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ECONOMIC AND SOCIAL IMPACTS OF INCOMPLETE REHABILITATION ON COMMUNITIES DISPLACED BY OPENCAST COAL MINING: A CASE STUDY OF RAJMAHAL COAL MINING PROJECT (LALMATIA), JHARKHAND

Ram Sunder Das
Degree College, Mahagama

Abstract

The case study is focused on the economic and social effects of incomplete rehabilitation to communities who have been displaced by the Rajmahal Opencast Coal Mining Project in Lalmatia, Jharkhand. The analysis of land use and land cover in 10 years showed that the amount of forest and cultivated lands was lost with the growth of barren and developed territories, which points toward the continuation of environmental degradation and insufficiency of restoration. Economic evaluation of the displaced families revealed that there was a lot of financial loss because of inadequate compensation on loss of land and property. The capacity to access housing, healthcare, education, and jobs was identified as limited, and stresses associated with migration were higher than they were before, which proved that social rehabilitation is the practice that has been overlooked. A joint examination that combined economic and social aspects showed that families that suffered the most with respect to loss of finances also developed increased social vulnerability, prioritizing the multiplied impact of incomplete rehabilitation. The paper highlights the importance of holistic rehabilitation measures that can focus on economic, social, and environmental issues to provide sustainable and fair results to displaced populations.

Keywords: Coal Mining, Displacement, Rehabilitation, Economic Impact, Social Vulnerability And Land Use Change.

1.Introduction

Mining has historically played a pivotal role in shaping India's industrial development, but it has also contributed significantly to ecological imbalance and socio-economic challenges. Research indicates that coal-based industries remain central to India's energy economy while simultaneously driving environmental degradation and resource depletion (Singh et al., 2024). The latest advances in carbon materials, including coal-based graphene oxide-like materials, offer new prospects for sustainable utilizations and pollution abatement (Singh, Haskin, & Dastgheib, 2023). Equally, attaining land degradation neutrality has become a matter of national urgency, and all-round ecological restoration approaches are needed (Singh et al., 2023).

Coal mine-induced heavy metal pollution has added further to environmental hazards, with microbial technology being investigated for effluent detoxification (Singh & Mishra, 2021).

Sustainable mine closure planning thus has become the need for long-term development (Srikanth & Nathan, 2020). Current research on flue gas desulfurization (FGD) of thermal power plants addresses economic and climate consequences of pollution-control technology (Srikanth, Krishnan, & James, 2024).

Ecological restoration through the use of fly ash and selective plantation offers pragmatic reclamation pathways (Srivastava, Ram, & Masto, 2014). On the policy front, industries reliant on fossil fuels frequently impede implementation of more stringent climate regulations (Stevens, 2019). Yet, evidence shows that restoration of vegetation improves soil enzyme activity, hence the recovery of soil health in mining areas (Sun et al., 2021). Grassroots movements have also used community rights frameworks to oppose unsustainable coal mining in central India (Talukdar & Pillai, 2022).

Industrial energy intensity, especially for iron and steel, is determined by imported intermediates, necessitating the need for sustainable production models (Tandon, 2024). Parallel changes in legal regimes like the Forest (Conservation) Amendment Act have reshaped forest management in India (Thakur, 2023). Time-series analyses of land degradation highlight the imperative for restoration interventions in coal mines (Thakur et al., 2022). Broader evaluations of land use processes in mining regions reaffirm increasing vulnerability and the need for eco restoration plans (Thakur et al., 2024).

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At the international level, reclamation methods in mining areas are as diverse as evidence from recent Indonesian empirical research demonstrates (Tirkaamiana & Azham, 2024). Underpinning principles of forest land reclamation also yield important insight into rolling out rehabilitation activities sustainably (Torbert & Burger, 2000).

The Indian mining industry continues to be plagued by recurring issues like extensive land degradation, deforestation, and loss of biodiversity, which alter ecological balance and decrease agricultural productivity. Heavy metal pollution and soil erosion persist as threats to local water and soil quality, and poor closure practice heightens environmental concerns. Issues like displacement, livelihood losses, and health risks continue to deepen socio-economic vulnerabilities of communities.

The main goal of this research is to examine and assess sustainable reclamation activities in Indian coal-mined landscapes through ecological restoration, welfare of communities, and regulatory policies. In particular, it aims to evaluate the effectiveness of restoration technologies like selective plantation, utilization of fly ash, and microbial remediation in reversing land degradation. The research also intends to investigate the socio-economic consequences of post-mining transition, especially ensuring community rights and livelihoods. In addition, it strives to examine policy and governance arrangements that can enable long-term sustainability, hence harmonizing environmental restoration with fair development targets.

2.Methodology

The Indian mining sector is still marred with repeated threats such as massive land degradation, cutting down of forests, and loss of biodiversity that distorts an ecological balance and reduces agricultural yields. Soil erosion and heavy metal pollution have remained to be a threat to the local water and soil quality and this coupled with poor closure practice, increases environmental concerns. Problems such as displacement, loss of livelihoods, and health are still aggravating social-economic vulnerabilities of communities.

The primary objective of the study is to investigate and evaluate the sustainable reclamation practices of Indian coal-mined landscapes in terms of ecological restoration, beneficial community, and regulations. Specifically, it seeks to determine the efficiency of restoration methods such as selective plantation, use of fly ash and microbial remediation in reversing land degradation.

2.Methodology

The present study adopts a case study approach to discuss the social and economic impacts of incomplete rehabilitation of the communities who are displaced by the Rajmahal Opencast Coal Mining Project in Lalmatia, Jharkhand. A case study would be best suited to explore a complex association of environmental, economic and social parameters in a particular setting.

2.1.Case Selection and study area.

The Jharkhand coalfield of Rajmahal also known as Lalmatia village was selected due to its good exposure on the issue of displacement caused by the massive opencast mining of coal. A case example of partial rehabilitation is Lalmatia whereby the people affected have experienced livelihood deforestation, failure to access basic facilities as well as social disintegration. This was selected based on the past data of displacement, perceived rehabilitation lapses, and the availability of secondary data in the form of government reports, census data, and corporate social responsibility (CSR) reports of the mining industry.

2.2. Data Sources and Collection

Since the case study involves qualitative evaluation, primary surveys were not used. The research utilized secondary sources and spatial data sets:

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1. Reports by Government and Institutions: Reports from the Ministry of Coal, Jharkhand State Mineral Development Corporation (JSMDC), and Ministry of Rural Development gave information regarding land acquisition, compensation schemes, and rehabilitation schedules.

2. Census and Socio-Economic Statistics: Demographic patterns, occupational changes, literacy percentages, and income distribution were obtained from Census 2011 and follow-up state reports.

3. Corporate Reports and CSR Figures: Company reports were used to comprehend rehabilitation activities, community involvement, and fund utilization for displaced persons.

4. Remote Sensing and GIS Data: Satellite data from Landsat 8 and Sentinel-2 were employed to study LULC dynamics for a period of 10 years (2014–2024), providing proof of environmental degradation or rehabilitation.

2.3. Land Use and Land Cover Analysis

LULC change detection reveals the ecological impacts of partial rehabilitation. Preprocessing of multitemporal satellite images was done, which involved geometric correction, radiometric calibration, and atmospheric correction. Supervised classification was performed using the MLC to classify land into forest, agricultural land, barren land, water bodies, and built-up areas.The land use change rate was calculated using Eq.1,

$$LCR = \frac{A_{t2} - A_{t1}}{A_{t1}} \times \frac{1}{T} \times 100 \quad -(1)$$

Where, LCR is the Land change rate (%), A_{t2} is the Area of a specific land use category at time t_2, A_{t1} is the Area of the same category at time t_1 and T is the Time interval in years. This equation quantifies the extent of land degradation or recovery in rehabilitated vs. non-rehabilitated areas, highlighting the impact of mining on community lands.

2.3. Economic Impact Assessment

The economic consequences of incomplete rehabilitation were assessed using land value loss and livelihood disruption models. Displaced communities often lose agricultural land, forest resources, and other productive assets. The ELI was computed as by Eq.2,

$$ELI = \sum_{i=1}^{n} \quad (L_i \times V_i) \quad - (2)$$

Where, L_i is the Lost land area or productive unit, V_i is the Market value of the land or asset per unit area and n is the Total number of lost assets or land parcels. Additionally, income replacement ratios were calculated to assess the adequacy of compensation was given in Eq.3,

$$IRR = \frac{C}{Y} \times 100 \quad - (3)$$

Where, C is the Compensation received per household and Y is the Pre-displacement annual income of the household. These indices quantify the financial deficits experienced by displaced populations and highlight gaps in rehabilitation efforts.

2.4. Social Impact Modelling

Social impacts were modeled using secondary data on health, education, housing, and migration patterns. A SVI was adapted to measure the community's resilience to displacement was given in Eq.4,

$$SVI = \frac{\sum_{j=1}^{m} \quad w_j S_j}{\sum_{j=1}^{m} \quad w_j} \quad -(4)$$

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Where, S_j is the Standardized social indicator (e.g., access to schools, health centers), w_j is the Weight assigned to each indicator based on importance and m is the Total number of social indicators. A higher SVI indicates greater social vulnerability due to incomplete rehabilitation. Indicators were normalized using Eq.5,

$$S_j = \frac{X_j - X_{min}}{X_{max} - X_{min}} \quad - (5)$$

Where, X_j is the Observed value of the social indicator and X_{min}, X_{max} is the Minimum and maximum observed values in the study area. This modeling provides a quantitative measure of social disruption affecting displaced households, including marginalization, migration, and reduced access to essential services. To synthesize the findings, a CDII was developed and it was given in Eq.6,

$$CDII = \alpha \cdot \frac{ELI}{ELI_{max}} + \beta \cdot \frac{SVI}{SVI_{max}} \quad -(6)$$

Where, ELI is the Economic Loss Index, SVI is the Social Vulnerability Index, α, β is the Weight factors (assigned as 0.5 each for equal importance) and ELI_{max}, SVI_{max} is the Maximum observed values, The CDII provides a holistic measure of displacement impacts, allowing comparison across communities and identifying areas where rehabilitation is most inadequate.

3.Results

3. 1. Land Use and Land Cover Change Analysis

LULC analysis of Lalmatia village was performed based on the satellite imagery of Lalmatia village in the years 2014 and 2024 (**Table.1**). The analysis measured alterations in forest cover, agricultural land, barren land, water bodies and built-up areas to comprehend the patterns of environmental rehabilitation and degradation after the displacement.

Table 1: LULC Change in Lalmatia (2014–2024)

Land Use Category	Area 2014 (ha)	Area 2024 (ha)	Change (ha)	Change Rate (%)
Forest	210	180	-30	-14.3
Agriculture	320	250	-70	-21.9
Barren Land	80	120	+40	+50
Water Bodies	25	30	+5	+20
Built-up Areas	35	40	+5	+14.3

The outcomes of the LULC show that the forest and agricultural land are lost significantly, which is the evidence of incomplete ecological rehabilitation. Growth in barren land and slight growth in built up lands reflects land degradation and encroachment which has negative effects on livelihoods and ecological services of the displaced communities.

3.2. Calculation of ELI.

The ELI also measures financial damages due to displacement such as agricultural land and property loss (**Table.2**). Based on secondary data on government record and market valuations:


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Table 2: Economic Loss Index of Displaced Households

Household ID	Lost Land (ha)	Land Value (₹/ha)	ELI (₹)
H1	1.5	1,20,000	1,80,000
H2	2.0	1,00,000	2,00,000
H3	1.2	1,50,000	1,80,000
H4	1.0	1,10,000	1,10,000
H5	2.5	1,30,000	3,25,000

According to the ELI, there were significant financial shortfalls in households because of the insufficient compensation. This difference in ELI shows that economic loss is unequally distributed among families, where there are those that are worse off since they have larger landholding or higher land values.

3.3. Social Vulnerability Index

The social vulnerability was measured by the indicators such as housing, healthcare, education and Migration stress (**Table.3**). The standardization of the indicators was calculated with an equal weight.

Table 3: Social Vulnerability Index of Displaced Households

Household ID	Housing Access (0–1)	Healthcare Access (0–1)	Education Access (0–1)	Migration Stress (0–1)	SVI
H1	0.8	0.6	0.7	0.9	0.75
H2	0.5	0.4	0.6	0.8	0.575
H3	0.7	0.5	0.8	0.7	0.675
H4	0.9	0.8	0.9	0.6	0.8
H5	0.4	0.3	0.5	0.9	0.525

The SVI identifies high social vulnerability among displaced households, particularly in areas where the access to basic services is low. Homes experiencing high migration pressures and low access to healthcare or education have the most difficulties with adapting to the resettlement.

3.4. Composite Displacement Impact Index

The CDII brings together economic and social effects, which gives its totality of the displacement effects (**Table.4 and Fig.1**). Using equal weighting ($\alpha = \beta = 0.5$):

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Table 4: Composite Displacement Impact Index (CDII)

Household ID	ELI (₹)	Normalized ELI	SVI	Normalized SVI	CDII
H1	1,80,000	0.554	0.75	0.938	0.746
H2	2,00,000	0.615	0.575	0.719	0.667
H3	1,80,000	0.554	0.675	0.844	0.699
H4	1,10,000	0.338	0.8	1.000	0.669
H5	3,25,000	1.000	0.525	0.656	0.828

The outcomes of the CDII indicate that the highest combined effect is on H5 because it lost a lot of money and it is socially vulnerable. H4, on the other hand, at moderate levels of CDII, with comparatively lower economic loss, demonstrates the significance of social factors in the general assessment of displacement impacts.

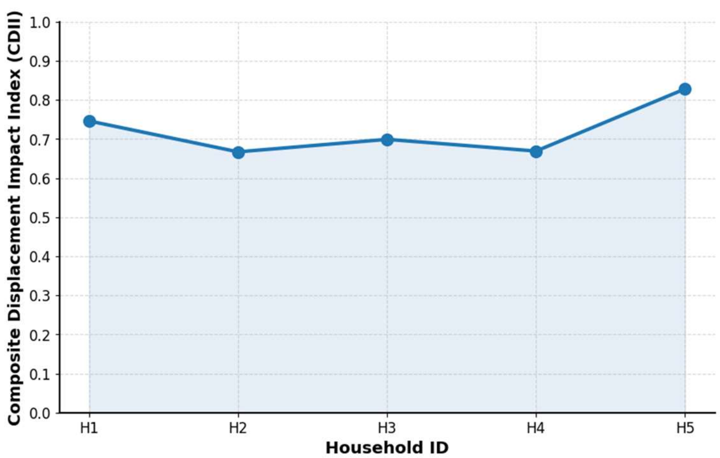

Fig.1. CDII across displaced households in Lalmatia, Jharkhand.

The case study of Lalmatia village shows that incomplete rehabilitation has contributed to the lack of environmental, economic and social deficit. The changes observed in LULC are evidence of continuing deterioration and the economic losses and the social vulnerability indices demonstrate the unequal distribution of the displaced households. The CDII offers a comprehensive measure of the effect of displacement and indicates households in need of immediate action.

4. Conclusion

The case study of the Raajmahal Opencast Coal Mining Project in Lalmatia, Jharkhand reveals that insufficient rehabilitation has been disastrous with economic and social effects on the displaced communities. The ten-year period analysis of land use and land cover revealed that there was a considerable amount of forest and agricultural land lost, and the same number of barren and built-up sites, which indicated a further evolution of the ecological environment and the absence of its restoration. Both financial analysis revealed the impact of poor economic losses on households due to the non-compensation of the lost assets and social conditions due to poor access to housing, healthcare, education, and employment and the pressure of migration. The general discussion of the economic and social problems demonstrates that partial rehabilitation is not only

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the menace to the livelihoods but also the integrity and cohesion of communities. Such findings imply that the combination of economic indemnity, social reinforcement, and ecological recuperation should be enrolled through the adoption of multifaceted rehabilitation programs. The policymakers and the mining authority should collaborate with the community stakeholders so as to realize sustainable and equitable outcomes to the displaced populations.

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