JOURNAL OF GEOINTERFACE, Vol.1, No.2, December 2022 pp.44-50

Spatial analysis of Biomass Cover status around an Iron ore mine in the Kalimati forest area of the Joda mining circle of Keonjhar district by using the NDVI application

Prithwiraj Sahu[1*] and DM Kumawat[2*]
[1]Senior Scientist Environment, Balda Block Iron Mines, M/s Serajuddin & Co., Keonjhar, Odisha, India
[2]School of Studies in Environment Management, Vikram University, Ujjain, Madhya Pradesh, India
*Corresponding author: prithwiraj72@gmail.com

Abstract: The biomass of vegetation cover supports biodiversity in a dynamic way in a forest ecosystem. The standing biomass of vegetation cover in an ecosystem helps to sustain the biodiversity with its extended support, i.e., availability of food, shelter, habitat conservation, preventing endemic animals from species dilution, and providing a basic scope of nourishment to the biodiversity within the specific ecosystem. Flora is an ecosystem's standing biomass that has both economic and aesthetic value. In other parts, the floral cover or the floral biodiversity of the forest cover hides the valuable mineral resources. Minerals such as iron ore, manganese ore, and so on are present beneath the ground covered with standing biomass from forests and have a higher economic value in industries that cater to the needs of human society. However, unmanaged and injudicious mining activities degraded the existing land and ecosystem. The modern mining process supports the management of natural resources. The vegetation cover within the core zone and buffer zone of mines was studied in the current study using recent remote sensing satellite data around Kalimati Forest in Keonjhar District, Odisha. The monitoring of vegetation cover was carried out by generating temporal land use and land cover maps and also by implementing the Normalized Difference in Vegetative Index (NDVI) to draw a clear picture of vegetation cover as standing biomass within the study area. The land use data was extracted from satellite data for the comparison of land use information for both the core zone and buffer zone of the mining area. The satellite data also shows some oscillation among the various types of forest cover that are delineated based on the density of vegetation. NDVI analysis of satellite images from specific study periods provided valuable information about the study area's standing biomass as vegetation and soil condition. The comparative study of temporal thematic data from satellite for the selective "region of interest" (ROI) and "sample sites," also promoting the data extracted for study, provides information regarding the vegetative vigor of the area. In general, NDVI analysis gives a pragmatic view regarding the vegetative condition, which could be significant when carrying out a site- specific or location-based environmental assessment and environmental management plan to sustain the natural resources.
Keywords: NDVI, mining, forest cover, vegetation cover, biodiversity, region of interest.

Introduction

Iron ore is an essential mineral for any development and economic growth of a nation, which is mined from the earth surface with the use of recent modern technology without disturbing the natural resources. It is quite true that mining activities are a destructive process; they deteriorate the existing natural ecosystems, biodiversity, etc. On the other side mining processes also have another aspect in that environmental management is a prime concern to maintain the nature's aesthetic value. Natural resource management is an integral part of mining activity (Tripathy et al., 2007). The Keonjhar district of Odisha is famous for metalliferous mineral mining. The vast reserve of iron and manganese ore is the major credential of this district. In Keonjhar district, the Joda mineral zone area is the major reserve of high-grade Iron ore. The land is well covered with the dense dry deciduous forests land; the forest having standing biomass as well very rich in biodiversity. The forest land mass supports the biodiversity also helping in nurturing in the forest dwellers and dependent species also acts as real habitat of very sensitive flora and fauna. The significant purpose of the study is to assess the biodiversity living within the land mass and the use of modern tools like remote sensing satellite data and image interpretation technology through the NDVI application reveals about the sustenance different standing crops of biomass that pertain to the specific area of the study and their status.

Mining activities naturally imbalance the status of natural resources which would have certain inevitable impacts, both positive and negative. The prime objective of this study is achieved using the data obtained from remote sensing satellite imagery, which acts as the latest tool and provides a synoptic view of the study area under uniform illumination at a regular periodicity. The periodic data of remote sensing satellite imageries provided dynamic information about the land use pattern and also support as input to the LULC (Land Use and Land Cover) pattern. LULC helps in generating a digital database for the study of various vegetation covers by using Geographic Information System (GIS) (Kivinen et al., 2018; Sahu, 2009; Tripathy et al., 2007). Such a database is used to provide location specific information about any natural ecosystems and about its vast biodiversity with respect to vegetation cover, which is very valuable for wildlife management. A proper study of the geographical conditions of any mineralized area greatly supports the restoration of existing landforms and natural habitats with respect to the existing standing biomass of the area (Mountrakis et al., 2011; Prakash and Gupta, 1998; Redondo-Vega et al., 2017; Wang et al., 2017).

Materials and Methods

Data used

The analysis of standing biomass in the specified study area with reference to the vegetative cover of this area is only possible through the periodical study of land use and land cover patterns in and around the Iron ore mine in the Kalimati forest area of the Joda mining circle near Balda village using the satellite imageries (Sahu, 2009; Wang et al., 2017). The cloud free temporal images of R2 LISSIV data from January 2016 and February 2020 were used for the assessment of biodiversity in the study area (Figs.1 and 2). The normalized difference in vegetative index (NDVI) analysis application is used to understand the changes in the area's vegetative cover (Beck et al., 2006; Jiya and Musa, 2011). The study reveals the potential impact of anthropogenic activities and mining operations on the biomass of the region of interest in a short period of time.

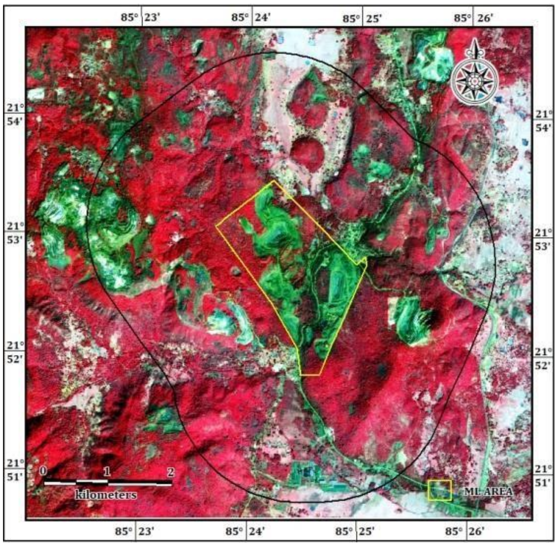


Fig. 1. LISS IV data of Buffer area around the corezone – January 2016.

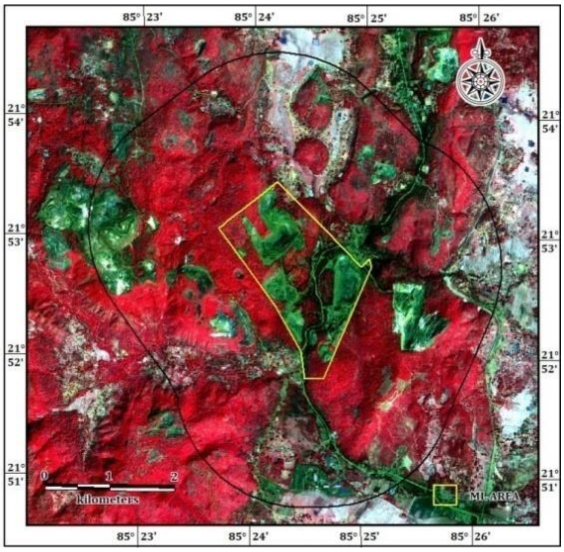


Fig. 2. LISS IV data of Buffer area around the corezone – February 2020.

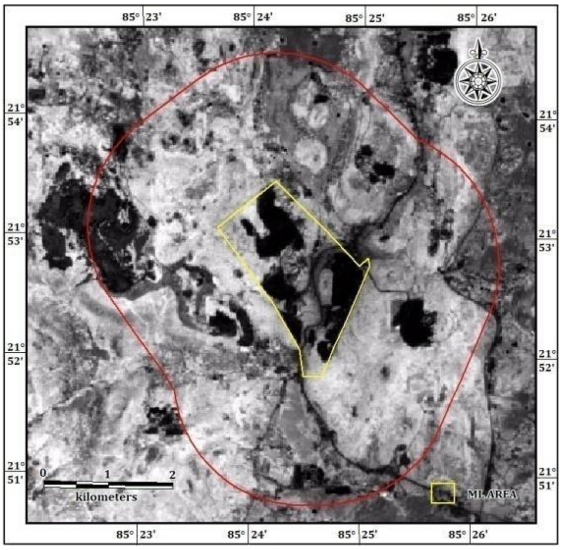


Fig. 3. NDVI map of Buffer area using LISS IV of January 2016.

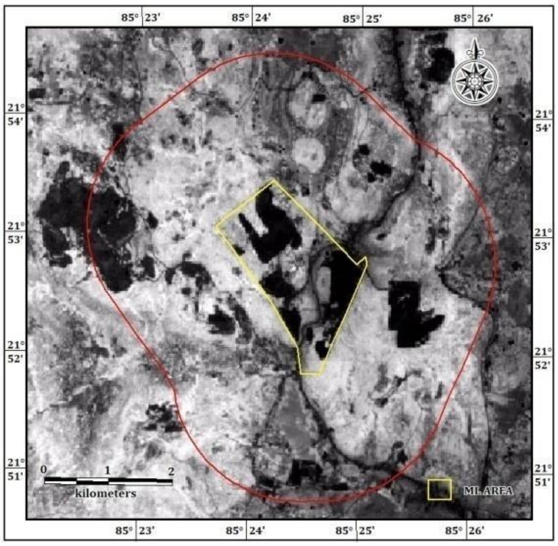


Fig. 4. NDVI map of Buffer area using LISS IV of February 2020.

Methodology

Temporal satellite data is used to investigate land use and land cover, as well as the vegetation vigor of mine-affected areas. Detail study of the existence of biodiversity in the study area is only possible by applying the normalized difference in vegetative index (NDVI) on the satellite images, which is a tool for analysing vegetation cover status. The remote sensing satellite imagery provided support for natural resource management preparation during mining planning (Jiya and Musa, 2011).

Monitoring of LULC around the buffer area and within the core zone was carried out in two phases: first generating temporal LULC maps for 2016 and 2020, and second implementing NDVI analysis to study the diversity of vegetation cover within the study area for the same two periods. Comparison of land use information as extracted from the satellite data, for both the core zone and buffer area. The available baseline data helped in assessing the vegetation cover changes in the buffer area and the core zone on account of mining activities in the adjacent area. Thus, the objective of the present study is to interpret satellite images and apply NDVI analysis tools to extract the information about the standing vegetation biomass vigor of the core and buffer area (Beck et al., 2006; Anil et al., 2010; Paull et al., 2006). The NDVI analysis of the buffer area is carried out to understand the nature of vegetative cover (Jiya and Musa, 2011). NDVI calculates the ratio between the cumulative values of Digital Number (DN) in the red (R) and near-infrared (NIR) spectral regions and their difference in DN values in the R and NIR regions. The study provides valuable information on the vegetative condition of an area. The NDVI is carried out for the whole sub-scene of selective “regions of interest” as well as some selective sample sites where a particular LULC category is predominant.

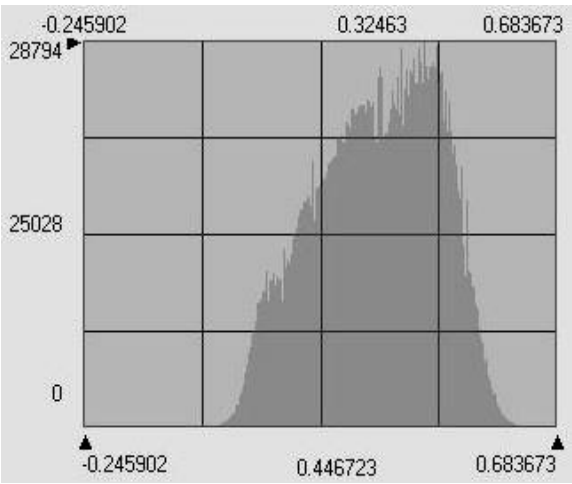


Fig. 5. Histogram of NDVI values (2016).

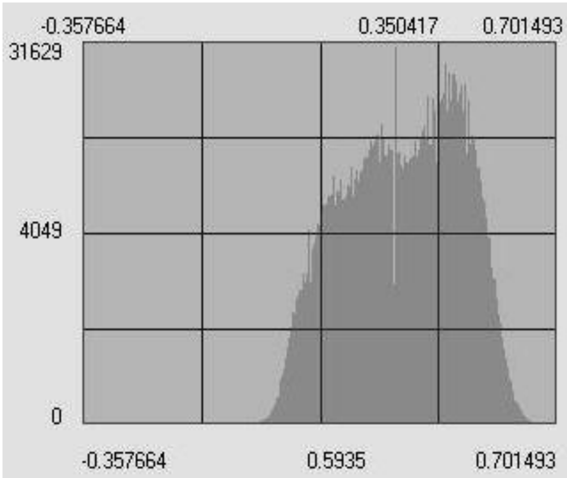


Fig. 6. Histogram of NDVI values (2020).

Results and discussion

It is to be mentioned that the extraction of all these sub-scenes from both 2016 and 2020 satellite data had identical upper left and lower right X-Y coordinates, so that the number of pixels and geo-locations of all the images remained the same (Figs. 1 and 2). The vegetation cover information was derived from NDVI analysis of sub-scenarios extracted from LISS IV data from January 2016 and February 2020 (Figs.1 and 2). The pixels show black or dark grey to light grey or near white due to the reason that the NDVI values range from -1.00 to +1.00 with -1.00 showing objects having a higher degree of absorption and reflectance. In our geographical environment, the value generally ranges from as low as -0.02 to as high as 0.71 with lower values representing water bodies. The higher values are due to the high reflectance of vegetation, which is well suited to throw light on the vegetative vigor and help in assessing the biomass productivity of an area. This approach was also applied in the present study to understand the general vegetative condition within the buffer area (Figs. 3 and 4). NDVI analysis of the satellite imageries reveals that the large patch of darker objects presents in the western, central, and eastern parts show the presence of mining area as they recorded low spectral reflection (DN) values. Vegetation with high reflectance shows positive values, and vegetation with thick canopies shows relatively higher reflectance than agricultural crops. The study area shows relatively thicker vegetation cover during 2020 as compared to 2016 data.

It is evident from the brighter tones seen during 2020, implying the presence of a higher degree of thick vegetative cover than in 2016. It is also evident from the cumulative statistical data and histogram obtained for both periods. NDVI analysis for the 2Km buffer area during 2016 showed a minimum value of -0.2459 and a maximum value of 0.6836 with a mean of 0.325. The most frequent occurrence value (Mode) is 0.4186, signifying the presence of vegetation with thick canopies, mostly forest cover. On the other hand, 2020 data revealed a minimum value of -0.35766 and a maximum value of 0.70149 with a mean of 0.350. The frequent occurrence value (Mode) is 0.42843, a relatively higher value signifying a more robust vegetative condition and biomass content (Figs. 5 and 6).

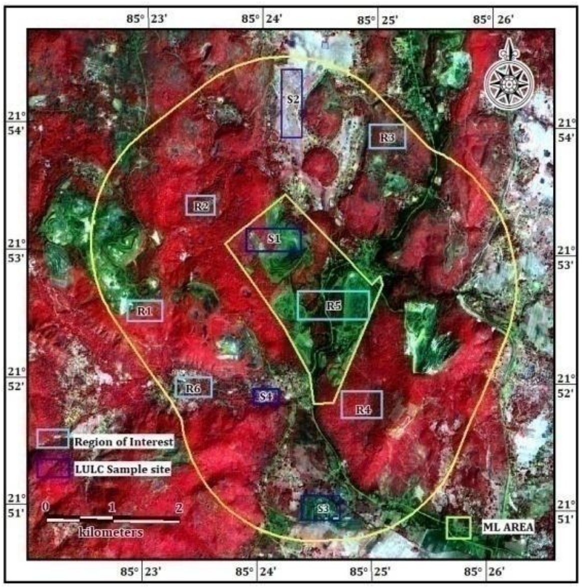


Fig. 7. Locations of ROI and LULC sample sites (LISS IV – Feb 2020).

The histogram values reveal information about the status of vegetation cover, as the minimum value in 2020 may reflect more intense mining activities than in 2016, while the higher maximum value in 2020 indicates denser and thicker vegetative growth, in this case "forest cover." To compare the changes in vegetation and its vigor using NDVI, four "regions of interest" (ROI) distributed in all four directions of the buffer area were selected. Similarly, a few "sample sites" of selective LULC categories were selected to understand their temporal behavior using NDVI. The locations of both ROI and sample sites of selective LULC features are shown in Fig.7.

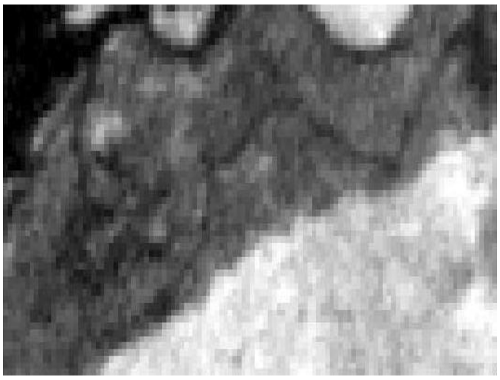
The regions of interest were chosen to be located around the core zone, to represent all parts of the buffer area, and to represent the major LULC present in that part judiciously. Similarly, LULC units such as mining areas mixed with vegetative cover, fallow land, industrial areas and villages were selected and their NDVI were studied to understand their effective influence on the local environment (Jiya and Musa, 2011; Mondal et al., 2013; Tripathy et al., 2007). Thus, the statistical details obtained through NDVI analysis for six regions of interest are shown in Table 1.

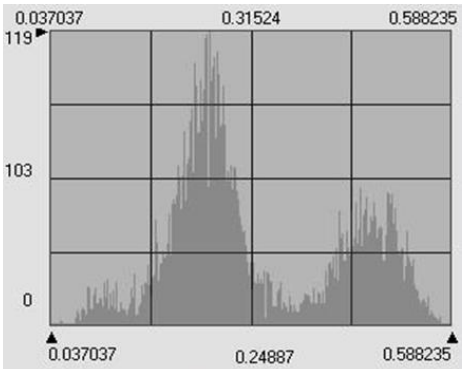
Table1. NDVI values for selected Regions within Buffer area.

Regional Sites	NDVI (2016)				NDVI (2020)			
	Min	Max	Mean	Mode	Min	Max	Mean	Mode
Region #1	0.037037	0.52324	0.304	0.23235	0.032337	0.58824	0.315	0.25235
Region #2	0.167880	0.59111	0.433	0.49688	0.147880	0.62341	0.463	0.52348
Region #3	0.146340	0.52128	0.356	0.33234	0.148650	0.57447	0.386	0.33829
Region #4	0.089286	0.59649	0.423	0.43205	0.113040	0.63134	0.452	0.49569
Region #5	-0.066667	0.54839	0.178	0.09190	-0.103450	0.61497	0.230	0.10703
Region #6	0.038961	0.57430	0.320	0.28363	0.551720	0.60396	0.349	0.32742

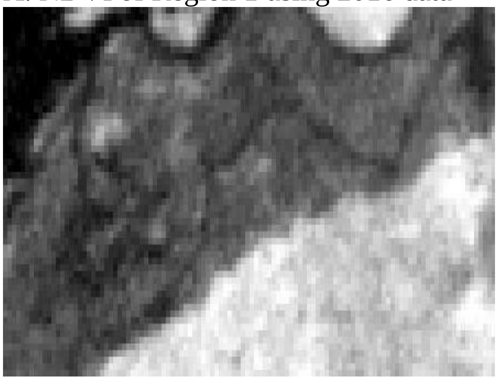
From the Table 1, it is revealed that region 1 had positive minimum and maximum values with a more frequent value of 0.232 (mode) for the year 2016 and 0.252 (mode) for 2020, whereas region 2 had positive minimum and maximum values with more frequent value of 0.496 (mode) for the year 2016 and 0.523 (mode) for 2020 and region 3 had positive minimum and maximum values with a more frequent value of 0.332 (mode) for the year 2016 and 0.338 (mode) for 2020, respectively. NDVI data reveals the prominent changes that occurred in the vegetation cover of the selected buffer area within a short period of time from 2016 to 2020. These values imply a dominance of vegetation of less vigor or that the canopies are not dense or thick. But the higher range of values observed during 2020 indicates relatively denser vegetation (Figs. 7 and 8). The mining activities restricted to within a certain limit of allocated area from 2016 to 2020. Already exhausted and mined lands are reclaimed and rehabilitated with massive plantations of indigenous species; waste dump plantations and safety zone plantations are religiously maintained to sustain the green belt in and around the mine core and buffer zone with less anthropogenic intervention on the forest cover. Most people in the vicinity of the mining area collect their fuel as firewood from the forest by cutting the saplings of Sal trees and other species for their household work. Already exhausted mined lands are reclaimed and rehabilitated with massive plantations of indigenous species; waste dump plantations and safety zone plantations are religiously maintained to sustain the green belt in and around the mine core and buffer zone with less anthropogenic intervention on the forest cover.

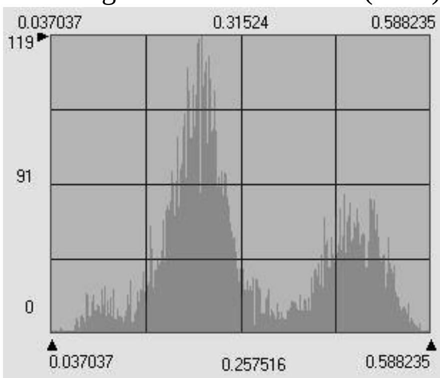
The anthropogenic intervention has a negative impact on the forest cover of the mining area's core and buffer zone. Mines owners and the local forest department combined efforts to raise awareness among the people, and massive plantation drive in the vacant areas of the core and buffer zone has given better scope for a new generation of forest cover. The people in the surrounding villages are mostly provided with LPG gas for cooking, which reduces the load on the firewood. Such steps by the local administration have had a positive impact on the vegetation growth and regeneration of forest species in the degraded forest floor. The prevention of forest fires by the mines and forest departments has also added a new chapter to the prevention of species destruction.


A. NDVI of Region 1 using 2016 data



B. Histogram of NDVI values (2016)


C. NDVI of Region 1 using 2020 data

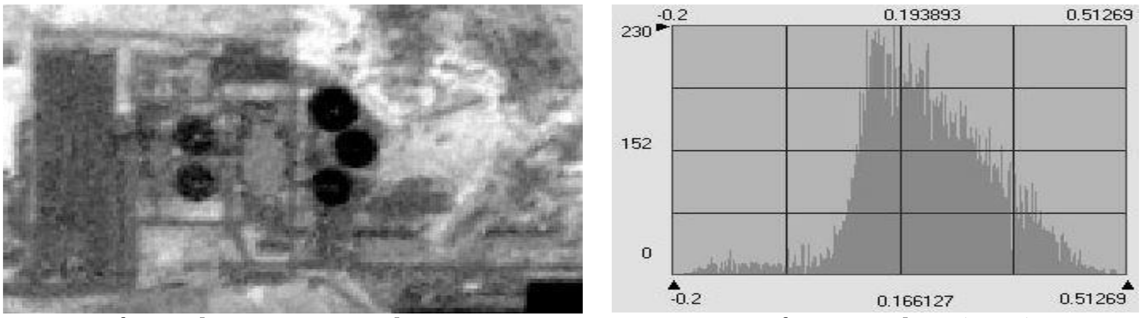


D. Histogram of NDVI values (2020)

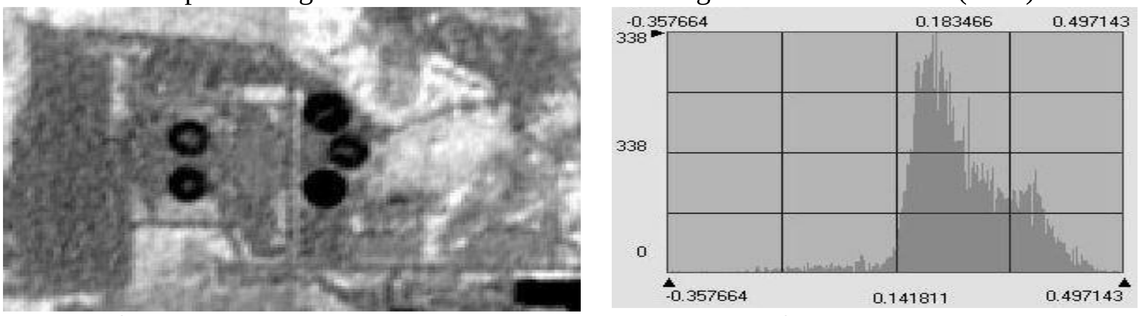
Fig. 8. NDVI of Region 1 (2016 and 2020) and their Histogram distribution.

Table 2. NDVI values for selected Sample sites within Buffer area.

Sample sites	NDVI (2016)				NDVI (2020)			
	Min	Max	Mean	Mode	Min	Max	Mean	Mode
Sample #1	-0.066667	0.63158	0.227	0.08608	-0.046296	0.66142	-0.06667	0.63158
Sample #2	0.129310	0.53097	0.272	0.28150	0.095238	0.50000	0.12930	0.53097
Sample #3	-0.200000	0.51269	0.194	0.14243	-0.357660	0.49714	-0.20000	0.51269
Sample #4	0.056856	0.60159	0.247	0.14410	0.060465	0.64055	0.05686	0.60159



A. NDVI of Sample 3 using 2016 data B. Histogram of NDVI values (2016)



C. NDVI of Sample 3 using 2020 data B. Histogram of NDVI values (2020)

Fig. 9. NDVI of Sample site 3 (2016 and 2020) and their Histogram distribution.

In other parts of the country, the local administration restricted shut down and luck down activities not only to limit the spread of Corona during the COVID-19 pandemic, but also to reduce lesser anthropogenic disturbances simultaneously observed in the forest area. The scheduled plantation work in the mining area and forest regeneration activities also support the luxuriant growth of the vegetation. Massive plantation work has been undertaken in the core and buffer zone of the mining area for the requisite fulfilment of plantations as per the mining scheme as mentioned in the mining closure plan. The spatial changes in forest cover area in the buffer region are clearly observed from the satellite images of 2016 and 2020 (Fig. 8).

Similar trends in values are seen for regions 2, 3, and 4, implying relatively denser vegetative cover during 2020 when compared to 2016. Region 5 is chosen within the core zone to observe the presence of vegetative cover within a mining area. The negative value (minimum) indicates the presence of a lower reflectance index in the mining area. Comparatively higher value was observed during 2016 as compared to 2020. At the same time, a higher range of “maximum” values during 2020 indicates denser vegetative cover than the previous period. Statistical values for Region 6, which is interpreted as “degraded forest,” also show a slight rise in range of values during 2020, implying an almost undisturbed natural vegetative cover (Fig. 7). To understand the utility of NDVI analysis in studying LULC, especially to observe periodical changes in LULC pattern, a few “sample sites” that were interpreted as “mining areas”, “fallow land”, an industrial area, and a village were studied, and their statistical values are tabulated in Table 2. The selected sample sites of Table 2 present in the buffer zone are marked on the satellite image (Fig. 7).

As per the above discussion the negative minimum value for “sample 1” indicates a lower reflectance values and in this case, it is the mining area with less vegetation (Fig. 8). The frequency of NDVI values of pixels (mode value) shows a lower value during 2016 than during 2020, which could probably be due to afforestation activity in that area. Sample 2, which is specifically selected for its representation of “fallow land,” showed lower “minimum” and “maximum” values during 2020 when compared to 2016 data. The “maximum value may be due to the presence of trees in the land parcel and lesser values around 0.2 indicate the presence of barren land with some shrubs or grass. Similarly, “sample 3” represents an industrial area identified in the southern periphery of the buffer area (Fig. 9). The negative values indicate the presence of water bodies within that area, and the “maximum” value is also greater in 2016 than 2020. At the same time, the higher “mode” value during 2020 indicates the presence of thick “vegetation cover” during the period when compared to 2016.

Conclusion

The NDVI analysis of satellite data brought out significant information on vegetative condition (forest cover) and soil condition of the study area. A comparative study of "regions of interest" (ROI) and "sample sites" resulting from analyzing 2016 and 2020 data has helped to assess the vegetative vigor of the area. In this study, the NDVI analysis has given an insight regarding the vegetative condition, and it could be significant when carrying out site-specific as well as location based environmental assessments with special reference to the real status of biomass available at the study area. NDVI analysis provides detailed information about the emergence of the standing biomass status as the area's vegetative cover, as well as the true health of the buffer area's vegetative condition. Such a study also signifies that periodic monitoring of satellite data is helpful to assess environment related issues. The LULC changes may studied with due consideration of seasonal influence carried out during periodical assessment especially focused on dynamic oscillation among various density of "forest cover". The NDVI study was carried out to assess site-specific vegetative covers pertaining to standing biomass in the region, and meteorological as well as geographical conditions in the study area. Such a study can help in assessing the balance between surface land cover clearance and the implementation of afforestation schemes in the environment management plan.

Acknowledgement

The authors remain thankful for the support extended by M/s Serajuddin & Co., Keonjhar for the support to study the land use changes in and around the iron ore mines with reference to the mining impact on the adjoining environment.

References

Anil, Z., Chitade, A.Z. and Katyar, S.K. (2010) Impact analysis of open cast Coal mines on land use/ land Cover using remote sensing and GIS technique: a case study, Int. Jour. Eng. Sci. Tech., v.2, pp.7171-7176.

Beck, P.S.A., Atzerberger, C., Hogba, K.A., Johansen, B. and Skidmore A.K. (2006) Improved monitoring of vegetation dynamics at very high latitudes: A new method using MODIS NDVI. Remote Sensing Environ., v.100, pp.321–334.

Jiya, S.N. and Musa, H.D. (2011) An Assessment of Mining Activities Impact on Vegetation in Bukuru Jos Plateau State Nigeria Using Normalized Differential Vegetation Index (NDVI). Jour. Sustainable Development, v.4(6), pp.150–159.

Kivinen, S., Vartiainen, K. and Kumpula, T. (2018) People and Post-Mining Environments: PPGIS Mapping of Landscape Values, Knowledge Needs, and Future Perspectives in Northern Finland. Land, v.7, p.151.

Mondal, S., Chakravarty, D. and Bandayopadhyay, J. (2013) Application of GIS Techniques for Assessment of Changes in Land Use Pattern and Environmental Impact of Mines over a Small Part of Keonjhar District of Orissa. IOSR Journal of Research & Method in Education (IOSR-JRME) v.2, pp.49-62.

Mountrakis, G., Im, J. and Ogole, C. (2011) Support vector machines in remote sensing: A review. ISPRS Journal of Photogrammetry and Remote Sensing, v.66, pp.247–259.

Paull, D., Banks, G., Ballard, C. and Gillieson, D. (2006) Monitoring the environmental impact of mining in remote locations through remotely sensed data. Geocarto Int., v.21, pp.33-42.

Prakash, A. and Gupta, R.P. (1998) Land-use mapping and change detection in a coal mining area -a case study in the Jharia coal field, India. Int. Jour. Remote Sensing, v.19, pp.391-410.

Redondo-Vega, J.M., Gómez-Villar, A., Santos-González, J., González-Gutiérrez, R.B. and Álvarez-Martínez, J. (2017) Changes in land use due to mining in the north-western mountains of Spain during the previous 50 years. Catena, v.149, pp.844–856.

Sahu, P. (2009) Spatial analysis of Ujjain Tehsil Grassland Status by Using Remote Sensing and GIS Techniques. GIS Development Weekly, 17 August, v.5 Issue 32.

Tripathy, G. K., Ghosh, T. K. and Shah, S. D. (1996) Monitoring of desertification process in Karnataka state of India using multi-temporal remote sensing and ancillary information using GIS. Int. Jour. Remote Sensing, v.12, pp.2243-2257.

Wang, G., He, G., Liu, J., Wang, M. and Cheng, B. (2017) Land Cover Change Monitoring of Mine City Using Multi- Temporal Satellite Remote Sensing Images. Jour. Adv. Information Tech., v.8, pp.17-22.

Manuscript received: 02-09-2022
Manuscript accepted: 10-11-2022