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A review of governance, challenges and sustainability in Goa, Karnataka, and Odisha iron ore mining, India

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Technical Note

Keywords
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Mining issues
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Legal framework

Abstract

The granting of mining leases for the extraction of different types of minerals towards sustainable development plays a crucial role in conservation and safety. The paper examines the challenges, socio-economic and environmental impact, governance, and sustainable practices associated with iron ore mining in Goa, Karnataka, and Odisha (South India). This analysis employed existing published data from the scientific literature, technical reports, and official regulatory and production data from the Indian Bureau of Mines, the Ministry of Mines, and regional directorate offices. ArcMap 10.8.2 was used to map the study area. The study revealed there is a steady increase in iron ore mining operations in Odisha (85.6 Mt in 2018-19 to 108.2 Mt in 2022-23), the production of Karnataka rose from 25.4 Mt to 38.6 Mt within the same period, and the production of Goa remained stable (4.8 – 5.3 Mt). This production growth led to land-use changes and affected local communities. The contiguous leasehold system, poor boundary demarcation, and inadequate enforcement have led to mineral loss, land degradation, and negative socio-environmental impacts. To promote more sustainable outcomes, improved practices should consider clearer on-ground demarcation by utilising GPS/GIS, regular audits, geotechnical investigations at decommissioning processes, enhanced governance transparency, and community engagement. To improve long-term effects, it is important to adopt sustainable mining practices, including the utilisation of resources, the management of waste dumps, the minimisation of waste generation, desilting, the pumping of pit water for recycling, and progressive mine closure to enhance ecological restoration.

1. Introduction

Mining plays a pivotal role in the industrial and economic development of resource-rich nations, particularly where mineral extraction greatly influences GDP growth, employment, and infrastructure development. India issues mining leases for extraction under the Mines and Minerals (Development and Regulation) Act, 1957 (MMDR). Proper on-ground demarcation of lease boundaries is a basic requirement of the state mining authorities. This process enables granted lease areas to be mined in a scientific manner with systematic development to extract the mineral, including conservation. Every leaseholder must prepare a mining plan, which also includes an environmental management plan, duly approved by the competent authorities, before starting any mining operation.

In the Goan iron ore mines, most of these leases were granted during the Portuguese regime, before independent India, in the form of mineral concessions. Later, the same concessions were termed as Mining leases. In the case of contiguous mining leases, the granted lease area is small, and mine development and extraction are restricted due to adjoining common lease boundary problems. These areas not only have significant mineral riches but also deal with overlapping legal, environmental, and socio-economic issues. The pits could not be excavated to greater depths due to weak wall rocks and friable and powdery ore zones.

In the case of iron ore leases, a similar issue occurs with waste generation and disposal, which not only has environmental impacts but also requires additional areas for dumping large volumes of waste. This article looks at the problems that come from overlapping mining operations, such as environmental damage, social and economic inequality,

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and legal issues. The goal is to push for better boundary management, eco-friendlier mining methods, and changes to the law. This analysis contributes to the ongoing discourse regarding sustainable mineral resource management in India and similar BRICS nations.

2. Methods and materials

The study employed primary and secondary data analysis and qualitative methodologies to examine the impacts of contiguous mining licenses in Goa, Karnataka, and Odisha. The data was sourced from various published scientific literature, across Scopus, Web of Science, Google Scholar, and the government official reports from the Indian Bureau of Mines (IBM), Ministry of Mines, and State Directorate of Geology websites by using contiguous, mining lease, iron ore, and challenges as keywords. Furthermore, production and mine-level data were obtained from mining plans, IBM's annual reports, and Mineral Conservation and Development Rules (MCDR) compliance reports (accessed in March 2024). Legal and policy papers were obtained from the Indian Kanoon and state government websites. GIS ArcMap (10.8.2) was used to delineate the study area to determine areas affected by land degradation. Nevertheless, the research leveraged insights from Environmental Impact Assessment (EIA) reports, public health studies, and policy reviews to evaluate the socio-environmental impacts of mining (Kumar & Nikhil, 2014). Figure 1 represents the map of iron ore-producing districts located in the states of Goa, Karnataka, and Odisha in India. Literature search.

3. Results

3.1 Quantitative assessment of iron ore production

There are numerous small-scale active iron ore mines in the region. In the fiscal year 2023–24, a provisional total of 2,036 mines reported production in accordance with the Mineral Conservation and Development Rules (MCDR). This number is lower than the 2,070 mines that were counted in the previous fiscal year, 2022–23. In the years 2023–24, the 2,036 reporting mines were distributed across states as follows: Madhya Pradesh had the most with 394, followed by Gujarat with 291, Tamil Nadu with 222, Andhra Pradesh with 182, Karnataka with 177, Odisha with 147, Chhattisgarh with 139, Rajasthan with 113, Maharashtra with 110, and Jharkhand with 67 mines (IBM, 2025).

Figure 2(A) shows ore production in major iron ore-producing states, including the studied regions, over a five-year period, from 2018–19 to 2022–23, with reference

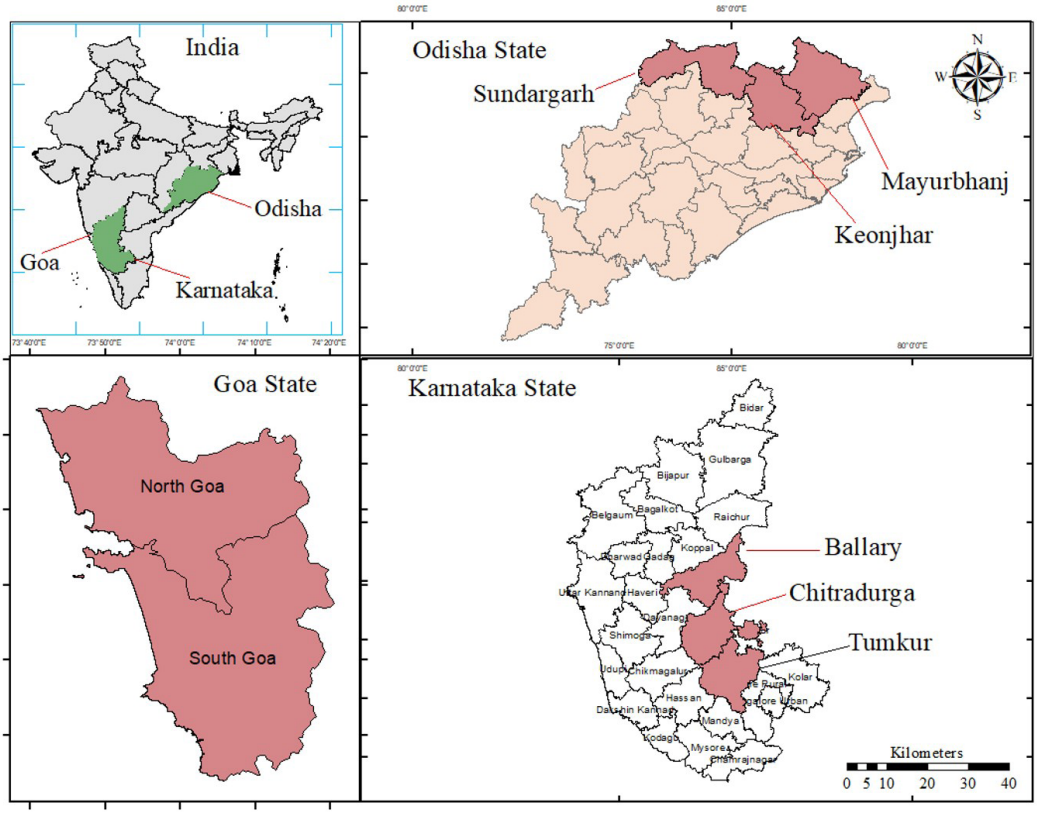

Figure 1. Location map of the study area and iron ore producing districts.

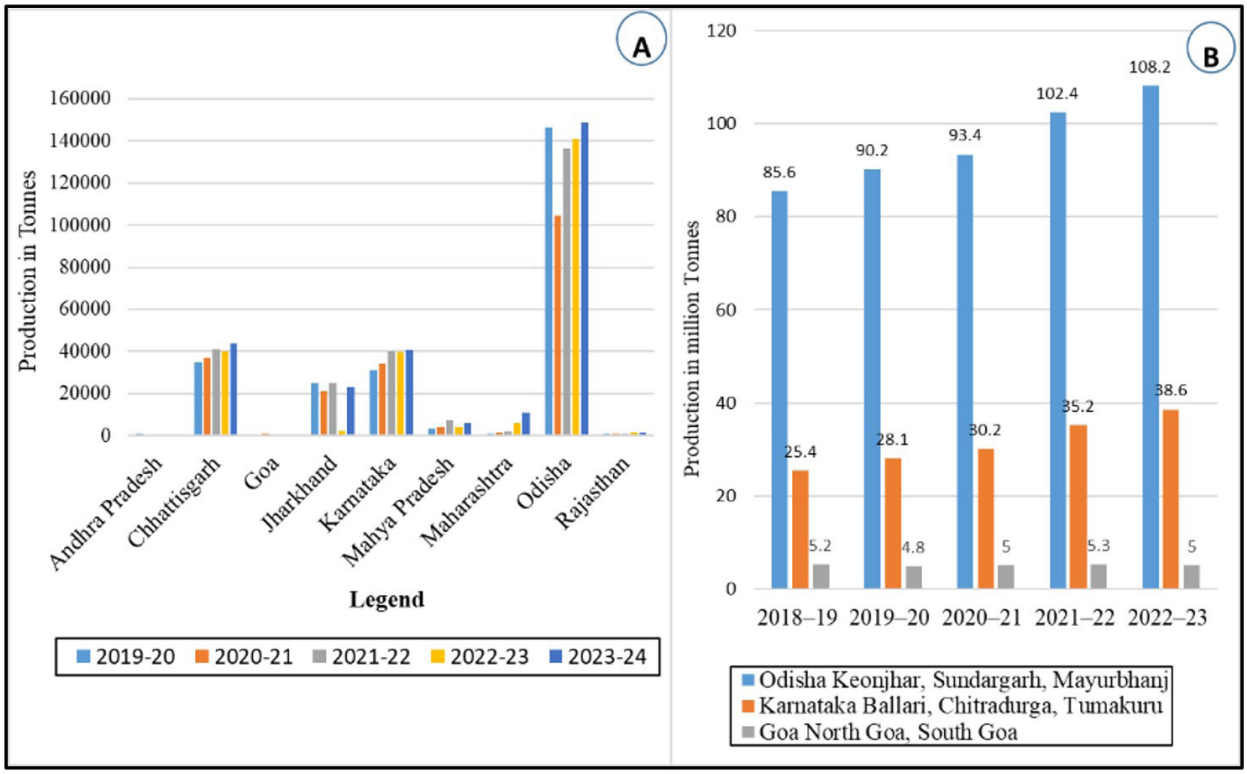

Figure 2. (A). Iron ore production in India (state-wise) during the last five years (thousand tonnes); (B). Key districts of iron ore production in the states of Odisha, Karnataka, and Goa (million tonnes). Source of Data: IBM (2025).

to other minor producing states of India. Among these, Odisha is a major producer of iron ore. From 2018 to 2019, it produced 85.6 million tonnes (Mt), and by 2022 to 2023, it had grown to 108.2 Mt. Karnataka, which includes the Bellary, Chitradurga, and Tumkur districts, shows a steady increase, rising from 25.4 Mt to 38.6 Mt over the time in question. The production in Goa, which includes both North and South Goa, stays steady, going up and down between 4.8 Mt and 5.3 Mt. This figure illustrates each state's contribution to India's total ore production (IBM, 2025).

Figure 2B presents a comparative overview of iron ore production in the three states. The data shows that production has been steadily rising, especially in Odisha, which has been on an upward trend for the past five years. Karnataka's growth is on track, while Goa's production has been mostly steady, with a slight drop in the last year.

3.2 Contiguous mining lease of iron ore in Goa

The problems of contiguous mining leases offer a strategic visualisation tool for legislators, scientists, and industry players seeking to assess operational intensity, transportation infrastructure, and regional environmental constraints.

3.2.1 The socio-economic challenges

Socially, mining has displaced indigenous populations and traditional businesses such as farming and fishing, causing tensions between mining companies and residents who suffer from pollution-related health issues, despite creating jobs (Table 1). Local towns have also been affected by air pollution from dust and fumes generated by heavy machinery and transportation. Furthermore, the financial benefits of mining are often unfairly distributed; profits tend to concentrate among a small group of stakeholders, while residents endure environmental and health problems (Basu, 2015).

The influx of individuals into mining-related employment exceeded 250,000 (Gaonkar & Faleiro, 2021). The sector directly employed around 11,000 people until the 2012 mining moratorium. Since 2011, the halt in mining activities has led to a slight increase of 7,171 unemployed individuals, aligning with the estimated numbers of those previously employed in the industry (Goa Foundation, 2025). This is frequently not the case, as many areas face water pollution, deforestation, and biodiversity loss due to weak enforcement (Rane & Matta, 2019).

3.2.2 Environmental challenges

The ecological consequences of the mining leases in Goa are substantial. The discharge of overburden pollutes water bodies, particularly the estuaries of the Mandovi and Zuari rivers, damaging aquatic ecosystems (Datar et al., 2019). Mining activities have caused permanent changes in the geomorphology of nearby areas due to sedimentation. Existing environmental legislation, including the Environment Protection Act of 1986 and the Water and Air Acts, requires that leaseholders obtain approvals, conduct Environmental Impact Assessments (EIAs), and comply with pollution control standards, but enforcement has often been insufficient (Patnaik & Datta, 2018).

3.2.3 The legal and governance challenges

This has reinforced the emphasis on the role of environmental law in governing mining within its parameters, through the focused rehabilitation/restoration of mining-impacted regions, as held in Goa Foundation v. Union of India [(2014) 6 SCC 590] (Casemine, 2014). The cohesive clustering of mining leases in Goa has been the lifeblood for the state. But this comes at a high ecological and social cost, necessitating sustainable techniques. Iron mining leases in Goa are governed by a legal framework that aims to reconcile economic development with ecological health and social equity. Some progress on legislation and judicial rulings, but implementation is a struggle in most places. This transforms the landscape of mining governance in Goa and highlights the importance of imposing institutional frameworks that consider equity issues (Daripa et al., 2023).

3.3 Contiguous mining lease for iron ore in Karnataka

Several contiguous mining leases, particularly in the Bellary, Chitradurga, and Tumkur districts of Karnataka, involve interrelated legal, environmental, and socio-economic problems. This section discusses some of the issues and the measures adopted for addressing these challenges.

3.3.1 Socio-economic challenges

Land acquisition and environmental degradation have caused the displacement of communities, especially indigenous groups and farmers. Between 1950 and 1991, mining and other development projects displaced about 2.6 million people nationwide, over half of whom were indigenous tribes (CSE, 2007). After the Supreme Court's 2011 mining ban, aimed at reducing illegal mining and environmental violations, over 25,000 people lost their jobs and were relocated to Karnataka, particularly in Ballari (Kumar, 2023). Health issues are also a major concern. Respiratory illnesses have risen due to particulate matter from mining activities, while water contamination has spread diseases in mining regions (Table 1). These challenges highlight the need for equitable development that balances economic growth with community well-being.

3.3.2 Environmental challenges

Bellary is one of Karnataka's iron ore-rich regions but has witnessed severe environmental degradation, including deforestation, soil erosion, and water pollution. Declining agricultural productivity, public health threats from contaminated water bodies, and biodiversity loss, as in Kudremukh National Park, are evident. As resources have become unsuitable for domestic or agricultural use because of heavy metals leaching into water supplies, this is a classic case of polluted water undermining the local ecosystem. Seventeen rivers in the state are highly polluted, making life difficult for local people (Kumar & Krishna., 2012; Jal Shakti Ministry, 2020). Karnataka lost around 54.1 thousand hectares of tree cover (as per the 2023 update) between 2001 and 23, and about 80% of the total forest loss from mining operations occurred in Bellary district.

3.3.3 Legal regulatory challenges

A prominent example is the Kudremukh Iron Ore Company Limited case, in which, in 2002, the Supreme Court of India ordered a halt to mining operations due to environmental violations (Supreme Court of India, 2002). Overlapping leases, illegal mining, and environmental violations continue to characterize the sector. The Lokayukta Report highlighted widespread irregularities in Bellary, revealing political collusion and systemic corruption within the mining industry. These conflicts delay project execution and hinder effective use of resources. Furthermore, tackling resource utilisation challenges involves adopting sustainable mining practices. Innovations are being investigated in various areas, such as how magnetisation roasting could turn low-grade ore into a more valuable product with less environmental impact and enhanced resource use (Basavaraja & Kumar, 2020). While Corporate Social Responsibility (CSR) initiatives increasingly support community welfare through education, healthcare, and skill development, they also show how industry can help reduce negative impacts and foster more inclusive development (Toli, 2022). Only then can Karnataka's mining sector attain responsible growth aligned with broader goals of sustainability and equity.

3.4 Contiguous mining lease for iron ore in Odisha

Legal and regulatory challenges remain key issues in disagreements, and Odisha's mineral wealth has been undervalued due to poor lease management. Mining companies often ignore the Forest Rights Act (FRA) of 2006, which aims to recognize the rights of indigenous and forest-dependent communities. For instance, the

Kalta iron ore deposit shows the importance of detailed resource studies. In this context, geostatistical methods are crucial for providing more accurate estimates of tonnage and grade, which are vital for effective resource planning (Sarkar & Roy, 2005).

3.4.1 The socio-economic challenges

The socio-economic impact of mining operations in Odisha has displaced indigenous communities through land acquisition, disrupting traditional agricultural practices and threatening food security (Republic of India, 2017) (Table 1). These impacts often result in socio-economic inequalities among affected communities. Moreover, health concerns among residents and workers in these regions have been significant. Poor living and working conditions near the Barsua and Kalta mines have been linked to a higher incidence of respiratory diseases and infections, such as malaria (Yadav et al., 1991).

3.4.2 The environmental challenges

Iron ore mining has caused significant environmental degradation in Odisha, especially in the Sundargarh district, which hosts the Kalta and Barsua mines. Records show that increased concentrations of particulate matter and other contaminants cause respiratory illnesses and waterborne diseases among nearby communities. Ambient air monitoring highlights the ongoing impacts on public health and environmental integrity. Initiatives for sustainable mining in Odisha have expanded, helping to reduce environmental and social impacts. Replanting efforts in degraded mining regions, mainly using indigenous plant species, have restored ecosystems. These efforts have also helped reduce biodiversity loss while addressing soil erosion and water conservation. Mishra et al. (2022) explore the integration of advanced technologies, including remote sensing and GIS, in monitoring land-use changes and ensuring compliance with environmental regulations. These technological applications are vital for aligning mining practices with sustainability goals.

3.4.3 Legal framework challenges

The ongoing challenges related to sustainability versus resource utilisation observed at Bursua, Tandih, and Kalta are linked to the persistence of mining leasehold arrangements. While mining benefits Odisha's economy, it also results in significant costs: environmental damage and social disparities. Due to these issues, substantial efforts are necessary to ensure that open lease management, strict enforcement of environmental laws, and community participation strategies are effective. In addition to recommended treatments tailored to each state's conditions, this table (Table 1) highlights the impact of mining activities on local communities in Goa, Karnataka, and Odisha, particularly regarding the issuance of contiguous mining leases.

4. Discussion

4.1 Comparative assessment of mining governance and impact across the three states

Variations in sustainability results across the three states are partly due to differences in governance quality and lease demarcation. Odisha shows rising documentation, facilitated by improved lease demarcation and regulatory oversight, though this has raised concerns about land-use pressure and environmental stress. Karnataka shows progress but is constrained

Table 1. Mining activities' impact on local communities in the study area.

State	Health Impact		Displacement	Employment
	Malaria	Respiratory Disease		
Odisha	Increased cases in areas such as Keonjhar (Murmu et al., 2018)	Increased cases of Asthma, Bronchitis, and Silicosis (Basu, 2024)	Between 2000 and 2010, over 30,000 tribals were displaced in Keonjhar and Sundergarh (Mukherjee, 2019)	Rise in employment in the mining sector.
Goa	No cases have been reported since 2023; imported cases rose from 585 in 2022 to 1,209 in 2023 (Oliveira et al., 2014).	Increase in occupational lung diseases among workers resulting from exposure to iron ore dust.	Statistics are unavailable; however, mining operations have resulted in alterations to land use that impact local	Employment is noted, although specific statistics are not available.
Karnataka	Increase in malaria coinciding with increased industrialization activities (Malaria Site, 2025)	Bellary has shown a high rate of respiratory disease due to the concentration of PM10 and OM2.5 in mining regions (Shalini et al., 2023)	Local communities have been affected by land changes resulting from mining activities; no specific figure for displaced people is available.	The data on employment in the mining sector in the available sources is not exact.

by segmented leases and compliance headwinds. Issues persist due to fragmented lease boundaries and legacy compliance monitoring challenges. Suspensions, blurred lease lines, and an economy and environment in free fall sum up today's Goa.

4.2 Environmental and land use implications of contiguous mining

Contiguous mining leases, if not effectively demarcated from one another and operated as individual entities, have cumulative environmental impacts that are often overlooked in project evaluations. Poorly coordinated excavation and dumping in the same area led to land disturbance, loss of topsoil, deforestation, and changes in surface drainage patterns (problems). Geo-environmentally, overburden removal and the exposure of new faces favor weathering, oxidation, and metal leachability. The lack of integrated planning across adjacent leases exacerbates cumulative environmental impacts.

4.3 Geotechnical implications of contiguous mining and lease mismanagement

The geotechnical implications of suboptimal contiguous mining leases are a vital yet neglected component of mining sustainability. Poorly coordinated excavation and dumping across contiguous leases commonly generate irregular pit geometries, steep overall slopes, and non-cohesive waste dumps heterogeneous in lithology and grain-size distribution. These conditions threaten both the stability of the slope and long-term settlements.

Especially in the case of waste dumps, which are erected without a standardized design and geotechnical investigation, the stability plays a significant role. Differences in moisture content, compaction, and strength profile within the dumps may result in progressive collapse, particularly during rainy seasons. In Goa, disused and poorly reclaimed dumps have degraded through slope erosion, slope deformation from waste sliding down from higher levees, and silting/drainage blockage, resulting in risks to downstream areas. There are similar apprehensions in places like Karnataka and Odisha, where expanding dumps encroach upon natural drainage channels and low-lying terrain.

Groundwater systems are also strongly influenced by the adjacent mining operations. A series of overlapping cones of depression shifts when adjacent pits are dewatered, which can alter regional flow patterns and lead to slope instability in pit walls and waste-rock masses. These hydrogeological reactions may persist beyond mine closure, complicating post-mining rehabilitation and future land use.

4.4 Role of GIS and integrated planning in geotechnical risk reduction

GIS-based analysis helps identify cumulative impacts and geotechnical risk zones across adjacent leases. Intersecting lease boundaries with waste dump sites, drainage networks, and sensitive land uses enables early identification of conflict hotspots and cumulative impacts. Integrating GIS into regulatory frameworks supports coordinated planning and reduces operational conflicts. This integration enables joint development among adjacent leaseholders and mitigates the risk of unplanned excavation, dumping overlaps, and post-closure instability.

5. Conclusion

This study demonstrates the importance of lease configuration and governance for mining sustainability in Goa, Karnataka, and Odisha. The results demonstrate that:

1. The quality of governance and the demarcation of effective lease boundaries are vital for managing land degradation, loss of minerals, and operational conflict between adjacent leases.
2. Poor coordination of mining activities leads to damage to the environment, including soil erosion, changes in drainage, and land instability.
3. Geotechnical hazards, such as waste dump instability, slope failure, and groundwater disturbance, are intensified by planning and operating contiguous leases independently.
4. Integrated planning using GIS provides an efficient tool for enhancing lease management, minimizing aggregated impacts, and promoting safe mine closure and land rehabilitation.

This study relies on secondary data, so future work should conduct site-specific geotechnical analysis and monitoring. Future investigations should focus on site-specific geotechnical characterization, numerical modeling of dump and pit stability, and long-term monitoring of the reclaimed land.

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Declaration of interest

The authors have no conflicts of interest to declare. All co-authors have observed and affirmed the contents of the paper, and there is no financial interest in reporting.

Authors' contributions

Ahmed Koko Suleiman Dalbon: conceptualization, data curation, visualization, writing – original draft. Edupuganti Naga Dhanamjaya Rao: conceptualization, methodology, supervision, validation. Kurry Satyanarayana Reddy: conceptualization, methodology, supervision, validation. Adibhatla Santha Ram: conceptualization, supervision, investigation, methodology, validation, writing – review & editing.

Data availability

All data examined in this paper are included in this article.

Declaration of use of generative artificial intelligence

This work was prepared without the assistance of any generative artificial intelligence (GenAI) tools or services. All aspects of the manuscript were developed solely by the authors, who take full responsibility for the content of this publication.

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