'An Investigation into Initiatives for Sustainable Development of Manganese Mining in Madhya Pradesh State'

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Contents

1. Introduction
2. Objective
3. Present status of Manganese Mining,
4. Sustainable Development in Mining & Mining of Manganese in MP & Selection of mines as a part of this Research work
5. Introducing the 3 Mines
6. Methodology adopted to study the various aspects of SDGs and adopting LIFE CYCLE ASSESSMENT as a method of studying SDGs in the study areas
7. Highlights on major areas
8. Conclusions and Discussions
9. Future Areas of Research which could not be covered

Introduction

Mining contributes over 2.5% of our GDP and is one of the key sectors to provide direct andin-direct employment to millions. It plays a key role in power, steel, fertilisers, infrastructure development. When we talk of steel sector, Manganese is one of the of the essential raw materials used in steel making. Its availability and also its mining continues to be an area of concern.

Madhya Pradesh is one of the major producer of Manganese from Balaghat, Jhabua districts where number of mines are under production.

OBJECTIVE OF THE STUDY

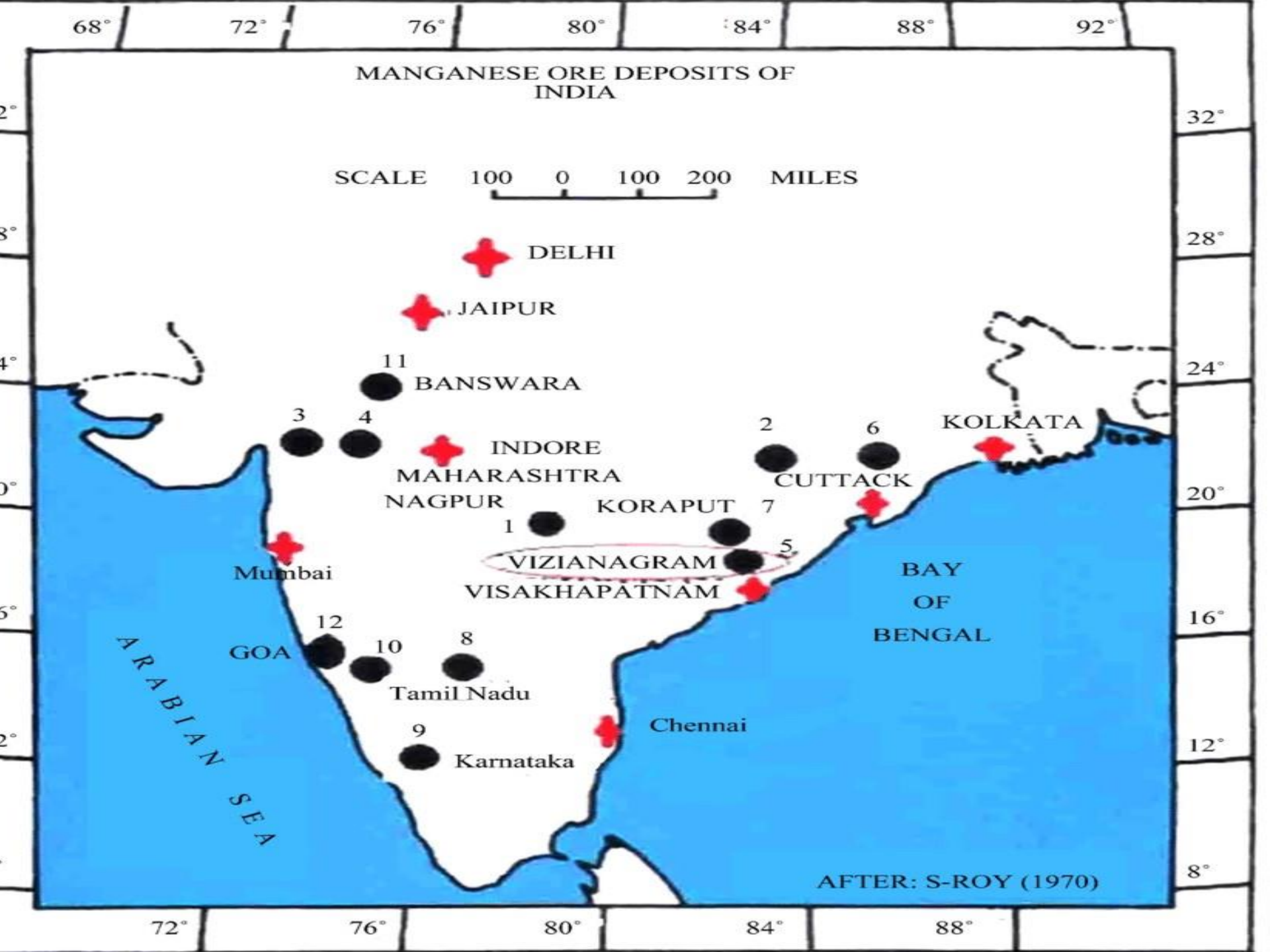
The Objective has been to present the trend of Manganese production in India, especially in the State of Madhya Pradesh from small scale with semi-mechanised mining methods.

Following shall be objectives of study -

i. Study of opencast manganese mining of Madhya Pradesh in general, trends of production and growth.
ii. Study of Sustainable development Goals in respect of selected opencast manganese mines of Madhya Pradesh state to compare the resource utilisation, optimisation of energy, impact on environment with social & Economical aspects.
iii. Collection of data based on life cycle analysis to quantify impact on sustainability in selected Manganese mines.
iv. Suggestion to further improve the sustainability of opencast manganese mines in Madhya Pradesh in general and in the country as a whole.

SCOPE AND LIMITATION

Using life cycle assessment, a comprehensive analysis of environmental, economic, social, technological and regulatory factors across all stages of the mining processes are being investigated. However, limitations viz. data quality, methodological constraints and regulatory uncertainties can affect the comprehensiveness & accuracy of the assessment.

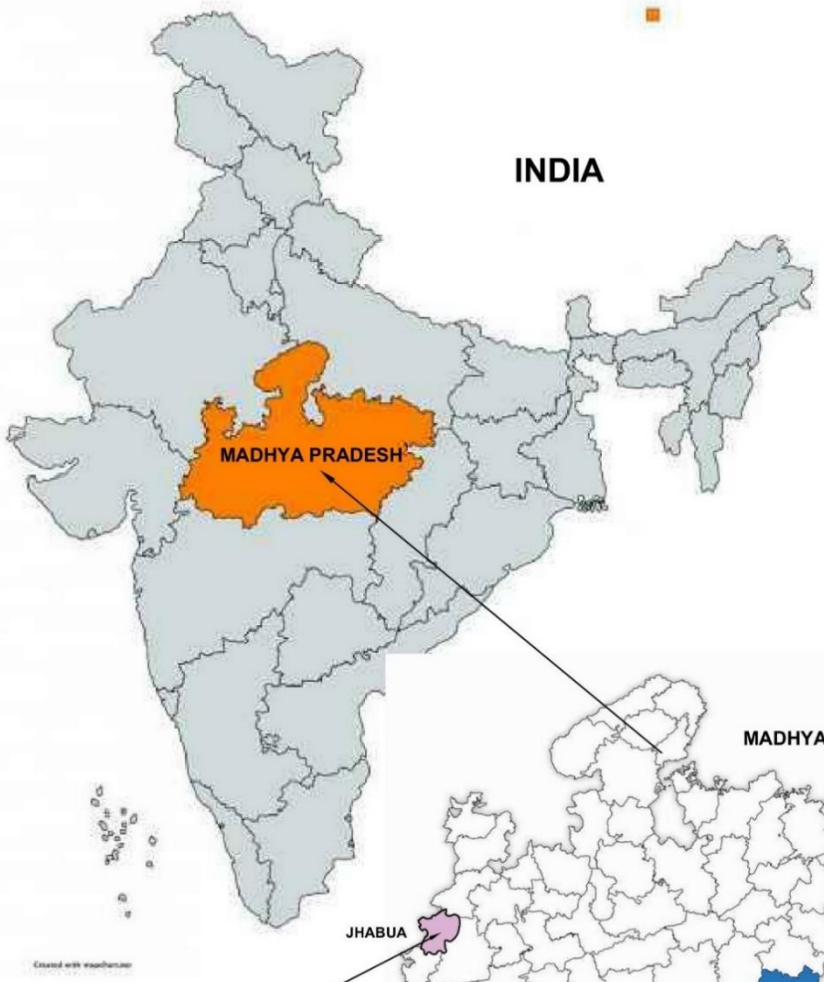

MANGANESE ORE DEPOSITS OF INDIA
SCALE 100 0 100 200 MILES
DELHI
JAIPUR
11
BANSWARA
3
4
INDORE
MAHARASHTRA
NAGPUR
2
6
CUTTACK
KOLKATA
KORAPUT
7
1
5
VIZIANAGRAM
VISAKHAPATNAM
Mumbai
BAY
OF
BENGAL
12
GOA
10
8
Tamil Nadu
Chennai
9
Karnataka
ARABIAN SEA
AFTER: S-ROY (1970)
68°
72°
76°
80°
84°
88°
92°
32°
28°
24°
20°
16°
12°
8°

THE CURRENT STUDY FOCUSES –

on surface mining, specifically opencast mines, which require significant land area for various operations such as infrastructure development, waste dumping, and stockpile maintenance. Despite the need for extensive land, these mines are cost-effective and provide numerous job opportunities. They also allow for quicker and safer production commencement. However, opencast mining comes with its own set of challenges, including land availability, deepening of mine workings, longer hauling distances for ore and waste, leading to increased diesel consumption by heavy earth moving machinery (HEMM), and depletion of economically viable ore reserves at accessible depths. These challenges are addressed in the research from technological, economic and social perspectives.

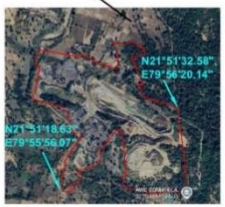
TO ADDRESS CHALLENGES IN MINING,

A transition from opencast to underground methods is being examined for its impact on resource utilization, energy optimization, environmental effects, and socio-economic factors. By January 2024, only two out of 41 small-scale opencast mines- the Ramrama and Palaspani manganese mines—have transitioned to underground operations, while the Kajli-Dongri mine is in planning for a similar shift. This transition has supported employment retention and mineral conservation.



Kajli Dongri Mn Mine
Lessee - M/s SR Ferro Alloys, Jhabua.
Area - 30.86 hect.

Palaspani Mn Mine
Lessee - M/s Krishnaping Alloys Limited, Pandhurna.
Area - 54.129 hect.



Ramrama Mn Mine
Lessee - M/s AP Trivedi Sons, Balaghat.
Area - 45.538 hect.

Figure 1 : The Global Goals for Sustainable Development(Source: UN)

TOWARDS SUSTAINABLE MINING Through –

Self-Assessment

- Internal Evaluation

This involves a comprehensive examination of their operations, policies, and practices

External Verification

- Independent Third-Party Verification: After completing the self-assessment, companies undergo external verification conducted by independent third-party assessors
- Site Visits and Audits: External verifiers conduct on-site visits and audits to verify the accuracy of the self-assessment data and assess the implementation of TSM principles at the operational level.

Verification Against TSM Protocols

- Protocols and Indicators: TSM provides conservation, and others.
- Verification against Protocols: The external verification process ensures that mining companies are meeting the established protocols and achieving the performance indicators set by TSM.

- Tier System: TSM uses a tiered system to categorize the level of performance. The tiers range from Level A (basic compliance) to Level AAA (industry leaders demonstrating continuous improvement). Companies aim to achieve higher tiers by demonstrating excellence in implementing sustainable practices.

Public Reporting:

- Transparent Reporting: Companies publicly report the results of their self-assessment, external verification, and performance against TSM protocols. This transparency is a key element of the program, providing stakeholders, including communities, investors and the public, with information about a company's sustainability performance.

Continuous Improvement

- Feedback and Improvement: TSM encourages continuous improvement. Companies receive feedback from the verification process, identifying areas for improvement and best practices. This feedback loop is essential for fostering a culture of ongoing sustainability enhancement within the mining industry.

Sustainable Development Framework – Indian Initiative

The Ministry of Mines developed a credible system of evaluation of mining footprints and instituted the Sustainable Development Framework (SDF) for taking up mining activity under its umbrella, encompassing inclusive growth without adversely affecting the social, economic and environmental well-being at present and also in future generation. Implemented through Indian Bureau of Mines

A two-tier system has been established for SDF, with mine operators completing self-evaluation templates, followed by validation by the Indian Bureau of Mines. The self-appraisal includes four modules for leaseholders to complete.

- **Module I**: Managing Impacts at the Mine Level
- **Module II**: Final/ Progressive Mine Closure and Landscape Restoration
- **Module III**: Addressing Social Impacts of R&R Requirements, Community Engagement and Welfare Programs
- **Module IV**: Assurance and Reporting

Identifying gaps for the sustainable development of opencast manganese mining in Madhya Pradesh it involves understanding areas where current practices or policies may fall short in achieving long-term environmental, social, and economic sustainability. Some potential gaps could include:

1. Environmental Impact Assessment (EIA)
2. Rehabilitation and Reclamation
3. Community Engagement
4. Monitoring and Enforcement
5. Water Management
6. Health and Safety
7. Biodiversity Conservation
8. Technology Adoption

Methodology

Based on a thorough literature review and the principles underlying **LIFE CYCLE ASSESSMENT (LCA) S**USTAINABILITY within the context of mining was assessed/evaluated. , a methodology is adopted focusing on key dimensions-

- resource utilization,
- energy consumption,
- environmental impact,
- social aspects, and
- economic viability.

The Primary investigation focused on

- physical survey and
- data collection.

To understand the socio-economic impact of surrounding villages.

LIFE CYCLE ASSESSMENT of small-scale manganese mining which is fully/Partially or under-planning for transition from opencast method mining to underground mining shall be studied based on resource utilisation, energy utilisation and optimization, environmental impact caused from opencast mining along with socio-economic analyses.

The adoption of life cycle assessment (LCA) methodologies in mining, popularized by Farjana et al. (2021) is being adopted for research. For this study, three different Small-Scale manganese mines in Madhya Pradesh are selected situated in rural area.

Methodology explained in the next slide -

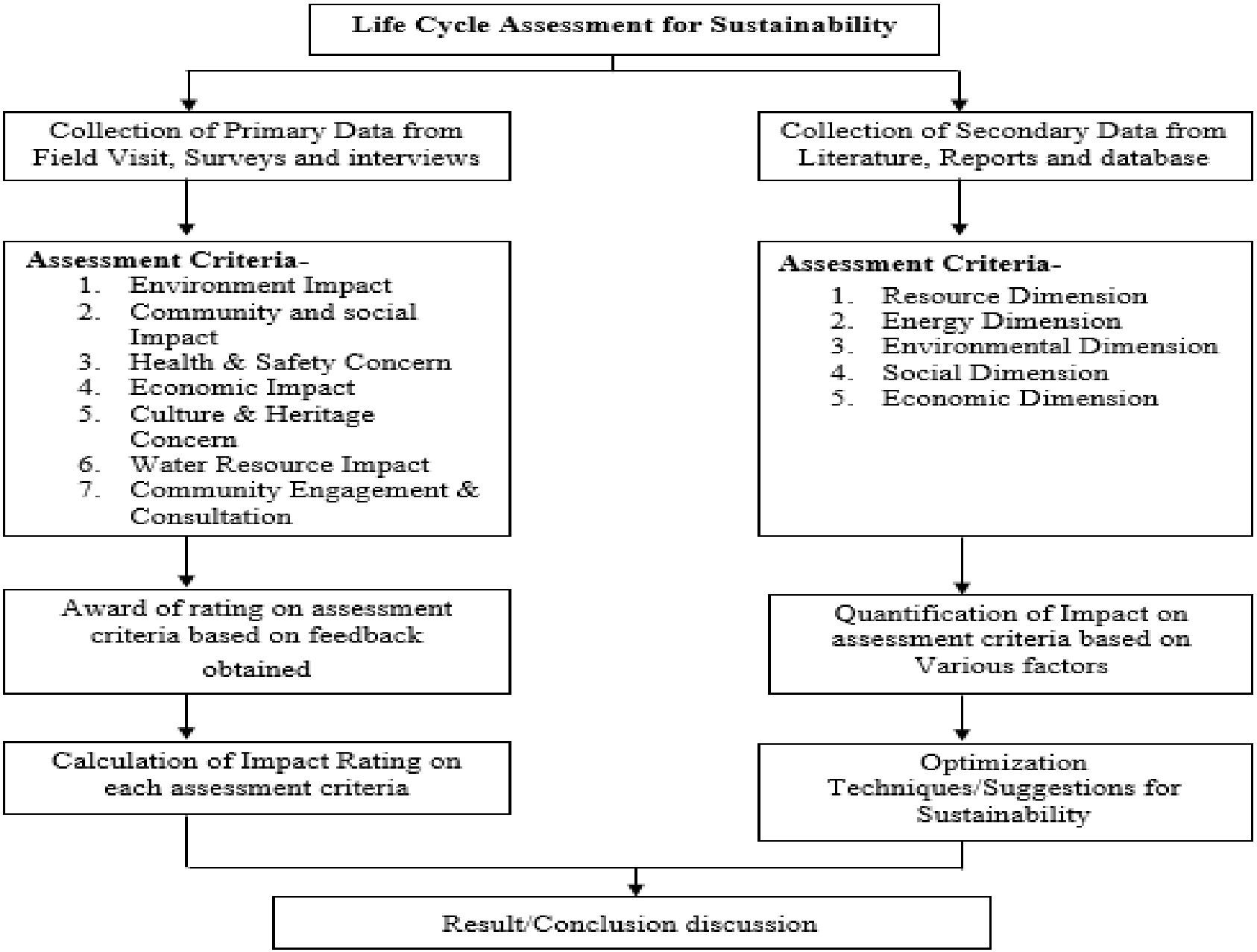


Figure-3.1: Flow Chart for the Research methodology

Data Analysis Technique

Feedback from personal interview on mining and their impact on social, environment and economy of the area was done for the selected research area. Based on feedback from respondents, the impact rating were allocated to assessment criteria as per there positive and negative impact. A comprehensive representation of what impacts may exist from mining, but indicate the ground level impacts that respondents were aware of, had experienced and were concerned about. Impact rating can be sub-divided into:

- **None- where respondents reported there were no impacts.**
- **Minor- where respondents reported the impacts were easily within their capacity to address, of minimal concern and temporary.**
- **Moderate- where respondents reported the impacts required attention and outside assistance.**
- **Major- where respondents reported the impacts were outside of their capacity to address, ongoing after mining activities had ceased and possibly irreversible.**

Impact score to be given as per severity rating and calculation to be made as per Rating-

Impact Rating	Score
None	0
Minor	1-2
Moderate	3-5
Major	5

The overall impact rating were sub divided into three categories as-

Minor- When overall impact rating is IR<30

Moderate- When overall impact rating is 30>IR<70

Major- When overall impact rating is IR>70

The Conclusion and discussion based on impact rating and score obtained through personal and analysis of impact rating was done to arrive at which mine is sustainable in all the assessment criteria.

CASE STUDY

To address the SUSTAINABLE related to mining of Manganese Mining in Madhya Pradesh three Opencast Mines situated in different district are selected for the research work, selected mines have been worked with opencast method of mining and consequently converted into underground mining due to different geological and economic challenges present with current mining practice. The impact created with opencast mining and impact created by change in method of mining can be understand with data interpretation for last one decade, field data collected during the study period.

Three figures in next slides show their locations. Table below gives a brief outline on them.

Name of Mine	Village	District	Lease Area (Hect)	Production Capacity (TPA)
Ramrama Mn Ore mine M/s A.P. Trivedi Sons	Ramrama	Balaghat (M.P.)	43.086 Hect	90,000
Palaspani Mn Ore mine M/s Krishnaping Alloys Ltd.	Palaspani	Pandhurna (M.P.)	54.129 Hect	84,000
Kajli Dongri Mn Ore mine M/s S.R. Alloys Ltd	Kajli Dongri	Jhabua (M.P.)	30.860 Hect	1,50,000

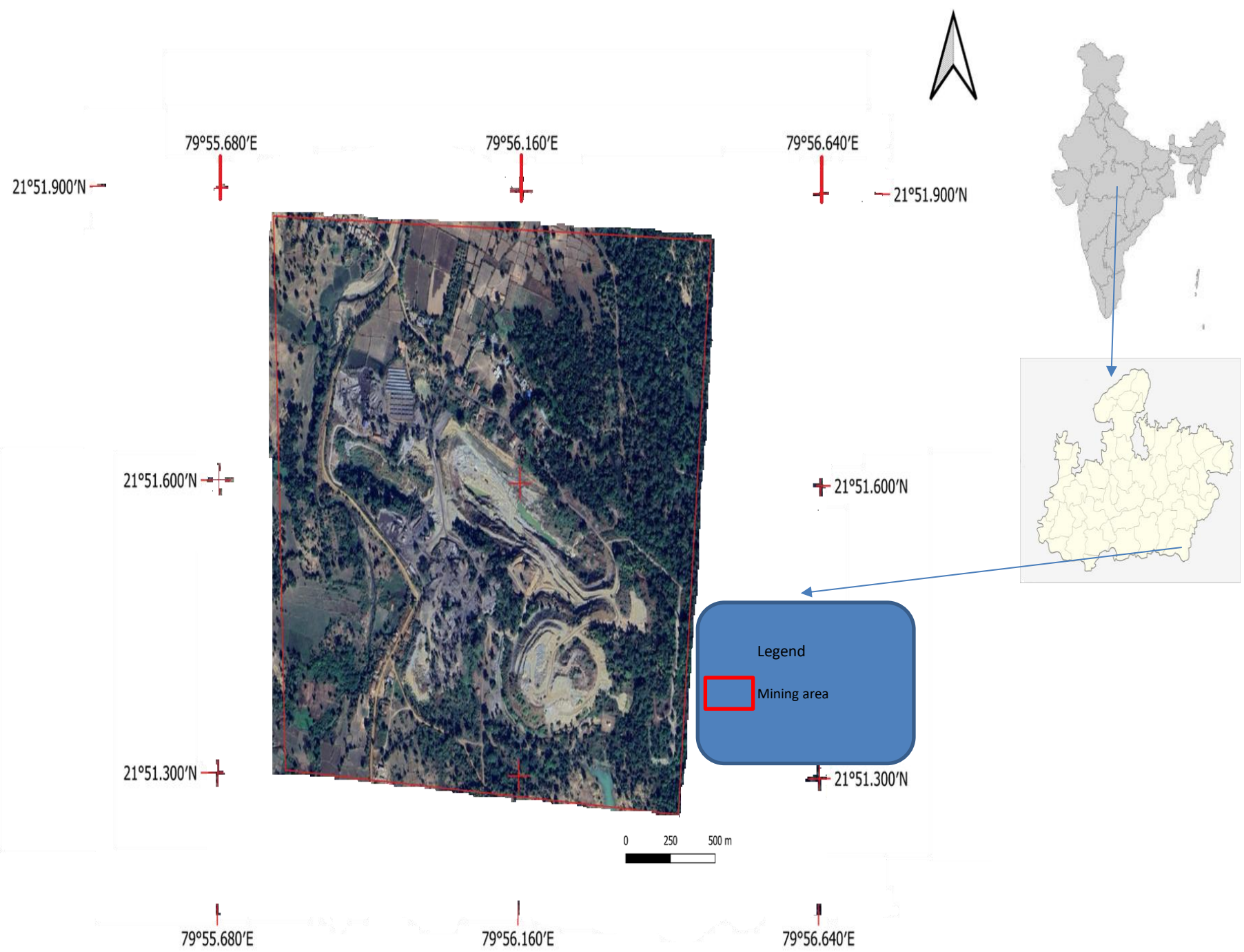


Figure 4.1 Location map of Ramrama Mn ore mine

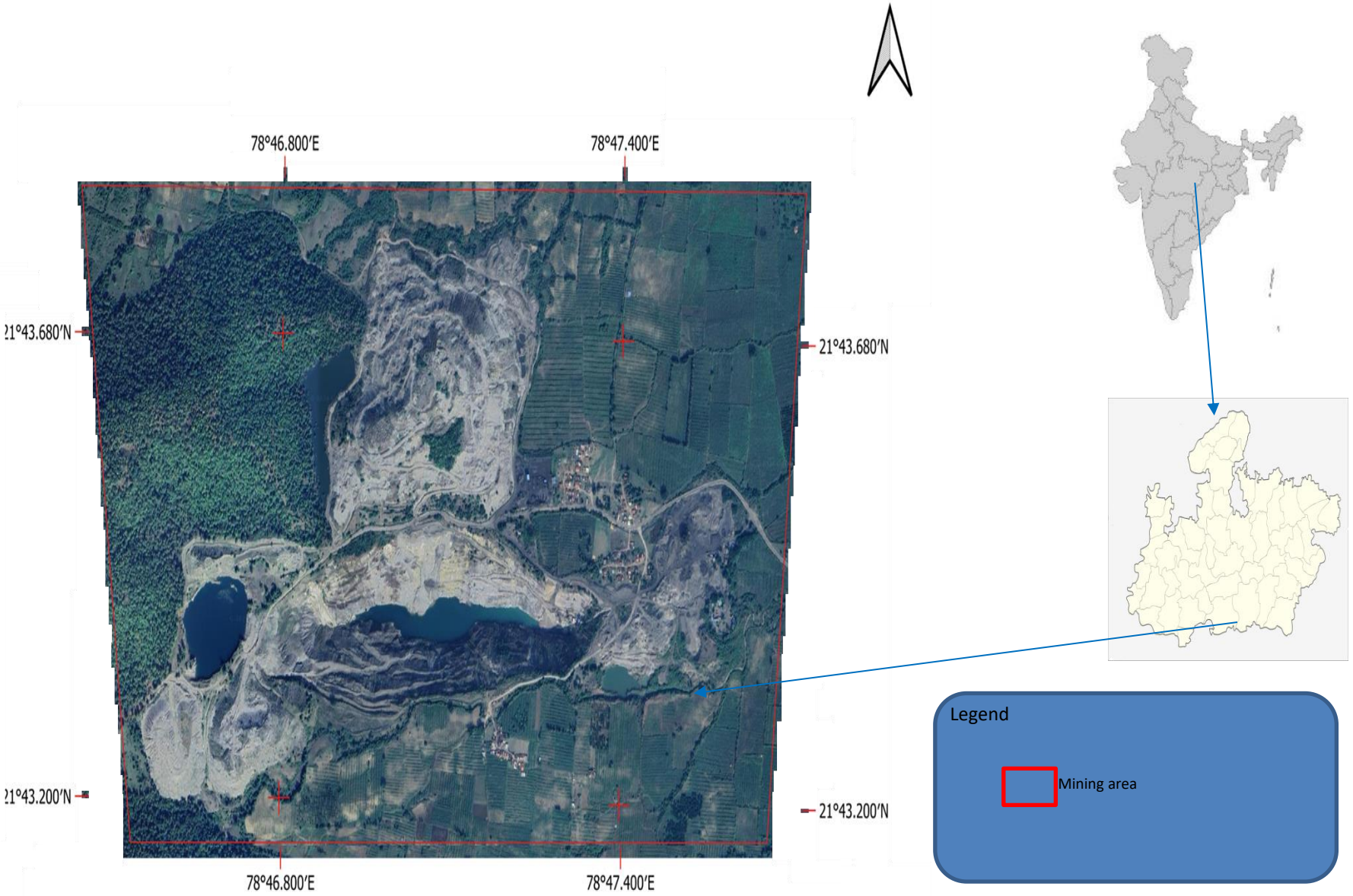


Figure 4.2 Location Map of Palaspani Mn ore mine

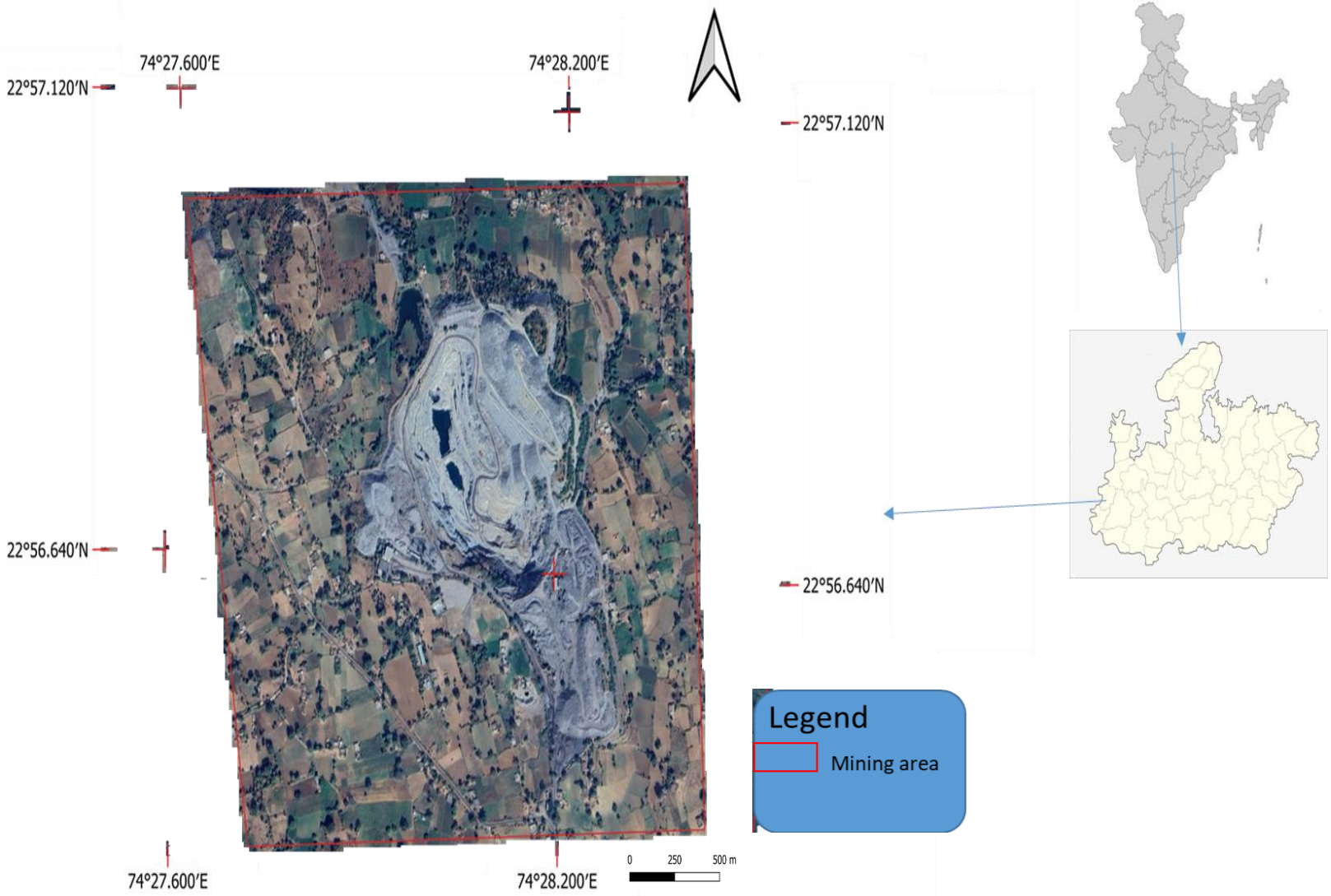


Figure 4.3 Location Map of Kajli Dongri Mn ore mine

PRIMARY

DATA COLLECTION & PROCESSING.

Preparation of Questionnaire: A comprehensive questionnaire is designed to address multiple parameters, including environmental impact, community and social effects, health and safety concerns, economic impacts, cultural and heritage considerations, water resource impacts, and community engagement.

Impact Scoring: Feedback from the interviews is used to rate each parameter on a scale from 1 to 10. The impact is classified into categories such as none, minor, moderate or major based on the scores. This helps in quantifying the extent of each impact.

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Summarization of Impact Ratings: The impact ratings are summarized to provide an overall impact score for each parameter. This step involves aggregating the feedback and ratings to get a clear picture of the mining impacts on the communities

Calculation of Overall Impacts: An overall impact calculation is performed for each parameter based on the summarized ratings. This provides a comprehensive view of how the mining activities affect different aspects of the local environment and community.

Sustainability Comments: Based on the calculated impact scores, comments and recommendations for sustainability are provided. These insights help in addressing the concerns raised by the community and in planning future actions to mitigate adverse impacts. This structured approach ensures a thorough assessment of the mining activities' effects on local villages and helps in developing strategies for sustainable mining practices.

At the Table 4.2 Summary of feedback obtained through 145 personal interviews for all the 3 mines were presented. As a sample data for Ramrama mine is below & Summary formother 2 mines. Ratings show the Impact Score of local environment and community. Higher score is not acceptable for Sustainability.

Mine-	Ramrama Mn Ore mine, Balaghat Total No. of Interview- 46		
Village Name	Ramrama	Katanjirri	Sirra
No. of interviews	16	20	10
1. Environmental Impact			
Soil Disturbance-	Minor	Minor	Minor
Land Use -	Minor	None	Minor
Vegetation fertility-	None	None	None
Water Quality-	None	Minor	Minor
2. Community and Social Impact			
Displacement of Communities-	None	None	None
Noise & Dust Pollution-	Minor	None	Minor
3. Health and Safety Concern			
Air Quality-	Minor	Moderate	None
Safety Hazards-	None	None	None
4. Economic Impact			
Employment Opportunities-	None	Moderate	Minor
Impact of Livelihood-	None	Minor	Minor
5. Cultural & Heritage Concern			
Cultural Sites-	None	None	None
6. Water Resource Impact			
Water Depletion-	Minor	Minor	Minor
Water Contamination-	Minor	Minor	Minor
7. Community Engagement & Consultation			
Public Participation-	Minor	Minor	Moderate

Table 4.3 Summary of Severity Rating

Mine-	Ramrama Mn Ore mine, Balaghat Total No. of Interview- 46		
Village Name	Ramrama	Katanjirri	Surra
None	7	6	5
Minor	7	6	8
Moderate	0	2	1

Table 4.4 Calculation of Overall impact Score

Mine-	Ramrama Mn Ore mine, Balaghat Total No. of Interview- 46		
Village Name	Ramrama	Katanjirri	Surra
None	14	12	10
Minor	35	30	40
Moderate	0	16	8
Major	0	0	0
Overall Impact Score-	**49**	**58**	**58**

Overall Impact Score of Palaspani

77	93	95

Overall Impact Scorwe of Kajli Dongri

152	142	145	152

Table 4.3 Summary of Severity Rating

Mine-	Ramrama Mn Ore mine, Balaghat Total No. of Interview- 46			Palaspani Mn Ore mine, Sausar Total No. of Interview- 43			Kajli Dongri Mn Ore mine, Jhabua Total No. of Interview- 56			
Village Name	Ramrama	Katanjirri	Surra	Tinkheda	Khairi	Borgaon	Rasodi	Nangavat	Pipalkutta	Piplода
None	7	6	5	5	4	2	1	1	1	1
Minor	7	6	8	4	3	4	1	2	1	1
Moderate	0	2	1	4	5	7	5	5	6	5
Major	0	0	0	1	2	1	7	6	6	7

Table 4.4 Calculation of Overall impact Score, Ramram had the best score due to transition to UG

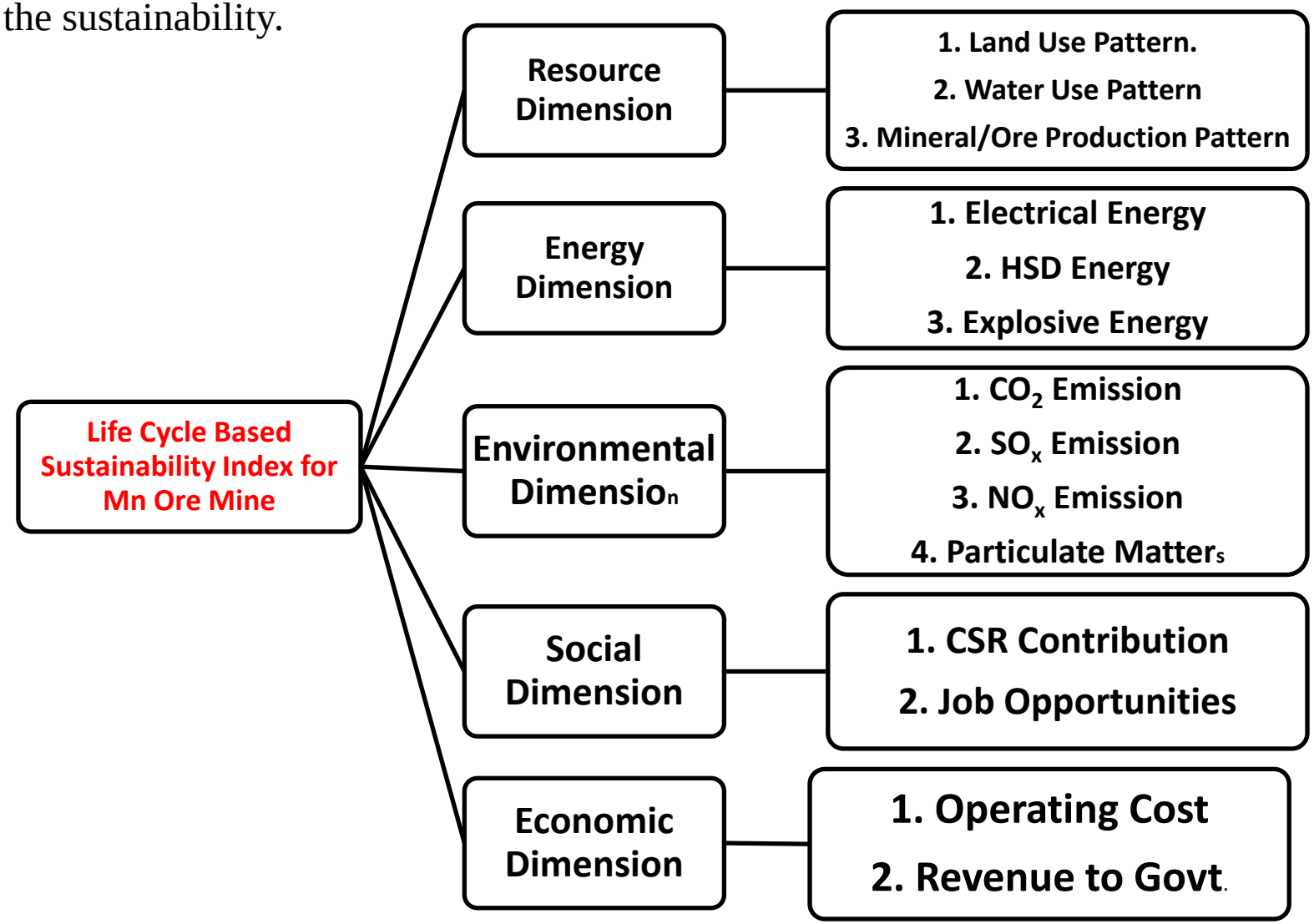
Mine-	Ramrama Mn Ore mine, Balaghat Total No. of Interview- 46			Palaspani Mn Ore mine, Sausar Total No. of Interview- 43			Kajli Dongri Mn Ore mine, Jhabua Total No. of Interview- 56			
Village Name	Ramrama	Katanjirri	Surra	Tinkheda	Khairi	Borgaon	Rasodi	Nangavat	Pipalkutta	Piplода
None	14	12	10	10	8	4	2	2	2	2
Minor	35	30	40	20	15	20	5	10	5	5
Moderate	0	16	8	32	40	56	40	40	48	40
Major	0	0	0	15	30	15	105	90	90	105
Overall Impact	49	58	58	77	93	95	152	142	145	152

Collection of Secondary Data

According to the literature on **Life Cycle Assessment (LCA)** and its associated concepts, sustainability indices can significantly differ across industries and organizations.

To address these variations, **a methodology has been adopted that evaluates sustainability** from multiple dimensions: resource use, energy consumption, environmental impact, social implications, and economic contributions. The LCA system is meticulously designed to examine various subcomponents within these dimensions.

An LCA framework has been developed for each of these mines to assess their impacts and contributions across environmental, social, and economic dimensions. This comprehensive approach allows for a detailed analysis of the sustainability aspects of manganese mining in Madhya Pradesh, focusing on the specific impacts and benefits associated with each mining operation. A comparative analysis of various sub- dimensions of framed LCA shall be studied to ascertain the sustainability.



Social Dimension

1. CSR Contribution 2. Job Opportunities

i. In rural areas such as Ramrama, Palaspani, and Kajli Dongri, the benefits from Corporate Social Responsibility (CSR) activities play a crucial role in community development. Key areas such as infrastructure development, healthcare, sanitation, and literacy enhancement are essential for improving the quality of life. The transition to sustainable mining practices will ensure the continuity of these benefits for local communities, thereby fostering social sustainability in the region, similar to other areas

LCA framework RESOURCE DIMENSION

1. Land Use Pattern. 2. Water Use Pattern 3. Mineral/Ore Production Pattern

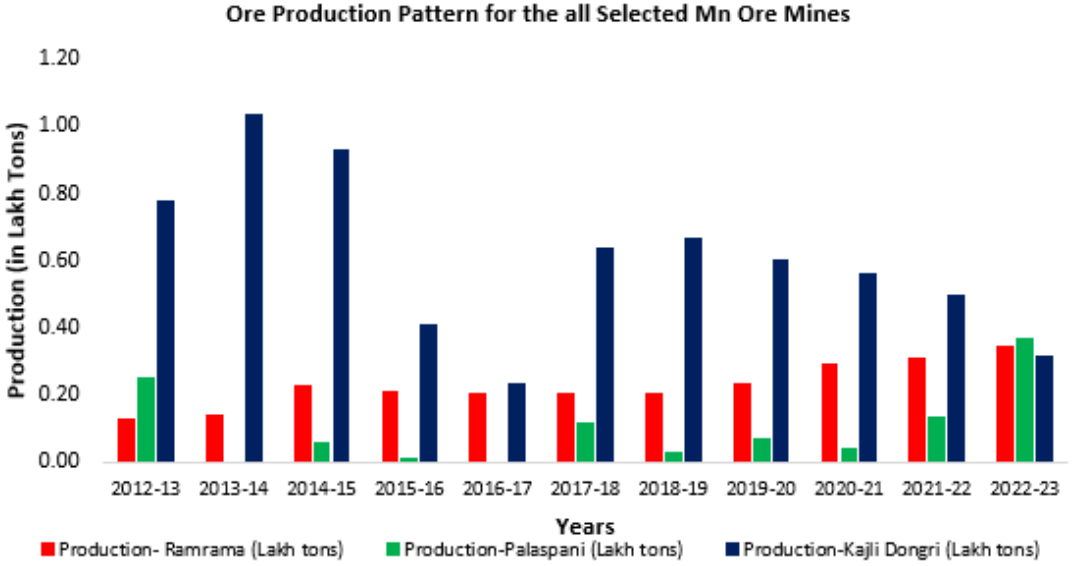


Figure 4.18 Comparison of Ore Production Pattern of the all selected Mn ore mines

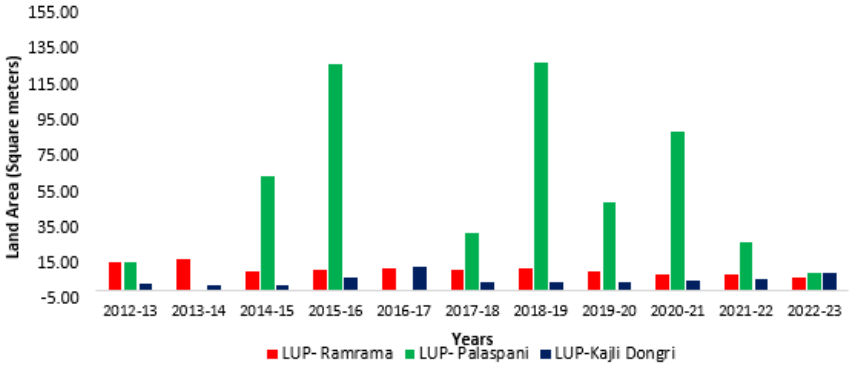


Figure 4.7 Comparison of land use pattern of selected Mn ore mines of Madhya Pradesh

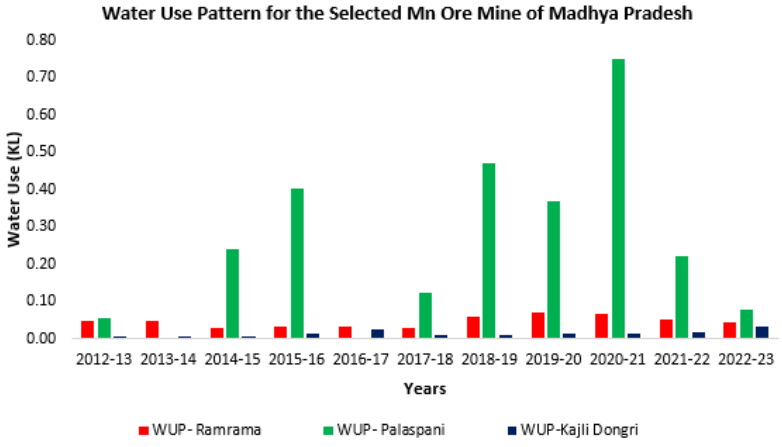


Figure 4.14 Comparison of Water use pattern (WUP) of selected Mn ore mines

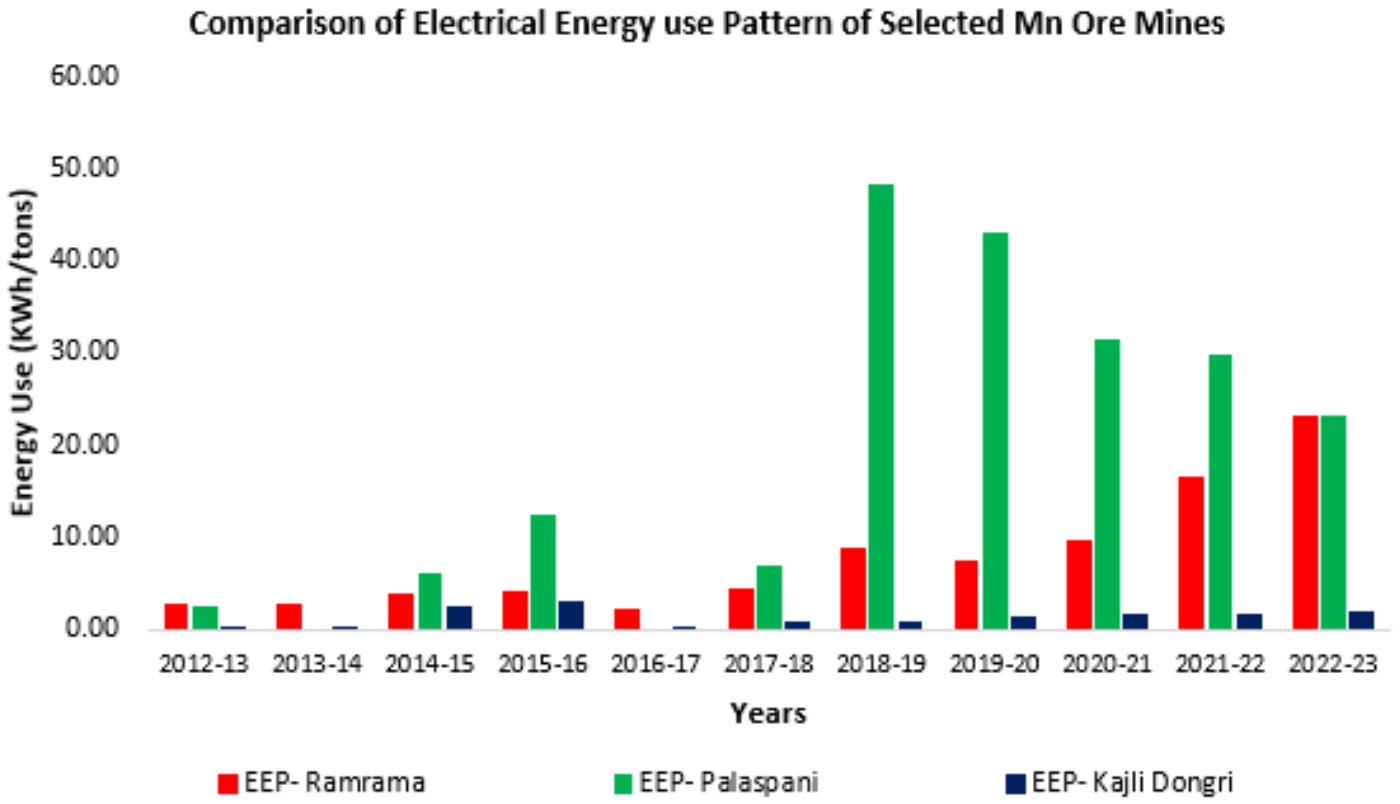
Energy Dimension –
1. Electrical Energy 2. HSD Energy 3. Explosive Energy

Life Cycle Assessment (LCA) studies indicate that a strategic shift from opencast to UG mining can significantly reduce carbon footprints, by decreasing reliance on high-speed diesel (HSD)-powered equipment. Research shows that replacing HSD equipment with electric alternatives in underground operations can reduce direct emissions by up to 40%. While UG mining increases the demand for electrical energy, this demand can be met sustainably- solar panel installations connected to the grid can supply 60-70% of the mine's energy needs.

Energy Efficiency & Conservation supported by Non-Conventional Sopurces of Energy has been a laudable initiative in all these 3 mines. STAR RATING also has taken this component into consideration.

Energy Dimension –
1. Electrical Energy 2. HSD Energy 3. Explosive Energy

When shift is from Opencast to UG due to develo work and low production Energy use is high. This is seen at Palaspani. Once mine is set for UG, energy use reduces. It is also having impact on Kg-CO2 Emission.



Energy Dimension –
1. Electrical Energy 2. HSD Energy 3. Explosive Energy

HSD consumption reduces drastically when UG is adopted as compared to Opencast Mining. It helps in reducing carbon foot print.

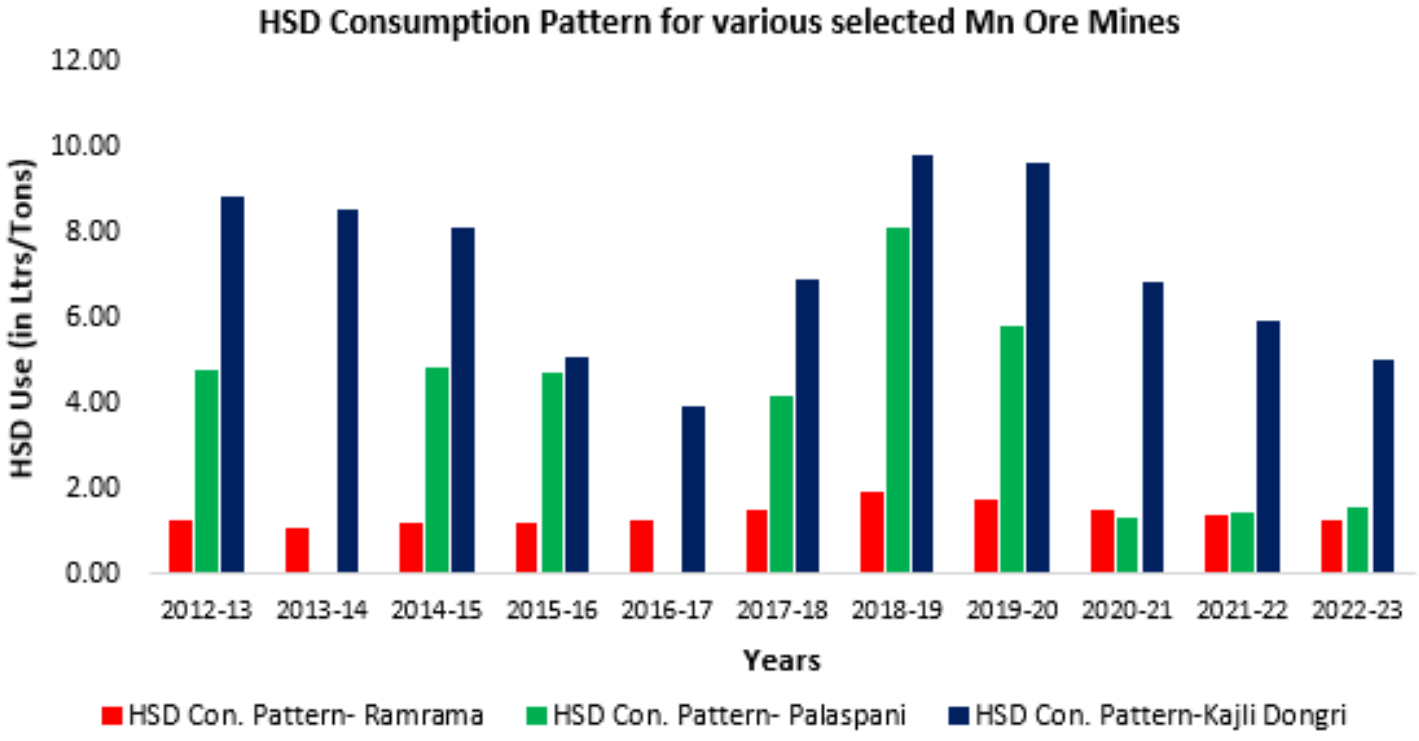


Figure 4.25 HSD Consumption pattern in various activity of all three selected Mn Ore mines

Environmental Dimension

1. CO_2 Emission 2. SO_x Emission 3. NO_x Emission 4. Particulate Matters

i. Environmental sustainability can be enhanced through initiatives such as efficient ore extraction and waste reduction, land rehabilitation with afforestation and barrier formation, and effective water recycling and reuse. These measures collectively help restore ecosystems and minimize environmental impact. Furthermore, transitioning to these practices can improve air quality. Studies indicate that pollutant levels are already below the standards set by the Central Pollution Control Board (CPCB), but further improvements are achievable through strategic initiatives.

Environmental Dimension

1. CO_2 Emission 2. SO_x Emission 3. NO_x Emission 4. Particulate Matters

UG mining has several advantages like sharp fall in dust, and other emissions

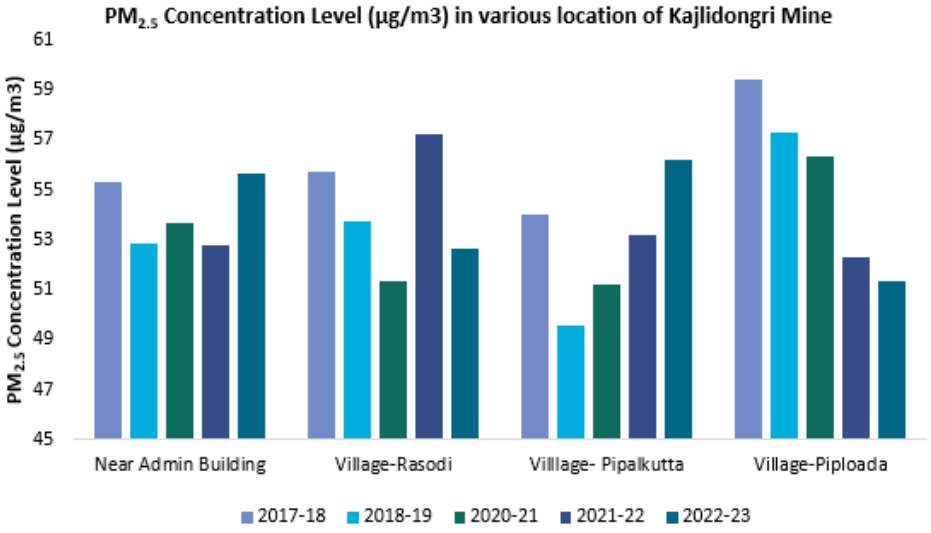


Figure 4.37 $PM_{2.5}$ Concentration level in Various location of Kajli Dongri mine

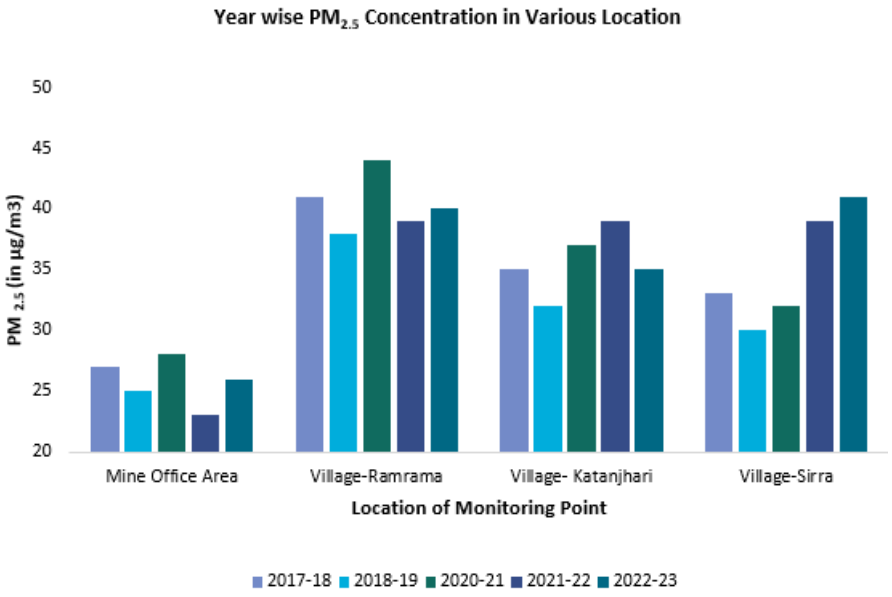


Figure 4.29 Year wise $PM_{2.5}$ Concentration in nearby Ramrama Mn ore mine

Social Dimension

1. CSR Contribution 2. Job Opportunities

i. In rural areas such as Ramrama, Palaspani, and Kajli Dongri, the benefits from Corporate Social Responsibility (CSR) activities play a crucial role in community development. Key areas such as infrastructure development, healthcare, sanitation, and literacy enhancement are essential for improving the quality of life. The transition to sustainable mining practices will ensure the continuity of these benefits for local communities, thereby fostering social sustainability in the region, similar to other areas

Social Dimension

1. CSR Contribution 2. Job Opportunities

Depleting ore in opencast result in higher cost and job loss plus loss of revenue for the Government to spend in the area. Shift to UG helps in improving economics.

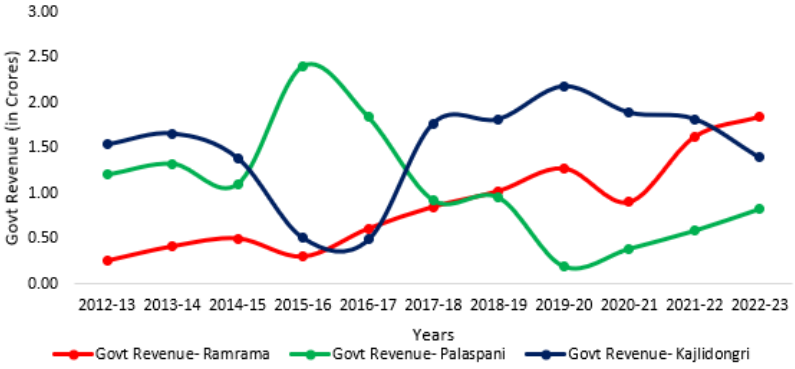


Figure 4.48 Trend of Revenue paid to govt in last one decade.

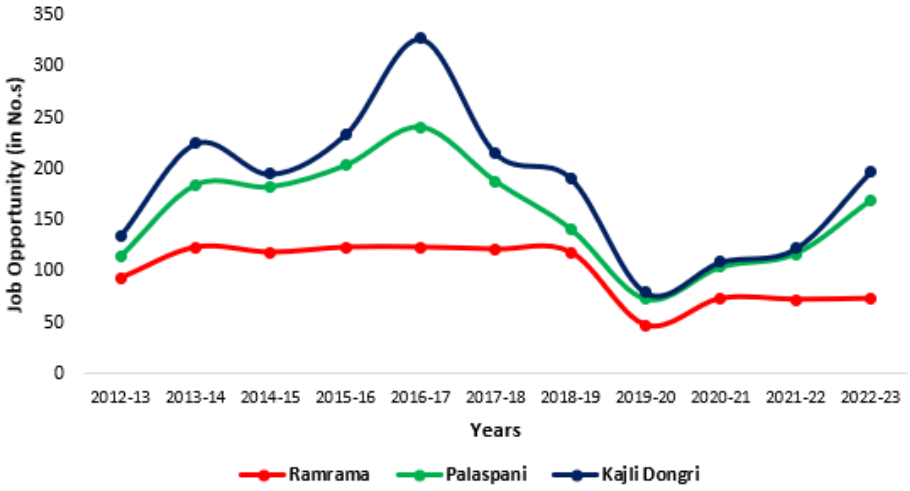


Figure - 4.40: Trend of job opportunities in the three selected mines

Integrating the concept of strategic transition will not only generate significant revenue but also act as a catalyst for both state and national economic growth. This contribution comes through royalties, DMF (District Mineral Foundation), NMET (National Mineral Exploration Trust), and dead rents. Additionally, it will stimulate the local and regional economy, attract investments, promote economic diversification, and support social development and poverty reduction. Ultimately, these efforts will contribute to the overall economic advancement of the nation.

A Life Cycle Assessment (LCA) an effective TOOL helped in assessing the SUSTAINABILITY of mining operations. There is an important role of advanced technologies for sustainability.

By improving resource utilization, land use pattern, and reducing waste, mining can become more efficient while decreasing energy consumption and promoting renewable energy. This shift not only minimizes the environmental footprint but also enhances social conditions by creating stable jobs, improving living standards, and providing better infrastructure. Economically, it stimulates growth in surrounding areas through increased efficiency and profitability. Overall, integrating sustainable practices benefits the environment, communities, and the economy.

6.2 Recommendations for future work The following recommendations aim to enhance the life cycle assessment (LCA) processes in the context of sustainable development for opencast mining operations:

1.Development of Standardized Characterization Models: There is a pressing need to create standardized characterization models specifically for impacts relevant to mining.

2.Further Research on Impact Categories: Additional research is essential to evaluate other life cycle impact categories for emissions.This help to bridge existing gaps in life cycle inventory (LCI) data for mining products.

3.Assessment of Individual Mining Processes: It is vital to assess the impacts of individual processes within mining operations. Current assessments often treat mining as a singular process, which limits the ability to identify and scrutinize critical stages in mining activities

4. Expanded Coverage of Mining Sites: Increasing the number of mines included in LCA studies is necessary.

5.Site-Measured Data Collection: The collection of site-specific measured data is

Mineral Conservation and Development Rules, 2017(Annexure 1) has an exclusive chapter on Sustainable Mining. A quick look of Fig.1, clearly indicate that for Coal Mining – the need is for -

1&2. Wages & Duties etc (as per Sl. No.1 & 2)

3&6. Health & Sanitation (Swacch Bharat, Health of mine workers and sanitation to be extended by the Owner, Agent or Manager, funding from CSR and/or District Mineral Foundation)

4. Quality Education to the existing workforce, newcomers, students who are groomed to join the industry in various mining activities (both statutory & non-statutory), SKILL DEVELOPMENT Initiatives

ICMM 10 Principles (International Council on Mining and Metals (ICMM)	Ministry of Mines (MoM) of Government of India's 8 Principles
ICMM's 10 principles for sustainable development are based on the issues identified in the Mining, Minerals and Sustainable Development project and were benchmarked against leading international standards, including the Rio Declaration, the Global Reporting Initiative, the Global Compact, OECD Guidelines on Multinational Enterprises, World Bank Operational Guidelines, OECD Convention on Combating Bribery, ILO Conventions 98, 169, 176, and the Voluntary Principles on Security and Human Rights. **Principle 1: Implement and maintain ethical business practices and sound systems of corporate governance.** **Principle 2: Integrate sustainable development considerations within the corporate decision-making process.** **Principle 3: Uphold fundamental human rights and respect cultures, customs and values in dealings with employees and others who are affected by our activities.** **Principle 4: Implement risk management strategies based on valid data and sound science.** **Principle 5: Seek continual improvement of our health and safety performance.** **Principle 6: Seek continual improvement of our environmental performance.** **Principle 7: Contribute to conservation of biodiversity and integrated approaches to land use planning.** **Principle 8: Facilitate and encourage responsible product design, use, re-use, recycling and disposal of our products.** **Principle 9: Contribute to the social, economic and institutional development of the communities in which we operate.**	Ministry of Mines in context of Indian Mining sector has developed Sustainable Development Framework based on 8 principles. They are: Principle 1: Incorporating environmental and social sensitivities in decisions on leases. Principle 2: Strategic assessment in key mining regions Principle 3: Managing impacts at the mine level impact through sound management systems Principle 4: Addressing land, settlement and other social impacts Principle 5: Community engagement, benefit sharing and contribution to socioeconomic development Principle 6: Mine closure and post-closure Principle 7: Ethical functioning and responsible business practices

Sustainable Development in Mining : India

5. Gender equality – provisions have been made in the Rules and (Amendment to the employment of Women Managers in UG Mines)

Regulations governing the engagement of female in mining activities,

6. & 7. In the areas of affordable & clean energy – every mine and mine management had laid thrust on energy from non-conventional sources and also adopt energy efficient methods

8&9. Role of research, innovation, up-gradation of technology, infusion of money for new developments etc are driver of the growth in the sector.

10-12. Mining industry is very much active in these areas.

13-15. Every mining organization had its own 'Sustainable Development Framework' in line with provisions of MMDR Act 2015. FIMI played a major role in this direction alongwith Mining Cos.

16. Place & Justice strong institutions – Over the years in India we have developed very effective and applicable regulation mechanisam to ensure safety, conservation, human rights related regulations, etc. Institutions under various Central Govt. ministries have played a vital role since pre and post independence period

17. Partnership for the Goals : Apart from partnership within various stakeholders in the country, India over the years had very strong and successful friendship or partnership with developed nations and organizations/institutions.

Regulatory mechanism vis-à-vis sustainable development

The various rules and regulations framed under the provisions of Mines Act, MMDR Act, and policy statements like National Mineral Policies, Star Rating of Mines and white papers have effectively ensured sustainable growth of Indian mining sector. Incorporation of Mine Closure Plans, Environmental Management provisions, DMF(District Mineral Foundation), NMEP, human resources development etc are going to make our surface mining operations sustainable.

Madhya Pradesh is endowed with rich deposits of coal and non-coal minerals. In case of Mining of Manganese Ore, it has a rich history of mining even in pre-independence years. Manganese Mining has seen rise in private and public sector investment and its size varies from few hundred tonnes production to few Million Tonnes per year in both mechanized and manual operations. Apart from having underground metal mines, there are a number of small opencast mines in and around Jabalpur-Katni, Balaghat and other districts. These mines have been identified as part of the research in respect of their sustainability.

Sustainable Development in Mining

With Special Reference to Mn Mines of MP mostly spread in Tribal and Forest areas -

-Tranisition from UG to Opencast and vice versa

-Shift from manual to semi-mechanized to mechanized mining

-Deepening mines through shaft deepening, shaft sinking etc

-Improvements in roof support, strata control, ventilation, ore hoisting, face mechanization, blasting, backfilling etc to create safe and productive environment in UG mines

-In small quarries adoption of proper benching, stabilizing slopes, pit layout as per approved Mining Plan, mechanization, waste management, in-pit and off-pit dumping etc

-Introduction and regular upgradation of technology, skill of manpower by training, skill development programs, etc

-Enforcement of Star Rating of Mines, CSR activities, local area development, creation of shelf help groups for improving malnutration-awareness against alcoholism-girl child education etc togetherwith job creation, digitization reach out in rural areas etc.

-R&D initiatives

SELECTED REFERENCES
As a part of Literature Survey

As a part of the Thesis, the following Articles/Books etc were referred:

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