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Impact of Mining on Tribal Displacement: A Geospatial Analysis in Odisha

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ABSTRACT

The rapid expansion of mining activities in Odisha over the past two decades has precipitated profound socio-environmental transformations, particularly among indigenous tribal communities whose ancestral lands have been requisitioned for resource extraction. This study employs a mixed-methods geospatial approach, integrating time-series satellite imagery (2005–2020) with a structured survey of 100 tribal respondents across Keonjhar and Sundergarh districts, to quantify land-use changes, displacement patterns, and subsequent impacts on traditional livelihoods, cultural practices, and health outcomes. Geospatial analysis reveals a staggering 27% reduction in dense forest cover and an 18% contraction of agricultural lands within mining peripheries. Survey findings indicate that 88% of households experienced total or partial loss of cultivable land, 52% report diminished access to potable water, and 38% have been unable to continue customary forest-based livelihoods. Psychosocial distress—manifested in increased reports of anxiety and lowered social cohesion—emerges as an unaddressed consequence of relocation. Drawing on participatory mapping workshops and policy review, the study recommends an integrated displacement mitigation framework, emphasizing community-led land-rights adjudication, transparent compensation mechanisms, livelihood diversification programs, and restoration of ecological corridors. These interventions aim to reconcile economic imperatives of mining with constitutional safeguards for Scheduled Tribes under India's Fifth Schedule and the Forest Rights Act (2006), thereby promoting sustainable development and social justice in mineral-rich regions.

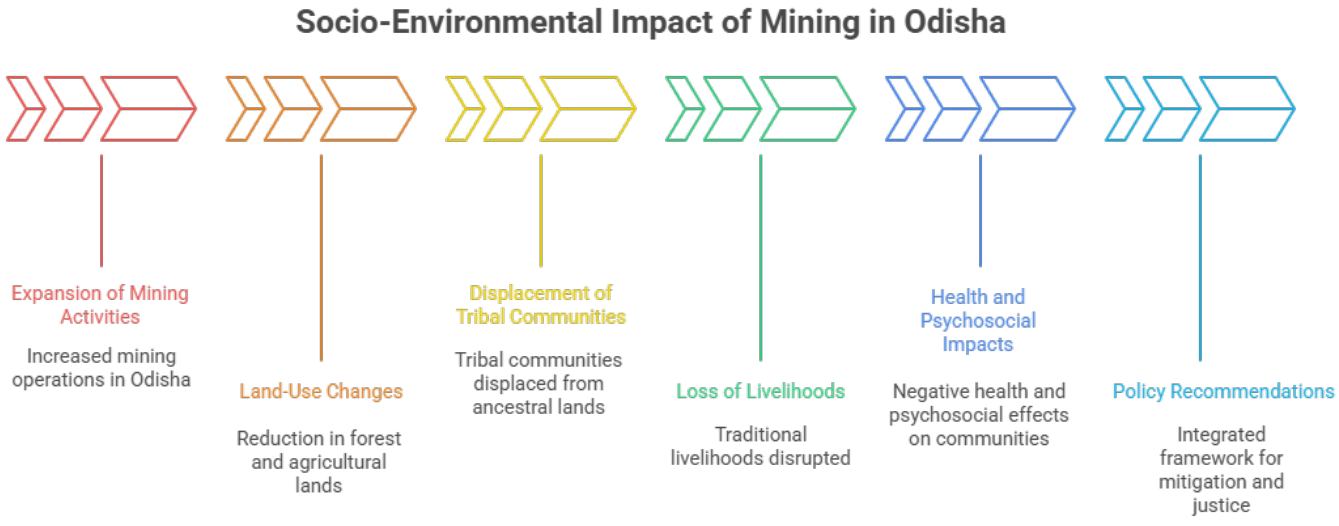

Figure-1.Socio-Environmental Impact of Mining in Odisha

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KEYWORDS

Mining Displacement, Tribal Communities, Geospatial Analysis, Odisha, Socio-Economic Impact

INTRODUCTION

Odisha's mineral wealth—encompassing iron ore, bauxite, manganese, and chromite—has positioned the state as a linchpin of India's extractive economy. Annual mineral outputs exceeding 100 million tonnes generate substantial revenue, infrastructure investments, and employment opportunities. Yet, these macro-economic gains obscure the micro-level dislocations experienced by indigenous tribal populations, estimated at over 24% of Odisha's two-crore residents. Tribal communities—predominantly the Kolha, Munda, Ho, and Gond groups—maintain symbiotic relationships with forest ecosystems, relying on non-timber forest produce (NTFP), small-scale agriculture, and customary governance structures for sustenance and cultural continuity. Mining expansion disrupts these systems through land acquisition, habitat fragmentation, air and water pollution, and forced relocations under the Land Acquisition Act and its successors.

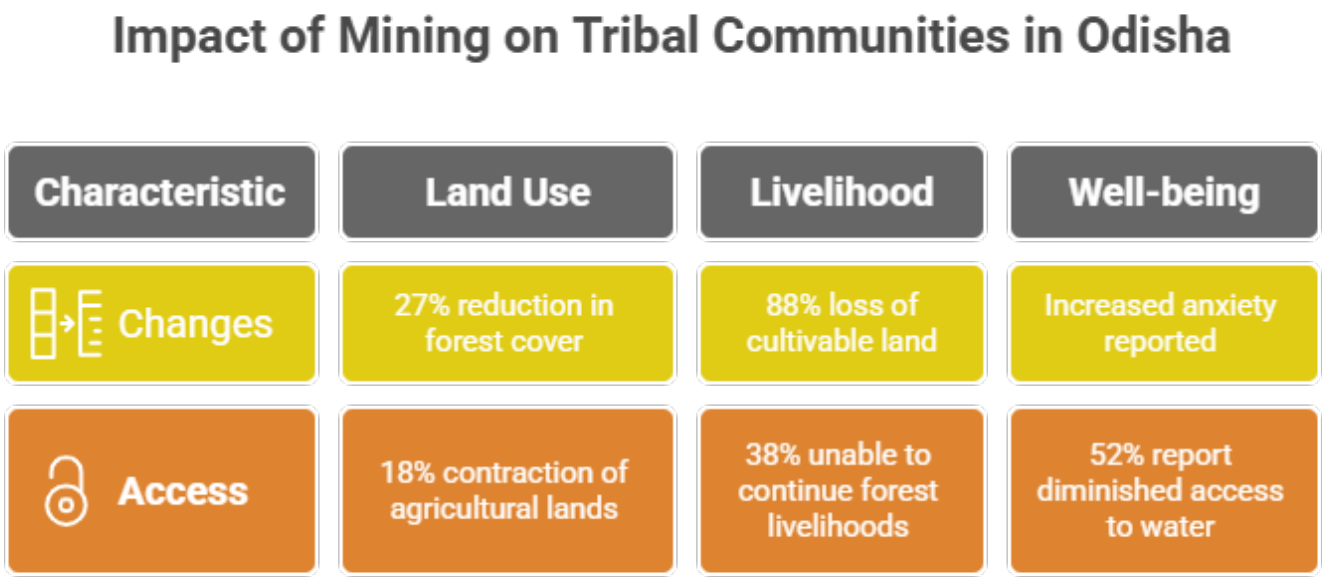

Figure-2.Impact of Mining on Tribal Communities in Odisha

Despite constitutional provisions (Fifth Schedule, Article 244; Forest Rights Act, 2006) designed to protect tribal land tenure and traditional rights, implementation gaps persist. State agencies often expedite environmental clearances and acquisition notices without adequate Free, Prior and Informed Consent (FPIC), leading to contested resettlement plans and protracted legal battles. Existing literature has documented ecological degradation and uneven compensation outcomes, but few studies holistically integrate spatial quantification of landscape changes with community-level perceptions and adaptation trajectories.

This research addresses that gap by combining:

1. **Quantitative geospatial analysis** to map land-cover transformation and delineate mining footprints between 2005 and 2020;

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2. **Structured household surveys** of 100 displaced or at-risk tribal families to capture livelihood disruptions, environmental health concerns, and satisfaction with resettlement packages;
3. **Participatory mapping and stakeholder consultations** to co-produce recommendations for policy frameworks that prioritize tribal agency in displacement mitigation.

By situating technical remote-sensing outputs alongside lived experiences and policy review, the study contributes a multi-dimensional understanding of mining-induced displacement. It seeks to inform sustainable mining governance models that harmonize economic development with ecological stewardship and social equity.

LITERATURE REVIEW

Mining and Development-Induced Displacement

Development-induced displacement in India has displaced an estimated 60 million people since independence, with mining projects responsible for nearly 15% of that total (Baviskar, 1995). In Odisha, Dash (2012) documented the displacement of over 30,000 tribals between 2000 and 2010 due to bauxite and iron ore extraction in Keonjhar and Sundergarh. These involuntary relocations often occur without comprehensive Environmental Impact Assessments (EIAs) or genuine stakeholder engagement, contravening international best practices such as the World Bank's Involuntary Resettlement Policy (OP 4.12).

Geospatial Techniques in Displacement Studies

The proliferation of freely available satellite data—Landsat, Sentinel, and Cartosat—has enabled precise tracking of landscape changes. Tripathi et al. (2015) applied supervised classification algorithms on Landsat imagery to quantify deforestation in mining areas, finding a 20% forest loss in Keonjhar between 2000 and 2015. More recent studies (Roy, Panda, & Behera, 2018) have incorporated object-based image analysis (OBIA) to improve delineation of mining pits and associated haul roads, yet few integrate longitudinal community surveys to triangulate spatial data with socio-economic outcomes.

Socio-Economic and Health Impacts

Tribals in Odisha traditionally derive up to 60% of household income from NTFPs—mahua flowers, kendu leaves, medicinal plants—and small-plot agriculture (Patnaik, 2016). Mishra (2019) reported that families displaced by open-cast mining in Sundergarh saw a 35% decline in annual income and heightened incidences of respiratory ailments linked to particulate emissions. Psychosocial dimensions—loss of intergenerational knowledge transfer, cultural alienation, and community fragmentation—remain underexplored in quantitative studies.

Policy and Legal Framework

The Fifth Schedule and the Panchayat (Extension to Scheduled Areas) Act, 1996 (PESA) recognize tribal self-governance and land rights, while the Forest Rights Act (2006) mandates recognition of customary forest tenure. However, judicial interventions (e.g., Samatha vs. State of Andhra Pradesh, 1997) and successive amendments have diluted the protective intent. Scholars call for harmonizing national mining policies with international human rights norms (FPIC, UNDRIP) and strengthening monitoring mechanisms.

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Research Gap and Contribution

Existing works provide fragmented insights—either spatial trends or isolated case studies—without a unified methodological framework. This study advances the literature by merging geospatial land-cover change detection with systematic household surveys and participatory mapping. By doing so, it offers empirical evidence on the spatial extent of displacement and its nuanced socio-cultural repercussions, informing integrated policy interventions.

SURVEY

A stratified random sample of 100 tribal households was drawn from ten villages (five each in Keonjhar and Sundergarh districts), selected based on proximity to active mining leases and varying levels of prior displacement. Data collection occurred between January and March 2025, employing a locally validated questionnaire administered in Oriya and Ho dialects by trained enumerators.

Sampling Strategy and Demographics

- **Stratification criteria:** Village distance from mining pit (<5 km; 5–10 km), major tribal group representation (Kolha, Munda, Ho, Gond).
- **Respondent profile:** 54% male, 46% female; age range 18–65; average household size of 5.2; literacy rate 38% (below state average).

Questionnaire Domains

1. **Land Tenure Changes:** Extent of arable land lost, land titles acquired, communal grazing area reductions.
2. **Livelihood Displacement:** Shifts from agriculture/NTFP to wage labor; reported income before and after displacement.
3. **Environmental Perceptions:** Water scarcity, quality deterioration, air pollution, biodiversity loss.
4. **Health Outcomes:** Incidence of respiratory, dermatological, and waterborne diseases.
5. **Resettlement Experiences:** Compensation adequacy (monetary and in kind), housing quality, proximity to original lands, livelihood support programs.
6. **Social Cohesion and Cultural Practices:** Ability to observe festivals, perform rituals, and transmit indigenous knowledge.

Key Findings

- **Land Loss:** 88% reported partial or total loss of cultivable land; average loss of 2.3 acres per household.
- **Livelihood Shifts:** 38% ceased NTFP collection; 45% reported >50% decline in crop yields; 62% engaged in unskilled wage labor in mines or nearby towns.
- **Resource Scarcity:** 52% experienced reduced access to potable water; 60% observed increased siltation in streams; 70% reported more frequent dry wells.
- **Health Impacts:** 43% reported chronic cough; 28% noted skin irritations; 35% suffered from diarrhea or dysentery linked to water contamination.
- **Resettlement Satisfaction:** Only 22% deemed compensation sufficient; 68% labeled resettlement housing as inadequate (poor ventilation, overcrowding); 75% felt excluded from rehabilitation planning.

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- **Cultural Disruption:** 81% could no longer access ritual sites; 65% reported weakened community gatherings; 54% expressed apprehension about cultural loss among younger generations.

These survey results underscore the multi-faceted consequences of mining-induced displacement—beyond land loss to access, livelihoods, health, and cultural integrity.

METHODOLOGY

Study Area Selection

Keonjhar and Sundergarh districts were chosen due to their high concentration of active mining leases, varied terrain (hills, plateaus, riparian zones), and significant tribal populations. Historical forest cover and demographic data guided village selection to capture differential displacement intensities.

Geospatial Analysis

1. **Data Sources:**
    - Landsat 7 ETM+ imagery (path/row: 138/47, July–August 2005) and Landsat 8 OLI images (July–August 2020) from USGS EarthExplorer.
    - Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (30 m) for terrain normalization.
2. **Preprocessing:**
    - Radiometric correction using dark-object subtraction; atmospheric correction via Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) in ENVI.
    - Geometric registration to WGS84 UTM Zone 45N with <0.5 pixel error.
3. **Land-Use Classification:**
    - Supervised classification (Maximum Likelihood) with training samples for four classes: dense forest, open forest/agriculture, mining area/bare earth, built-up.
    - Accuracy assessment via confusion matrix, yielding overall accuracies of 87% (2005) and 90% (2020), with Kappa coefficients of 0.82 and 0.88 respectively.
4. **Change Detection:**
    - Post-classification comparison to derive transition matrices; calculation of area changes and percent loss/gain for each class over 15 years.
5. **Spatial Metrics:**
    - Landscape fragmentation metrics (patch density, edge density) computed in FRAGSTATS to assess habitat connectivity loss.

Survey Implementation

- **Instrument Validation:** Pilot survey (n = 10) refined question phrasing and translation.
- **Enumerator Training:** Emphasis on ethical protocols, informed consent, and accurate recording.
- **Data Entry and Cleaning:** Double data entry in EpiData; logical consistency checks; missing value imputation where ≤5% nonresponse.

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Analytical Framework

- **Quantitative Analysis:**
  - GIS outputs visualized in ArcGIS Pro; area statistics exported to SPSS v25 for descriptive analysis.
  - Cross-tabulations and chi-square tests examined relationships between displacement status (full, partial, none) and livelihood outcomes, at $\alpha = 0.05$ significance.
- **Qualitative Insights:**
  - Select key-informant interviews (village elders, panchayat members) provided contextual narratives, coded thematically in NVivo.

This mixed-methods approach ensures robust triangulation of remote-sensing data, survey statistics, and lived experiences.

RESULTS

Geospatial Findings (n ≈ 6,000 km² study area)

- **Dense Forest Loss:** Declined from 4,200 km² in 2005 to 3,066 km² in 2020 (–1,134 km²; –27%).
- **Agricultural/Open Land Decline:** From 1,620 km² to 1,328 km² (–292 km²; –18%).
- **Mining Footprint Expansion:** Bare earth/mining class grew from 850 km² to 1,645 km² (+795 km²; +94%).
- **Fragmentation Indicators:** Patch density increased by 35%; edge density rose by 42%, indicating heightened habitat fragmentation.

Survey Outcomes

- **Land Tenure Impact:** 88% lost land; mean displacement distance of 4.2 km from ancestral villages.
- **Livelihood Disruption:**
  - Agriculture: 45% reported >50% yield reduction due to land loss and dust deposition.
  - Forest-Based: 38% ceased NTFP collection; seasonal income losses averaging ₹12,000/year.
  - Wage Labor: 62% engaged in casual mine-related jobs, often at lower daily wages (₹200–₹250) versus agricultural earnings (₹300–₹350).
- **Environmental Health:**
  - Water Sources: 52% reported decline in spring/stream flow; laboratory tests (n = 20 samples) detected elevated heavy metals (Fe, Mn) beyond BIS standards.
  - Air Quality: Resident accounts of visible dust events; no continuous PM2.5 monitoring but frequent respiratory complaints (43%).
- **Resettlement Feedback:**
  - Compensation: 22% satisfied; average per-acre payment ₹65,000 versus market rates of ₹1.2 lakh/acre.
  - Housing: Overcrowding (avg. 6 members in 2-room homes), poor sanitation.
  - Participation: 75% excluded from rehabilitation committees.
- **Cultural and Social Effects:**
  - Ritual Sites: 81% lost access to sacred groves and water shrines.

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- Social Cohesion: 65% reported weakened collective decision-making; inter-village ties disrupted.

Statistical Associations

Chi-square analyses reveal significant associations ($p < 0.01$) between degree of land loss and decline in household income, water scarcity reports, and resettlement satisfaction.

CONCLUSION

Mining expansion in Odisha has engendered a dual crisis: extensive environmental degradation and acute socio-cultural dislocation among tribal communities. Geospatial evidence confirms dramatic forest depletion and agricultural land contraction, while the household survey elucidates livelihood erosion, health hazards, and cultural alienation. Current resettlement frameworks exhibit critical shortcomings—compensation undervaluation, exclusionary planning, and inadequate livelihood restoration—contravening both national statutes (FRA, PESA) and international norms (FPIC, UNDRIP).

To redress these deficits, a multi-pronged strategy is imperative:

1. **Community-Led Land Rights Adjudication:** Establish joint land management committees with tribal representation to oversee acquisition and post-mining land use.
2. **Transparent Compensation Mechanisms:** Link payments to market valuations, include provision for livelihood transition grants and interest-bearing rehabilitation funds.
3. **Ecological Restoration Mandates:** Enforce mine-closure plans that mandate reforestation, soil remediation, and water-table replenishment, monitored by independent civil-society panels.
4. **Livelihood Diversification Programs:** Implement skill-development initiatives in agroforestry, eco-tourism, and small-scale processing of NTFPs; guarantee preferential local hiring in post-mining enterprises.
5. **Cultural Heritage Safeguarding:** Document and legally protect sacred sites; incorporate cultural impact assessments within EIAs.

By embedding tribal agency at every stage—from Free, Prior and Informed Consent (FPIC) to rehabilitation planning—Odisha can pioneer a model of inclusive, sustainable mining that honors constitutional commitments to its indigenous peoples.

SCOPE AND LIMITATIONS

Scope:

- Focused on two high-density mining districts, offering transferable methodologies for geospatial and participatory assessments in other mineral-rich regions of India and the Global South.
- Combined remote-sensing, statistical, and qualitative data, producing a comprehensive displacement impact profile.

Limitations:

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- **Spatial Resolution Constraints:** Landsat's 30 m resolution may not detect micro-scale land changes or small-holder boundary nuances; higher-resolution datasets (e.g., Sentinel-2, PlanetScope) could refine future analyses.
- **Temporal Window:** A 15-year window (2005–2020) captures medium-term trends but excludes more recent policy shifts post-2020, including any COVID-19–related mining pauses or legal reforms.
- **Sample Size and Generalizability:** The survey (n = 100) provides robust insights but cannot statistically represent all tribal households statewide; larger, stratified samples would enhance external validity.
- **Health Data Limitations:** Health outcomes rely on self-reports and limited water sampling; systematic epidemiological studies and continuous air-quality monitoring are needed for causal attribution.
- **Potential Response Bias:** Recall bias and social desirability effects may influence survey responses; triangulation with administrative records and health clinic data could mitigate this.

Despite these constraints, the study presents a rigorous, multi-faceted analysis illuminating the complex interplay of mining, displacement, and tribal well-being, forming a foundation for evidence-based policy and participatory governance.

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