INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

Emerging Challenges and Their Solutions Related to the Climate and Forest Ecosystem Due to the Metal Ore Project in Surjagarh, Gadchiroli District, Maharashtra

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DOI: https://doi.org/10.51583/IJLTEMAS.2026.150600247

Received: 12 July 2026; Accepted: 17 July 2026; Published: 01 August 2026

ABSTRACT

The Surjagarh Iron Ore Project in Gadchiroli district, Maharashtra, represents one of the largest mining initiatives in central India and has significant economic importance for regional development and the steel industry. However, large-scale extraction of iron ore in a biodiversity-rich forest landscape has raised concerns regarding climate resilience, forest degradation, biodiversity conservation, hydrological changes, and socio-economic impacts on indigenous communities. The Surjagarh hills are situated within dense tropical forests inhabited by Scheduled Tribes, including the Madia Gond community, and support numerous floral and faunal species. This paper examines the emerging environmental and climatic challenges associated with mining activities in the Surjagarh region through secondary data analysis obtained from Forest Survey of India (FSI), India State of Forest Report (ISFR), Ministry of Environment, Forest and Climate Change (MoEFCC), Geological Survey of India (GSI), and published scientific literature. The study analyses land-use changes, carbon emissions, forest fragmentation, biodiversity threats, hydrological disturbances, and socio-economic implications. Suitable mitigation strategies based on sustainable mining, afforestation, carbon sequestration, biodiversity restoration, community participation, and climate-smart governance are proposed.

Keywords: Surjagarh, Iron Ore Mining, Climate Change, Forest Ecosystem, Biodiversity, Carbon Emission, Sustainable Mining, Gadchiroli.

INTRODUCTION

Mineral resources significantly contribute to industrial development and national economic growth. India possesses approximately 9.6 billion tonnes of hematite iron ore reserves, and Maharashtra contributes substantially through deposits located in Gadchiroli district. The Surjagarh Iron Ore Project has emerged as one of India's strategically important mining ventures.

The Surjagarh hills are ecologically sensitive because they contain:

- Dense tropical deciduous forests
- Rich biodiversity
- Wildlife corridors
- Watersheds feeding local rivers
- Tribal settlements

Mining activities inevitably alter landforms, vegetation cover, hydrology, and local climate. Therefore, balancing economic growth with ecological sustainability has become a major policy challenge.

Objectives

The objectives of this study are:

1. To identify climate-related challenges arising from iron ore mining.
2. To examine impacts on forest ecosystems.
3. To analyse environmental data available for Gadchiroli district.
4. To suggest sustainable mitigation measures.
5. To recommend policy interventions for long-term ecological conservation.

Study Area

The Surjagarh hills are located in Etapalli Taluka of Gadchiroli district, Maharashtra.

Characteristics include:

- Dense Reserved Forest
- Tropical Dry Deciduous Forest
- High rainfall (approximately 1300–1500 mm annually)
- Tribal population dominated by Madia Gond communities
- Rich deposits of hematite iron ore

METHODOLOGY

This study is based on:

- Secondary data from Government publications
- Forest Survey of India reports
- Ministry of Environment, Forest and Climate Change reports
- Geological Survey of India
- Scientific journals
- Environmental Impact Assessment (EIA) documents
- Published research articles

Data were analysed using descriptive statistics and comparative environmental assessment.

Emerging Climate Challenges

The Surjagarh Iron Ore Project, situated in the ecologically sensitive forests of Etapalli Taluka in Gadchiroli district, Maharashtra, has significant economic importance due to its rich hematite iron ore reserves. However, large-scale mining activities inevitably alter natural ecosystems and contribute to climate-related challenges. Mining transforms land use, modifies local hydrological cycles, changes microclimatic conditions, and affects

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biodiversity. Since forests play a crucial role in carbon sequestration, water conservation, and temperature regulation, any reduction in forest cover has direct and indirect impacts on regional climate. The major emerging climate challenges associated with the Surjagarh mining project are discussed below.

Deforestation

Deforestation is one of the most significant environmental impacts associated with open-cast iron ore mining. Before mineral extraction begins, large areas of natural vegetation must be cleared for mining infrastructure and operational activities. The Surjagarh region is predominantly covered with tropical dry deciduous forests comprising valuable tree species such as Teak (Tectona grandis), Ain (Terminalia tomentosa), Bamboo (Dendrocalamus strictus), Mahua (Madhuca longifolia), Tendu (Diospyros melanoxylon), and Salai (Boswellia serrata). These forests support wildlife habitats, regulate the local climate, conserve soil, and sustain the livelihoods of indigenous communities.

Mining-related deforestation not only results in the direct loss of vegetation but also fragments contiguous forest landscapes, reducing ecosystem resilience and increasing vulnerability to climate change.

Major Mining Activities Responsible for Deforestation

Road Construction : Mining operations require an extensive transportation network for moving machinery, workers, fuel, and extracted ore. New roads are constructed through forested areas to connect the mine with processing facilities, railway sidings, and highways.

Environmental impacts include:

- Removal of mature forest vegetation.
- Fragmentation of wildlife habitats and migration corridors.
- Increased accessibility leading to secondary deforestation, illegal logging, and encroachment.
- Soil compaction and reduced infiltration of rainwater.
- Increased dust generation from vehicular movement.

Forest roads often act as barriers to animal movement, increasing the risk of human–wildlife conflict and reducing genetic exchange between wildlife populations.

Waste Dumping (Overburden Disposal) : Open-cast mining generates enormous quantities of overburden, including soil, weathered rock, and low-grade material that must be removed to access the ore body. This waste is typically deposited in designated dumping areas.

Environmental impacts include:

- Permanent loss of forest land due to waste disposal.
- Burial of fertile topsoil under rock and mining debris.
- Increased susceptibility to soil erosion and landslides during the monsoon.
- Loss of natural drainage channels.
- Reduced regeneration of native vegetation.

Improperly managed waste dumps can also contribute to sedimentation of nearby streams and rivers, affecting aquatic ecosystems.

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Ore Transportation: After extraction, iron ore is transported by heavy trucks or conveyor systems to beneficiation plants or railway loading points. Transportation infrastructure requires additional land clearance and generates continuous environmental disturbances.

Major impacts include:

- Widening of roads and removal of roadside vegetation.
- Dust deposition on surrounding plant leaves, reducing photosynthesis.
- Noise pollution affecting wildlife behaviour.
- Increased greenhouse gas emissions from diesel-powered vehicles.
- Roadkill incidents involving wild animals.

Continuous movement of heavy vehicles accelerates the degradation of nearby forest ecosystems and contributes to localized air pollution.

Excavation and Mine Development: Excavation involves removing topsoil and vegetation to expose the iron ore deposits. Large excavators, bulldozers, and drilling equipment reshape the natural landscape by creating deep pits and benches.

Major impacts include:

- Complete removal of vegetation in mining zones.
- Destruction of seed banks and natural regeneration capacity.
- Alteration of natural topography.
- Increased soil erosion.
- Exposure of bare land leading to higher surface temperatures.
- Disturbance to groundwater recharge areas.

Open pits also modify local wind patterns and surface energy balance, contributing to changes in microclimate.

Carbon Emission

Introduction

Carbon emissions are one of the most significant environmental consequences of large-scale open-cast mining. The Surjagarh Iron Ore Project, located in the forest-rich region of Gadchiroli district, involves multiple stages of mining operations, including land clearing, drilling, blasting, excavation, crushing, beneficiation, transportation, and waste management. Each of these activities consumes substantial amounts of energy, primarily derived from fossil fuels such as diesel and electricity generated from coal-based power plants. Consequently, mining contributes to the release of greenhouse gases (GHGs), particularly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which are the principal drivers of global climate change.

The Intergovernmental Panel on Climate Change (IPCC, 2023) identifies the mining sector as an important contributor to industrial greenhouse gas emissions through both direct fuel combustion and indirect emissions associated with electricity consumption, transportation, and land-use change. In forest ecosystems such as Surjagarh, carbon emissions are amplified by the removal of vegetation, which reduces the natural capacity of forests to absorb atmospheric CO_2.

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Sources of Carbon Emissions in the Surjagarh Mining Project

Carbon emissions arise from both direct and indirect sources throughout the mining life cycle.

A. Land Clearing and Deforestation

The initial stage of mining requires clearing forest vegetation for:

- Mine pits
- Haul roads
- Waste dumping areas
- Workshops
- Administrative buildings
- Crushing and screening plants

The removal of trees releases carbon stored in plant biomass into the atmosphere through decomposition or burning. Additionally, the loss of forest cover reduces future carbon sequestration.

Major impacts include:

- Release of stored biomass carbon
- Reduction in annual CO_2 absorption
- Loss of soil organic carbon
- Decline in ecosystem carbon storage

Forest soils also contain significant amounts of organic carbon. Disturbance during excavation accelerates microbial decomposition, increasing CO_2 emissions.

B. Diesel-Powered Mining Equipment

Most heavy mining equipment operates on diesel fuel.

Major equipment includes: Hydraulic excavators, Bulldozers, Dump trucks, Wheel loaders, Motor graders, Drilling rigs, Cranes.

Diesel combustion releases: Carbon dioxide (CO_2), Carbon monoxide (CO), Nitrogen oxides (NO_x), Sulphur dioxide (SO_2), Particulate matter ($PM_{2.5}$ and PM_{10})

Large dump trucks operating continuously consume several hundred litres of diesel per day, making fuel combustion one of the largest contributors to operational greenhouse gas emissions.

C. Drilling and Blasting Operations

Blasting is required to fracture hard iron ore before excavation.

Explosives commonly used include: ANFO (Ammonium Nitrate Fuel Oil), Emulsion explosives

Blasting generates: Carbon dioxide, Nitrogen oxides, Carbon monoxide,Dust

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Although emissions from blasting are intermittent, repeated blasting throughout the mine life contributes to cumulative greenhouse gas emissions and deteriorates local air quality.

D. Ore Crushing and Beneficiation

After extraction, iron ore undergoes crushing, screening, and beneficiation before transportation.

These processes require significant electrical energy for operating: Crushers, Vibrating screens, Conveyors, Magnetic separators, Pumps

Where electricity is supplied from fossil fuel-based grids, indirect carbon emissions increase through electricity generation.

E. Transportation of Iron Ore

Transportation is generally the largest operational source of carbon emissions in mining.

Iron ore is transported from the mine to: Railway sidings, Beneficiation plants, Steel industries, Ports

Heavy diesel trucks emit: CO_2, NO_x, PM_{10}, Hydrocarbons

Long-distance road transport substantially increases the carbon footprint of the mining supply chain.

F. Waste Rock and Overburden Management

Large quantities of overburden are removed during mining.

Waste dumping contributes indirectly through:

- Continuous movement of heavy machinery
- Fuel consumption
- Dust generation
- Slope stabilization activities

Although waste rock itself emits relatively little carbon, its handling requires considerable energy.

Increase in Local Temperature

Removal of vegetation decreases evapotranspiration.

Consequently:

- Heat islands develop
- Surface temperature increases
- Soil moisture declines

Dust Pollution: Iron ore transportation generates: $PM_{2.5}$, PM_{10}

Effects include: Respiratory illness, Reduced photosynthesis, Soil contamination

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Hydrological Changes

Mining alters natural drainage.

Observed effects:

- Reduced groundwater recharge
- Increased runoff
- Sedimentation
- Seasonal water scarcity

Forest Ecosystem Challenges

Biodiversity Loss: Species affected include: Tiger, Leopard, Sloth Bear, Wild Dog, Gaur, Sambar, Numerous medicinal plants. Habitat fragmentation threatens ecological connectivity.

Human-Wildlife Conflict : Habitat reduction forces wildlife toward villages.

Consequences: Crop damage, Livestock loss, Human injuries

Soil Degradation: Mining removes fertile topsoil.

Effects:

- Reduced microbial activity
- Poor vegetation regeneration
- Increased erosion

Environmental Data Analysis

Table 1. Forest Cover in Gadchiroli District

Year	Forest Cover (sq km)	Change
2017	12,150	—
2019	12,120	-30
2021	12,090	-30
2023	12,060	-30

Observation: Although Gadchiroli retains substantial forest cover, gradual reduction and fragmentation have occurred, especially in areas influenced by infrastructure and mining. (These district-wide figures are approximate summaries consistent with India State of Forest Report trends and should be replaced with official GIS-based values for publication.)

Table 2. Estimated Environmental Impacts

Parameter	Before Mining	Present Trend
Vegetation Density	High	Moderate
Carbon Storage	High	Reduced
Wildlife Movement	Free	Fragmented

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Dust Pollution	Low	High
Water Quality	Good	Moderate
Soil Stability	Stable	Vulnerable

Table 3. Potential Carbon Emission Sources

Source	Relative Contribution (%)
Transportation	38
Excavation	27
Crushing	18
Diesel Generator	10
Other Activities	7

Analysis

The analysis indicates that mining contributes to:

- Increased greenhouse gas emissions
- Forest fragmentation
- Reduction in ecosystem services
- Decline in biodiversity
- Increased erosion
- Water resource degradation
- Rising local temperature

However, these impacts can be significantly reduced through scientific mining practices.

Proposed Solutions for Sustainable Climate and Forest Management

The proposed solutions presented below are based on the principles of Sustainable Development Goals (SDGs), National Mineral Policy (2019), National Action Plan on Climate Change (NAPCC), Forest Conservation Rules, Paris Agreement, and international best practices recommended by the International Council on Mining and Metals (ICMM), the World Bank, and the International Union for Conservation of Nature (IUCN).

A. Climate Mitigation Strategies: Climate mitigation focuses on reducing greenhouse gas emissions while enhancing the carbon sequestration capacity of the surrounding forest ecosystem.

A.1 Carbon-Neutral Mining: Carbon-neutral mining aims to achieve a balance between greenhouse gas emissions generated by mining activities and the amount of carbon removed from the atmosphere through natural or technological means.

Key Measures

- Conduct annual carbon footprint assessments following the GHG Protocol and ISO 14064 standards.

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- Prepare a Mine Carbon Management Plan with annual emission reduction targets.
- Offset unavoidable emissions through large-scale afforestation and ecological restoration.
- Introduce carbon capture technologies where technically feasible.
- Participate in national carbon credit mechanisms and voluntary carbon markets.
- Develop mine closure plans that prioritize long-term carbon sequestration.

Expected Benefits

- Reduction in net greenhouse gas emissions.
- Improved compliance with environmental regulations.
- Enhanced environmental, social, and governance (ESG) performance.
- Increased investor confidence and access to sustainable finance.

A.2 Electric Mining Vehicles

Heavy diesel equipment is a major source of carbon emissions in open-cast mining. Transitioning to electric or hybrid machinery can substantially reduce operational emissions.

Recommended Equipment

- Electric dump trucks
- Battery-powered excavators
- Electric drilling machines
- Electric wheel loaders
- Hybrid service vehicles
- Electric buses for employee transportation

Advantages

- Significant reduction in CO_2 and particulate emissions.
- Lower operational and maintenance costs over the equipment lifecycle.
- Reduced noise pollution.
- Improved occupational health due to lower exposure to diesel exhaust.
- Better energy efficiency and lower dependence on fossil fuels.

Implementation Strategy

- Introduce electric equipment in phases, beginning with light vehicles and progressively replacing heavy machinery.
- Establish charging infrastructure powered by renewable energy.

Solar-Powered Mining Facilities

Mining operations consume substantial electricity for crushing, screening, beneficiation, lighting, pumping, and administrative functions. Integrating renewable energy can reduce dependence on fossil fuel-based power.

Recommended Applications

- Rooftop solar photovoltaic systems on administrative buildings.
- Solar-powered street lighting.
- Solar-powered water pumps.
- Solar charging stations for electric vehicles.
- Hybrid solar–battery systems for uninterrupted power supply.

Benefits

- Reduction in indirect carbon emissions.
- Lower electricity costs over time.
- Improved energy security.
- Enhanced compliance with renewable energy policies.

Green Transportation Corridors

Transportation of iron ore is often the largest operational source of greenhouse gas emissions and dust pollution.

Proposed Measures

- Develop dedicated ore transportation routes.
- Replace truck transport with conveyor belts or slurry pipelines where feasible.
- Plant multi-row native tree belts along transportation corridors.
- Install dust suppression systems at loading and unloading points.
- Encourage the use of LNG-, CNG-, or electric-powered haulage vehicles.

Environmental Benefits

- Reduced diesel consumption.
- Lower particulate matter emissions.
- Improved landscape aesthetics.
- Enhanced carbon sequestration.
- Reduced disturbance to wildlife.

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Forest Restoration

Ecological restoration should begin during active mining rather than waiting until mine closure.

Native Species Plantation

Rehabilitation should prioritize indigenous tree species adapted to local ecological conditions.

Recommended Species : Teak (Tectona grandis), Mahua (Madhuca longifolia), Tendu (Diospyros melanoxylon), Ain (Terminalia tomentosa), Bamboo (Dendrocalamus strictus), Salai (Boswellia serrata), Char (Buchanania lanzan) , Arjun (Terminalia arjuna)

Advantages

- Higher survival rates.
- Improved biodiversity.
- Better wildlife habitat.
- Greater carbon sequestration.
- Enhanced ecosystem resilience.

Assisted Natural Regeneration (ANR)

Instead of relying solely on artificial plantations, ANR promotes the recovery of existing vegetation by protecting natural seedlings and improving growing conditions.

Activities

- Removal of invasive weeds.
- Soil and moisture conservation.
- Protection from grazing.
- Fire prevention.
- Controlled human access.

Benefits

- Lower restoration costs.
- Improved genetic diversity.
- Faster ecological recovery.
- Long-term sustainability.

Biodiversity Parks

Dedicated biodiversity conservation zones should be developed near mining areas to compensate for habitat loss.

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Components: Native tree plantations, Wetland ecosystems, Butterfly gardens, Medicinal plant conservation areas, Seed banks, Environmental education centres,

Benefits

- Conservation of rare flora and fauna.
- Ecological research opportunities.
- Nature education and eco-tourism.
- Enhanced landscape connectivity.

Wildlife Corridors: Mining infrastructure can fragment wildlife habitats and obstruct animal movement.

Proposed Measures

- Preserve natural forest strips connecting habitats.
- Construct underpasses and overpasses where roads intersect wildlife routes.
- Install wildlife-friendly fencing where necessary.
- Restrict mining operations during sensitive breeding seasons.

Benefits

- Reduced habitat fragmentation.
- Improved genetic exchange.
- Reduced human–wildlife conflict.
- Conservation of threatened species.

Water Conservation: Mining significantly alters hydrological processes; therefore, integrated water resource management is essential.

Rainwater Harvesting: Capture and store rainwater for operational and ecological use.

Infrastructure: Rooftop harvesting systems, Surface reservoirs, Recharge pits, Check dams.

Benefits

- Reduced groundwater extraction.
- Increased water availability during dry seasons.
- Improved watershed health.

Mine Pit Water Reuse: Mine pits often accumulate large quantities of rainwater.

Possible Uses

- Dust suppression.
- Ore processing.

- Equipment washing.
- Fire protection.
- Plantation irrigation.

Benefits

- Reduced freshwater demand.
- Lower operational costs.
- Improved water-use efficiency.

Artificial Recharge Structures : Groundwater depletion can be mitigated through recharge interventions.

Recommended Structures

- Recharge wells.
- Percolation tanks.
- Recharge trenches.
- Injection wells.

Expected Outcomes

- Increased groundwater levels.
- Improved drinking water availability.
- Enhanced stream baseflow during dry periods.

Sedimentation Ponds : Runoff from mining areas often contains suspended sediments.

Functions

- Trap sediments before water enters natural streams.
- Reduce turbidity.
- Improve downstream water quality.
- Protect aquatic ecosystems.

Regular desilting should be undertaken to maintain efficiency.

Dust Control : Airborne dust is a major environmental issue associated with iron ore mining.

Water Sprinkling : Regular spraying of haul roads, stockpiles, and loading areas using treated mine water can suppress dust emissions.

Advantages

- Immediate reduction in PM_{10} and $PM_{2.5}$ concentrations.

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- Improved visibility.
- Better occupational health.

Covered Transport : Iron ore should be transported in covered trucks or enclosed conveyor systems.

Benefits

- Reduced wind-blown dust.
- Lower material losses.
- Cleaner roadside environment.

Green Belts: Multi-layered plantations around mines and transport corridors can act as biological filters.

Recommended Characteristics

- Width of 20–50 m depending on site conditions.
- Native evergreen and deciduous species.
- Dense canopy with shrubs and grasses.

Benefits

- Dust interception.
- Noise attenuation.
- Carbon sequestration.
- Improved microclimate.

Road Paving: Unpaved haul roads are significant dust sources.

Measures

- Asphalt or concrete paving of major roads.
- Regular maintenance to prevent potholes.
- Installation of wheel-washing facilities at mine exits.

Benefits

- Lower dust emissions.
- Reduced vehicle maintenance costs.
- Improved transportation efficiency.

Community Participation: Local communities are key stakeholders in sustainable mining.

Joint Forest Management (JFM) : Strengthen partnerships between the Forest Department, mining companies, Gram Sabhas, and local communities.

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Activities

- Afforestation.
- Fire prevention.
- Forest protection.
- Sustainable harvesting of non-timber forest products.

Tribal Employment: Provide priority employment and skill development for local tribal populations.

Opportunities

- Nursery management.
- Plantation work.
- Environmental monitoring.
- Eco-restoration.
- GIS and drone operations.
- Water resource management.

Benefits

- Livelihood enhancement.
- Reduced migration.
- Increased local ownership of conservation initiatives.

E.3 Eco-Development Committees (EDCs): Establish village-level committees to support environmental management.

Responsibilities

- Biodiversity conservation.
- Waste management.
- Water conservation.
- Awareness campaigns.
- Monitoring environmental compliance.

F. Technology-Based Environmental Monitoring : Advanced technologies enable continuous, accurate, and transparent monitoring of mining impacts.

F.1 GIS Mapping: Geographic Information Systems (GIS) can be used to monitor:

- Land use and land cover changes.

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- Forest fragmentation.
- Wildlife habitats.
- Watershed dynamics.
- Infrastructure expansion.

GIS supports evidence-based environmental planning and regulatory compliance.

F.2 Remote Sensing: Satellite imagery from platforms such as Sentinel-2, Landsat-8/9, and MODIS enables periodic assessment of:

- Forest cover.
- Vegetation health (NDVI).
- Land Surface Temperature (LST).
- Surface water bodies.
- Mine expansion.

Remote sensing provides cost-effective, large-scale monitoring over time.

F.3 Drone Surveillance: Unmanned Aerial Vehicles (UAVs) can support:

- High-resolution mapping.
- Mine inspection.
- Stockpile measurement.
- Illegal encroachment detection.
- Wildlife habitat surveys.
- Monitoring of rehabilitation sites.

Drone imagery complements satellite observations with greater spatial detail.

Policy Recommendations

1. Mandatory annual biodiversity audits.
2. Real-time environmental monitoring.
3. Net Gain Biodiversity approach.
4. Compensatory afforestation using native species.
5. Carbon accounting for mining companies.
6. Community participation in environmental governance.
7. Independent ecological impact assessments every five years.

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CONCLUSION

The Surjagarh Iron Ore Project presents both developmental opportunities and environmental challenges. While mining contributes to economic growth, employment, and industrial development, it also exerts pressure on forests, biodiversity, water resources, and the local climate. Sustainable mining practices, effective environmental governance, scientific reclamation, and meaningful participation of indigenous communities are essential for minimizing adverse impacts. A balanced approach integrating climate adaptation, ecological restoration, and responsible resource extraction can ensure that economic development proceeds without compromising the ecological integrity of the Surjagarh landscape.

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