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Geospatial analysis of land use and land cover around iron ore mine near Balda village of Keonjhar district of Odisha using remote sensing satellite data

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ABSTRACT
Mineral mining is one of the major resources of development and economic growth in India. Unmanaged and injudicious mining activities in general degrade the existing land and ecosystem. It is known that Land use and land cover (LULC) of an area is governed by land and water resources. The present study reveals about impact of mining activity on the LULC within the Core zone and surrounding buffer area. The study was carried out using remote sensing satellite data to trace the significant impact of mining near Balda village of Barbil tehsil, Keonjhar district, Odisha. Temporal LULC maps play a significant role in monitoring changes in the LULC within the study area. The comparison of land use information extracted from satellite data of the core zone and buffer zone showed drastic changes in due course of the time span due to mining activities. Rural urbanization is a major issue and its impact on the environment is observed from the study. The anthropogenic intervention such as mining activities plays a negative impact on the forest cover of the core and buffer zone of the mining area. Mine owners and the local forest department combined an effort of awareness among the people and a massive plantation drive in the vacant areas of the core and buffer zone giving a better scope for the new generation of forest cover. The land use land cover's sustainability and its role in the restoration of the environment is a burning issue and its impact is prominent on the surrounding area. This is a risk to the sustainability of the environment as well as to the life support system of the area.

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1. INTRODUCTION

Mineral mining contributes to the development and economic growth of a nation but on the other side, it deteriorates the existing natural ecosystems, the biodiversity, and its serene beauty (Kivinen et al., 2018). Natural resource management should be an integral part of mining activity. The mineral-rich area located in Keonjhar district of Odisha is famous for its reserve of Iron and Manganese ore. Keonjhar district Joda mineral zone area is seeking reserves of high-grade Iron ore. The land is well covered with dense vast forests land and those areas are the real habitat of very sensitive flora and fauna. The Land use and land cover (LULC) of an area reflects the natural settings of terrain i.e., its geology, landform, soil, slope, and climate, indicating the predominance of certain natural resources. Any imbalance in such resources due to industrial activities including mining would have certain inevitable impacts, both positive

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and negative. Hence, it is paramount to carry out periodical monitoring of LULC is considered one of the significant parameters while studying environmental impact assessment (EIA) around mining areas (Paull et al., 2006). To cater the objective of such study, data obtained from remote sensing satellites forms a formidable tool providing a synoptic view of the study area under uniform illumination at a regular periodicity (Mondal et al., 2013). Such dynamic input on LULC patterns helps in generating a digital database using Geographic Information System (GIS) to provide location-specific information (Mountrakis et al., 2011). A proper study of the geographical conditions of any mineralized area greatly supports the restoration of existing landforms and natural habitats (Wang et al., 2017; Redondo-Vega et al., 2017).

Industrialization plays a vital role in the overall development and progress of any region. Along with the development, at the same time, it has an adverse impact on the environment such as air pollution, water pollution, urban sprawl, and others. This region has witnessed a lot of changes in land use/land cover (LULC) due to the exploration of iron ore and manganese minerals and subsequently the adverse impact on the environment (Jiya and Musa, 2011). Studies of LULC changes can be detected by using remotely sensed images of specific periods or seasons of a year or year together, using LISS images of the relevant study period (Joshi et al., 2006). The satellite images can be rectified and geo-referenced using GPS data collected by point positioning mode observations. Ground truth information collection for the LULC classification accuracy assessment has been done using a GPS instrument. Image analysis operations have been carried out using ERDAS Imagine software (Sahu, 2009; Prakash and Gupta, 1998).

Mining, in general, and open-cast mining may lead to severe environmental degradation. Paradoxically, from an environmental point of view, any metalliferous or non-metalliferous mining is a major habitat-transforming activity that has several detrimental environmental consequences, namely soil erosion, acid-mine drainage, and increased sediment load as a result of abandoned and un-reclaimed mined lands (Li, 2006). Besides, a considerable amount of solid waste piled in the form of huge overburden dumps, destruction and degradation of forest and agricultural lands, and discharge of effluents from mines into nearby waterbodies are some of the other associated problems that have adverse environmental impacts. Continuous monitoring of these lands is, therefore, essential for their effective reclamation and management. However, reliable and timely information on the nature, extent, spatial distribution pattern, and temporal behavior of degraded lands including land subject to mining, which is a prerequisite for their reclamation and management, is generally not available. Mapping mining activities and evaluating associated environmental concerns are difficult problems because of the extensive area affected and the large size of individual mines. Monitoring and controlling these changes have been more difficult because of the expense and time of producing reliable and up-to-date mapping. Besides, a successful monitoring approach for evaluating surface mining processes and their dynamics at a regional scale requires observations with frequent temporal coverage over a long period to differentiate natural changes from those associated with human activities (Sahu and Kumawat, 2022). To meet such challenges, urban planners and decision-makers need to have accurate and up-to-date information.

2. MATERIALS AND METHODS

2.1. Data used

The temporal study of land use and land cover pattern around the Iron ore mine near Balda was carried out using cloud-free Resource-sat 2 LISS IV satellite data to gather qualitative information pertaining to the land use environment. Certain image enhancement applications are carried out to refine and update the mapped LULC categories and their boundaries. LULC map being prepared by using GIS environment and comparative study made for changes in LULC pattern for the study area.

3. METHODOLOGY

A spatial method is adopted as the most suitable tool for the monitoring of land masses through the utilization of satellite imagery and GIS techniques (Papadavid et al., 2013; Singh et al., 2010). Monitoring of LULC around the buffer area of the mines and within the core zone is being studied for the generation of temporal LULC maps. A comparative study made for data with physical verification through ground survey and available baseline data helped in assessing the cover changes in the buffer area and the core zone leading to impact assessment due to mining activities in the adjacent area. The

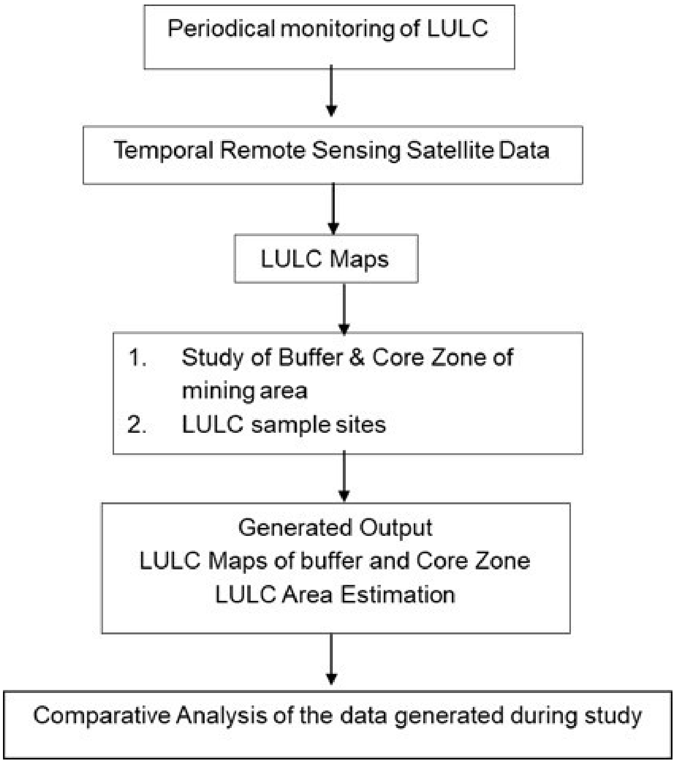

Fig. 1. Flow chart showing data flow in the Land use analysis of the study area.

information gathered by the Image interpretation technique to identify various types of image elements such as color, tonal differences, texture, shape, size, and association elements were interpreted to delineate various LULC categories and were transformed into a GIS database (Sahu, 2009; Jiya and Musa, 2011). The area of respective LULC categories was extracted for both periods and a comparison of the spatial pattern of LU categories and their extent were discussed. The GIS maps are made through the transformation of LULC details in the GIS spatial environment (Sahu and Kumawat, 2022). The flow chart depicting the procedure adopted for such temporal analysis of LULC of the Core zone area and 2km buffer area around the iron ore mine near Balda village (Fig. 1). Monitoring of LULC around the buffer area and within the core zone was carried out in two phases, viz., image interpretation of satellite data and geospatial analysis of satellite data and generating temporal LULC maps of 2015 and 2022.

Land use and land cover categories within the study area, grouped and labeled with specific nomenclature done as per national level classification system are being followed as recommended by the National Remote Sensing Centre (NRSC), Department of Space, Government of India (Table 1).

Table 1. Major LULC units of the study area.

Sl. No.	Major Category	Land use unit
1	Built-up Land	Village
		Infrastructure Facilities
2	Agricultural Land	Fallow land
		Plantation
3	Forest Land	Dense Mixed Forest
		Sparse Mixed Forest
		Open Forest Degraded Forest
		Forest Blank
4	Waste Land	Land with Scrub
		Barren Area
		Mining / Dump area
5	Water bodies	Ponds / Tanks

4. RESULTS AND DISCUSSION

The study was made on the impact of mining activities on changes in Land use and land cover categories within the buffer and core zone of the mining area. The data extracted from imageries are thoroughly verified with the ground truth of the study area by field verification, the LULC categories are adopted and grouped, and labeled with specific nomenclature done as per national level classification system (Table 1). Different landmarks are verified by field ground control points for field accuracy to study the changes in the LULC of the area.

4.1. Spatio-temporal pattern of LULC of buffer around iron ore mining lease area

Selected satellite images have been taken and data enhanced to lucidly bring out these features showing distinct boundaries among them and the LULC pattern of the selected temporal data. Data are compared to identify the changes in land use and land cover in and around the buffer region of the mining lease area (Beck et al., 2006; Anil et al., 2010). Spatio-temporal study of LULC pattern involves interpretation of temporal satellite data for a 2km buffer area around the mining lease covering an area of about 32.20 km^2. Preliminary investigation reveals that natural vegetation is the predominant category around the ML area and observed with a mixed scrub forest of varying density, scrub land, barren area, fallow land, mining, and associated infrastructure and industrial activities apart from the presence of small hamlets.

4.2. LULC pattern changes of buffer region

LULC map of the buffer zone around the mining area is generated by using satellite data of R2 LISS IV of

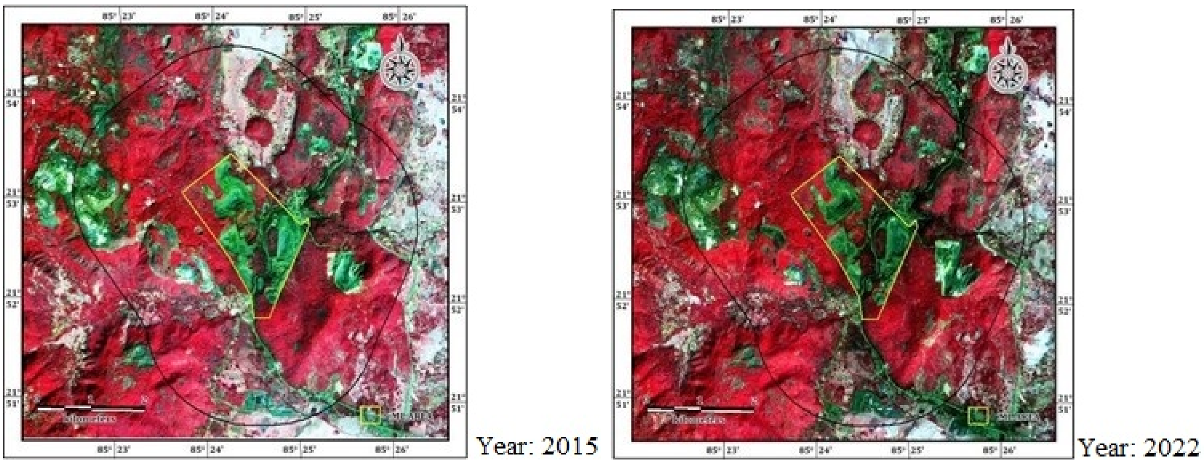

Fig. 2. LISS IV Satellite data of 2 Km Buffer areas around the core zone in 2015 and 2022.

2015 and 2022 (Fig. 2). The ground survey and satellite data reveal the status of the land and information collected about the sparse mixed forest, which is of predominant category and it is observed within the buffer area followed by open mixed forest and degraded forest. There are small patches of tree groves that are delineated as plantation areas. Apart from these vegetative cover, patches of fallow land parcels are also seen in the northern, eastern, and southern periphery of the buffer region of the mines. The residential area was also significantly identified as a few hamlets which are gradually constructed as concrete buildings and pavement of the roads and ground area observed in comparative satellite data. The stream path adjacent to the mines lease area also seems very narrow which is preventing the water passage due to sprawling urbanization and encroached by the constructed area.

Settlement areas are observed as small and scattered patches and delineated by their typical greyish-red color, medium tone, and medium to coarse texture, association with roads, foothills, and plains. There are villages like Balda, Kalimati, Tadpani, and Jampani are identified in the buffer area. Industrial units are delineated prominently by their typical shape, grey tone, and presence of green belt vegetation grown around premises. Cumulatively, the spatial extent of settlements and industrial areas including infrastructure buildings area estimated as 2.035 km^2 representing 6.32 % of the buffer area. Land use patterns are interpreted from the satellite data, the fallow land and plantation area are marked as two separate classes which are identified under the agriculture category. Fallow land areas are identified by their typical greyish-white color, smooth tone, medium texture, geometrical pattern, and association with certain landforms such as narrow valleys and plains. 2.78 km^2 area of fallow land representing 8.66 % of the buffer area, which is located in the western part as small patches along the periphery of the buffer area whereas the plantation area is noticed as the fragmented portion of the buffer area covering 0.007 km^2 of 0.02% of buffer area.

The GCPs of the forest area reveal more information about the forest strata of the region. The accuracy of the species found in the forest bed is collected from field GCP data for verification of vegetation. The forest area covers one-third part of the buffer area as "wooded area" or "forest" of varying density with deciduous trees, shrubs, and scrubs. Some of the trees such as Sal (*Shorea robusta*), Sidha (*Lagerstroemia parviflora* Roxb.), Teak (*Tectona grandis* Lf.), Gambhari (*Gmelina arborea* Roxb.), Tendu (*Diospyros melanoxylon* Roxb.), Mahua (*Madhuca longifolia* J.F.Macbr.), Pia Sal (*Pterocarpus marsupium* Roxb.), Harida (*Terminalia chebula* Retz.), Bahada (*Terminalia bellirica* Roxb.), Bombax (*Bombax ceiba* L.), Bamboo (*Dendrocalamus strictus* Roxb.), Chironji (*Buchanania lanzan* Spreng.) are commonly seen along with Palas (*Butea monosperma* Lam.), Bel (*Aegle marmelos* L.), and shrubs. Based on the image elements such as color, tone, and textural variations, forests are delineated qualitatively as "dense mixed forest", "sparse mixed forest", "open mixed forest" and lastly "degraded forest" cover. Apart from this, a vacant place devoid of any vegetative cover among the wooded area is termed as "forest blank". The qualitative separation of forest cover based on density may not exactly reflect crown density but indicate the nature of vegetation present in the area and is influenced by season as well. In the buffer area sparse

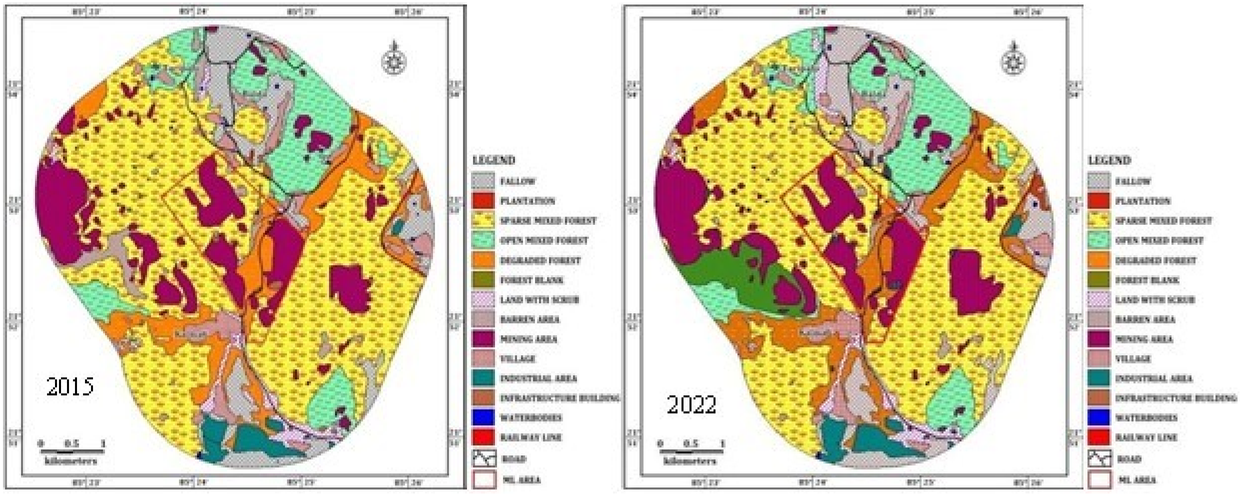

Fig. 3. LULC map of Buffer area generated from LISS IV satellite imagery of 2015 and 2022.

mixed forest, open mixed forest, and degraded forest are delineated based on the above explanation. “Sparse mixed forest” (SMF) with relatively lesser dense vegetative cover with the presence of tall deciduous trees, shrubs, and scrubs were delineated using image elements such as red to reddish brown color, medium tone, and medium texture mostly associated with hill slopes and along the foothills. It covered an area of 15.13 km^2 representing 46.99 % of the study area. “Open mixed forest” (OMF) is also delineated by using similar image elements as that of SMF covering 3.51 km^2 representing 10.90% of the buffer area. Degraded forest (DF) cover showed a few scattered wooded areas with sporadic scrubs, shrubs, and stunted trees. It is confined to the plain area within the buffer region. The area is delineated by brown color, coarse tone, coarse texture, and associated elements such as industrial area and mining area. It covered an area of 2.89 km^2 representing 8.98% of the study area. The wasteland category consists of land with scrubs and barren land (including stony/rocky/sandy wastes), which is unproductive land parts even after the implementation of conservation measures. “Land with scrub” which is identified with a coarser tone and coarser texture associated with settlements and industrial area covering 0.74 km^2 as 2.31% and land devoid of vegetation is identified as “barren area” covering 0.83 km^2 representing 2.58 % of the buffer area respectively. Similarly, the mining area is distinguished from the barren area by its image characteristics of typical linear and curvilinear shape with a bright tone, green to light green color along with other indicative excavation marks. The mining area also covered an area of 4.15 km^2 representing 12.90% of the buffer region.

4.3. LULC pattern study

Satellite data of R2 LISS IV acquired in February 2022 (Fig. 2) is being studied to delineate various LULC and a map is generated (Fig. 3). The preliminary observation of the recent date satellite data revealed a more dynamic vegetative cover when compared with the previous 2015 data. In some parts of the buffer area, especially in the western periphery, forest cover is evident wherein it is almost barren during the 2015 period. The buffer area is seen with the presence of “sparse” and “open mixed forest” apart from a relatively more “dense mixed forest” (DMF). There is an increase in mining activities as well but most of the LULC pattern remains almost similar and undisturbed. It is understandable that oscillation among “forest cover” from “dense” to “sparse” or more “open” or vice versa owing to seasonal influence causing the changes in spectral reflectance pattern while delineating from satellite data. Settlements such as Balda, Kalimati, Tadpani, and Jampani have not shown much change except some marginal change in their spatial extent. The industrial area and buildings are also identified in the 2km buffer area and delineated accordingly. The spatial extent of settlements and industrial area is estimated around 1.299 and 0.64 km^2 respectively showing 4.04% and 2.0% of the total buffer area. Cumulatively, the spatial extent of the built-up category is estimated at around 2.11 km^2 representing 6.55% of the study area. Fallow land and Plantation as delineated from the satellite data showed a marginal reduction in area for fallow land and an increase in area for Plantation as recorded as an area of 2.65 and 0.08 km^2 respectively, which is representing 8.24% and 0.25% of the buffer area.

Table 2. LULC units within 2km Buffer zone and their Spatial Extent.

Sl. No	LULC Name	Area (km^2) (2015)	Area % (2015)	Area (km^2) (2022)	Area % (2022)	Change % in LULC
1.	Fallow	2.7871	8.66	2.6533	8.24	−0.42
2.	Tree Grove	0.0071	0.02	0.0795	0.25	+0.22
3.	Dense Mixed Forest	---	---	1.1050	3.43	+3.43
4.	Sparse Mixed Forest	15.1293	46.99	13.9848	43.43	−3.56
5.	Open Mixed forest	3.5085	10.90	3.6319	11.28	+0.38
6.	Degraded Forest	2.8909	8.98	2.8838	8.96	−0.02
7.	Forest Blank	0.0201	0.06	0.0153	0.05	−0.01
8.	Land with Scrub	0.7431	2.31	0.8655	2.69	+0.38
9.	Barren Area	0.8321	2.58	0.3497	1.09	−1.50
10.	Mining Area	4.1546	12.90	4.4256	13.74	+0.84
11.	Village	1.2531	3.89	1.2996	4.04	+0.14

Similarly, “forest cover” occupies nearly 67.15% of the total buffer area. The forest densities of the study area are studied and differentiate various classes of forest cover based on density. It was qualitatively delineated as “dense”, “sparse” and “open” mixed forest cover each comprising various degrees of an abundance of tall trees, climbers, shrubs, and scrubs. Interpretation of recent satellite data of this period highlighted the presence of “dense mixed forest” (DMF) delineated by their dark red color, medium tone, medium texture, and association with hillocks, which is observed in the western part of the buffer area. Degraded forest cover is also seen along with the mining and industrial areas where human interference is relatively high. The spatial extent of these categories is identified and delineated as DMF of 1.10 km^2, SMF of 13.98 km^2, OMF of 3.63 km^{2,} and DF of 2.88 km^2 which are covering 3.43%, 43.43%, 11.28% and 8.96% of area respectively.

The wasteland which is demarcated as land with scrub and barren areas is not any significant difference in its pattern and shows a marginal increase in the barren area of the studied region. The mining area in the 2 km buffer shows some increased activities and complements with barren area. Spatial estimation of various LULC as derived from interpretation of respective satellite data, their percentage as well as the changes in their percentage is shown in Table 2.

4.4. Temporal changes in LULC pattern within 2km buffer area

A comparison of both satellite data from 2015 and 2022 reveals information about relatively larger vegetative cover in 2022 times within the buffer area. The presence of thick vegetative cover is seen in the western part of the buffer area which was almost barren during 2015. An industrial area is observed in the eastern part alongside fallow land and another industrial site in the southern part, which was noticed as a barren area and scanty vegetation in 2015. Much of the scrub shows affinity with degraded forest and interpreted with relatively more vegetative cover during 2022 due to massive plantation and noninterference of anthropogenic activities due to restriction of the statutory bodies. Mining activities also show some changes in its spatial pattern with evidence of expansion of a mining area near the southeastern part of the buffer area. Despite such activities, vegetative cover remains almost undisturbed except for localized changes besides some seasonal oscillations among them.

Spatial estimation of the area shows that the agricultural category – fallow land and plantation decreased up to 0.20% during 2022 when compared with LULC generated from 2015 satellite data. On the other hand, “forest cover” shows 21.55 km^2 is 66.93% of the buffer area during 2015 and 21.62 km^2 is 67.15% in 2022 respectively. Similarly, an increase in the spatial extent of built-up categories of 0.23% along with the expansion of mining activities of 0.84% in the study area is being observed.

4.5. LULC pattern within the core zone

LULC within the core zone was studied using temporal satellite data of LISS IV acquired in 2015 and 2022 revealing clear information about periodical mining activities within the mining lease area which is considered a core zone area and secondly to generate a verifiable record of confinement of mining activities within the ML boundary. The image enhancement technique is also applied to the image so that the feature boundaries are properly enhanced more lucidly to demarcate and delineate them separately. A large stretch of Vegetation is also seen within the ML area, which includes “sparse

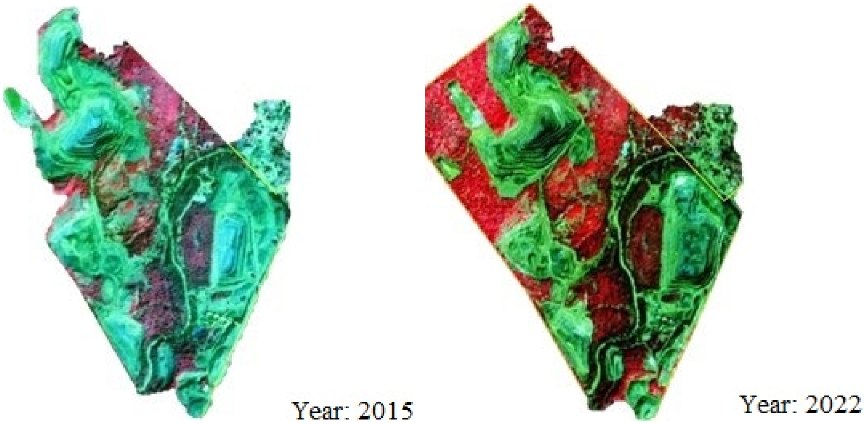

Fig. 4. Comparative images of Core zone during 2015 and 2022.

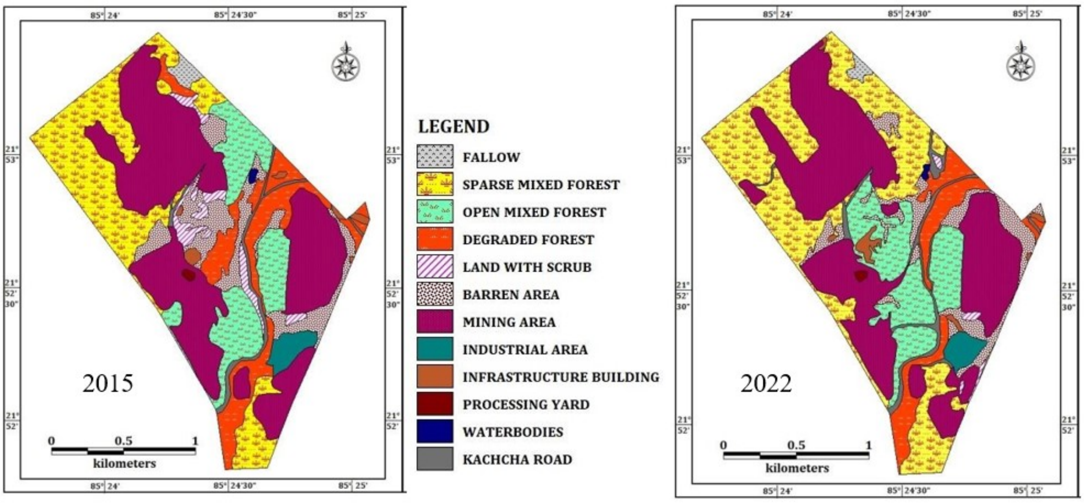

Fig. 5. Comparative LULC maps of Core Zone of the mining area during 2015 and 2022.

mixed forest", "open mixed forest", and "degraded forest" cover. Infrastructure buildings such as office, processing yard, and an industrial unit are also delineated within the core zone (Fig. 4).

The LULC categories as delineated from the satellite data are also compiled for the generation of LULC maps of the core zone (Fig. 5). Spatial computation of these LULC units within the core zone for both periods is being estimated using the GIS domain (Table 3).

The GIS data reveals that a healthy vegetative cover predominates apart from an area dedicated to mining activities. There has been a drastic increase in the area of "sparse mixed forest" at 7.27% in the core zone during 2022 as compared to the LULC map of 2015. A marginal increase in Open Mixed Forests around 1% is also observed whereas 4.15% of the degraded forest decreased during 2022 when compared with the LULC map of 2015. A uniform decline in the spatial extent of scrub at 2.47% and barren area at 2.17% during 2022 is also observed. At the same time, an increase of 1.1% area on Kachcha Road connecting mine pits and barren areas in the core zone is also observed.

5. CONCLUSION

The present study reveals that periodical monitoring of satellite data may be helpful in assessing environment-related issues pertaining to LULC and due consideration may be given to seasonal influence while carrying out periodical assessment, especially on the social and environmental impacts due to mining activities as well as impact on the density of "forest cover". The ground truth verification supports the analysis of accuracy for the database extracted for the study of the spatial extent of different LULC of the study area. Such a study can help assess the balance between surface land cover clearance and the implementation of afforestation schemes.

Forest cover during 2022 has increased as compared to 2015 even within the core zone area. The

Table 3. LULC Categories within the Core Zone and their Spatial Extent.

Sl. No	LULC Name	Area (Ha) 2015	Area % 2015	Area (Ha) 2022	Area % 2022	Change % of LULC
1.	Fallow	2.864	0.85	1.644	0.49	−0.36
2.	Sparse Mixed Forest	68.130	20.30	92.516	27.57	+7.27
3.	Open Mixed forest	42.878	12.78	46.025	13.71	+0.94
4.	Degraded Forest	36.616	10.91	22.704	6.77	−4.15
5.	Land with Scrub	9.993	2.98	1.690	0.50	−2.47
6.	Barren Area	32.216	9.60	24.936	7.43	−2.17
7.	Mining Area	127.259	37.92	126.920	37.82	−0.10
8.	Industrial Area	5.887	1.75	4.998	1.49	−0.26
9.	Infrastructure Building	2.684	0.80	3.459	1.03	+0.23
10.	Processing Yard	0.521	0.16	0.495	0.15	−0.01
11.	Waterbodies	0.466	0.14	0.440	0.13	−0.01
12	Kachcha road	6.080	1.81	9.770	2.91	+1.10
	Total	**335.594**	**100.00**	**335.594**	**100.00**	

spatial pattern of LULC did not show much variation except for “forest cover” which was delineated based on the density of vegetation. The mining area showed some minor expansion within the core zone. The study of temporal LULC around the buffer and core zone area of Iron Ore Mines near Balda village and comparison of periodical images helps to highlight areas that show changes in LULC pattern emphasizing the necessity of using temporal remote sensing satellite data to monitor such changes. Accordingly, precautionary measures might be taken during the preparation of an environmental management plan for the mining area with consideration of economic as well as environmental sustainability. Still, steps must be undertaken to improve upon the “forest cover”, indigenous saplings might be planted near places where human interference is more to sustain natural cover and to mitigate pollution-related issues during mineral transportation through the roads passing through the mines area.

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