining regions of Meghalaya, including data availability, technological constraints, and local environmental conditions.

6. To identify key GIS-based tools and methodologies that have been successful in mitigating environmental risks associated with coal mining and propose future directions for improving GIS applications in this domain.

7. To provide a comparative analysis of GIS applications in coal mining impact assessments in other regions and how these methods can be adapted or improved for the East Jaintia Hills context.

These aims and objectives will provide a structured approach to evaluating existing research, identifying gaps, and offering insights into how GIS can be used more effectively to address the environmental challenges posed by coal mining in this specific region of Meghalaya.

3. Methodology

This review paper primarily relies predominantly on pre-existing datasets to evaluate the role of Geographic Information Systems (GIS) in assessing the environmental impact of coal mining activities in the district. The methodological framework applied in this research is highlighted below:

Data Collection:

This paper is structured around a comprehensive review of secondary data sourced from various published research articles, reports, theses, government publications, and environmental impact assessments (EIAs) concerning the coal mining activities in East Jaintia Hills.

Data were sourced from peer-reviewed journals, books, government documents, and online databases like Google Scholar, Scopus, and other academic sources. Special attention was given to studies where GIS technology was applied to assess environmental impacts, particularly in coal mining regions.

Assessment of Relevant Publications:

Criteria for inclusion in this review included studies that specifically focused on the application of GIS in environmental impact assessments (EIA) in coal mining areas, with a particular emphasis on the East Jaintia Hills district.

Studies that addressed various environmental aspects such as land degradation, deforestation, water contamination, air pollution, and biodiversity loss due to mining operations were prioritized.

Only studies published within the last 15-20 years were considered to ensure relevance and the inclusion of recent advancements in GIS technology.

Data Analysis:

The collected secondary data was systematically analyzed to identify the role of GIS in the assessment of environmental impacts, with a specific focus on its application to the East Jaintia Hills.

Essential GIS applications, such as spatial data analysis, environmental monitoring, land use change mapping, and hazard prediction, were examined across the selected studies.

The effectiveness of GIS as a tool for identifying, quantifying, and mitigating environmental degradation in the context of coal mining was critically analyzed.

4. Synthesis of Findings

Highlighted findings here include those that have been supported by previous findings and are incorporated in this review paper.

Land Use and Land Cover (LULC) Changes: A study by Syiemlieh et al. (2019) employed GIS and remote sensing to assess land-use changes in the East Jaintia Hills region due to coal mining activities. They found significant deforestation and land degradation, leading to a decrease in agricultural land and forest cover, which affected local biodiversity. The study emphasized the need for GIS-based monitoring to track these changes and plan for sustainable land management.

Impact on Water Quality: According to a study by Roy et al. (2018), GIS applications have been widely used to evaluate the degradation of water quality in the mining-affected areas of Meghalaya. Their findings

revealed elevated levels of heavy metals, including iron and manganese, in streams and rivers due to coal mining runoff. GIS was used to analyze the spatial distribution of these contaminants and highlight areas of high environmental risk, particularly for local communities relying on surface water. The Central Pollution Control Board (2019) reported that unscientific coal mining practices, particularly 'rat-hole' mining, have resulted in severe water quality degradation in the region. The study documented acid mine drainage leading to highly acidic water in rivers and streams, with pH levels as low as 2.2, rendering the water unfit for human and animal consumption. This underscores the critical need for implementing pollution control measures and continuous water quality monitoring.

Table 1.0 Water Quality Data of Rivers in East Jaintia Hills

Name of Rivers	Location	District	Years	pH		
				Ave	Min	Max
Lukha River	Sunapur	East Jaintia Hills	**2014**	6.63	4.40	7.60
			2015	6.7	4.8	7.3
			2016	7.2	6.4	8.1
			2017	7.2	6.7	7.6
			2018	7.1	7.2	7.4
Lunar River	Myndihati	East Jaintia Hills	**2014**	6.67	2.20	3.00
			2015	2.6	2.2	3.00
			2016	2.8	2.7	3.0
			2017	3.0	2.8	4.4
			2018	3.0	2.8	2.7
Kyrhukhla River	Khliehriat	East Jaintia Hills	**2014**	2.93	2,40	3.50
			2015	3.2	2.8	3.6
			2016	3.0	2.8	3.3
			2017	3.2	2.78	3.7
			2018	3.1	3.0	3.1

Soil Erosion and Sediment Transport: A study by Lyngdoh et al. (2017) integrated GIS with erosion models to assess soil erosion in the coal mining regions of East Jaintia Hills. Their research suggested that coal mining activities, especially those involving unregulated mining practices, contributed significantly to soil erosion and sediment transport, which in turn led to siltation of nearby rivers and streams. GIS analysis helped pinpoint vulnerable areas prone to soil erosion.

Air Quality Monitoring: A study by Baidya and Dey (2020) used GIS to map air quality changes in regions impacted by coal mining in Meghalaya. By combining satellite imagery and ground-level air quality data, they identified hotspots with elevated concentrations of particulate matter (PM) and other pollutants. This spatial analysis helped visualize the areas most affected by coal dust and emissions, providing valuable insights for pollution management and policy-making.

Biodiversity Loss and Habitat Fragmentation: According to a study by Tiwari et al. (2021), GIS was used to assess the impacts of coal mining on biodiversity in Meghalaya's forests. Their research revealed that mining activities were responsible for habitat fragmentation, disrupting migration corridors for wildlife. GIS-based habitat modeling identified areas of high biodiversity that were under threat from mining, providing a tool for conservation planning. Moreover, regarding the Impact on Vegetation and Biodiversity, in a study focusing on the impact of coal mining on plant diversity and tree population structure, Sarma et al. (2010) found that mining activities led to a reduction in tree species diversity near mining sites. Conversely, these areas exhibited a higher number of herbaceous species compared to unmined regions. The research emphasized the necessity of understanding mining's effects on vegetation to develop effective conservation strategies.

Health outcomes in local populations: A study by Kumar et al. (2019) employed GIS to investigate the health impacts of coal mining on local populations in Meghalaya. They linked spatial data on mining sites with health records, finding correlations between proximity to mining operations and respiratory illnesses, particularly among children and elderly residents. The study used GIS to identify high-risk areas and suggested more targeted public health interventions.

Land Restoration and Mine site rehabilitation: In a study by Baruah et al. (2016), GIS was utilized to monitor the effectiveness of land reclamation efforts in post-mining landscapes. The research demonstrated that GIS could track vegetation regrowth and soil stability over time, providing crucial information for assessing the success of restoration projects in East Jaintia Hills.

Environmental equity and risk Mapping: A study by Dey and Saikia (2022) explored the use of GIS in assessing environmental justice issues in the coal mining areas of Meghalaya. Their research used GIS to map the social vulnerability of communities, identifying those most affected by environmental degradation caused by mining. Vulnerability assessments were coupled with spatial data on pollution and mining activities to understand the disproportionate impacts on marginalized groups.

Disaster Risk Geospatial Monitoring: The North Eastern Space Applications Centre (NESAC) has conducted studies employing remote sensing data and GIS to map coal mines and assess their environmental impacts in Meghalaya. Their research identified over 24,000 coal mines in the Jaintia Hills districts, highlighting the extensive landscape disturbances caused by mining activities. NESAC's work demonstrates the utility of geospatial technologies in environmental monitoring and management.

Environmental Metal Toxicity Analysis: NESAC has also undertaken projects to create geospatial databases and study heavy metal contamination in coal mining areas of the Jaintia Hills. These studies aim to assess the degree of heavy metal contamination and its environmental impacts, providing essential data for remediation efforts and policy formulation.

Collectively, these studies underscore the significant environmental challenges posed by coal mining in the East Jaintia Hills. They also highlight the critical role of GIS and remote sensing technologies in assessing and mitigating these impacts.

These findings illustrate the diverse applications of GIS in understanding the environmental and socio-economic impacts of coal mining, with specific relevance to East Jaintia Hills in Meghalaya. Integrating GIS with other environmental data allows for comprehensive assessments that are essential for developing mitigation strategies and sustainable management practices.

5. Literature Review Gaps and Prospective Research Paths

In addition to reviewing the current literature, the paper also identifies gaps in existing research, particularly areas where GIS has not been fully utilized for environmental impact assessment in the East Jaintia Hills.

Future research directions are suggested to enhance the integration of GIS technology in environmental management, policy-making, and sustainable mining practices in the region.

6. Limitations

The review is based on existing secondary data and may be subject to biases inherent in the selected studies. The availability and accessibility of data, especially for localized studies in remote regions like East Jaintia Hills, were also limitations.

The lack of primary data collection from fieldwork in this review means that the conclusions drawn are based on existing research and may not capture the most up-to-date field-level changes.

By synthesizing the findings from multiple secondary sources, this review paper provides an in-depth understanding of how GIS can aid in environmental impact assessment and sustainable management in coal mining areas, specifically in the East Jaintia Hills district of Meghalaya.

7. Conclusion

The application of Geographic Information Systems (GIS) in environmental impact assessments of coal mining in East Jaintia Hills has proven to be a valuable tool in understanding and mitigating the adverse effects of mining on the environment. GIS facilitates the analysis of spatial data to track land use changes, monitor water and soil quality, and predict future environmental outcomes, thus providing a scientific basis

for sustainable management practices. As coal mining remains a major economic activity in the region, the integration of GIS with regulatory frameworks and community engagement is essential for ensuring that the benefits of mining are balanced with environmental protection and social well-being.

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