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Assessment of ecological restoration success and vegetation dynamics through spatial-temporal change detection in Gevra opencast mine, Korba coalfield, India

Preety Shah[1], Gunjan Patil[2] and Damini Sharma[1]

Department of Forestry, Wildlife and Environmental Sciences, Guru Ghasidas Vishwavidyalaya, Bilaspur, Chhattisgarh, India

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ABSTRACT

Mining activity causes a huge amount of land degradation by altering the land use pattern of the area. It is extremely difficult to restore and reclaim this degraded land because of the unfavourable Physico-Chemical conditions for plant growth. The purpose of the present study was the monitoring of land use and land cover, diversity and species composition of Gevra Opencast (OC) Mine of Korba Coalfield, Chhattisgarh and assessment of restoration success over the period of time. A phytosociological survey has been accompanied and a random quadrate sampling method was adopted for vegetation analysis and the change in vegetation cover was observed using Arc GIS software. The finding show that the area comprises 48 tree species with the Shannon-wiener index (H¢), Concentration of Dominance (D) (Simpson's index) Species Evenness (E) and species richness (R) were 2.72, 0.127, 0.70 and 6.38 respectively. A comparative analysis of land use and land cover based on data from 2001 and 2021 reveals that the degradation of agricultural land is caused by increased mining activities while similar efforts were made to restore the mine soil dump areas. NDVI value of the study site helps in monitoring the vegetation cover over a period which can be used as a monitoring tool for maintaining restoration success.

Key words: *Ecological restoration, Sustainability, Reclamation, Land Degradation, NDVI.*

Introduction

Despite the fact that coal is a key source of energy and one of the world's most important fossil fuels, mining activity is currently causing negative changes in land use patterns. Coal mining, which comprises both underground and opencast mining, plays a significant role in India's economic growth and development (Bandyopadhyay and Maiti, 2019) as it is the 2nd largest producer and consumer of coal in the world after China. India has 3,52,126 Million Tonnes (MT) of geological coal reserves, of which Chhattisgarh ranks third with 73,424 MT (20.85%), after Jharkhand with 86,217 MT (24.48%), and Odisha with 84,878 MT (24.10%) (Inventory of Coal Resources of India, 2021). Korba coalfield of SECL is one of the largest coa lfields in Chhattisgarh which only accounts for 12,976 MT (3.68%) of coal reserve in India up to the depth of 1200 m (Coal Directory of India, 2020-21). Coal reserves are aboundingly present beneath forested terrain; hence, coal mining has a detrimental effect on the environment. It involves the removal of overlying soil and rock fragment and disposal in another area to construct the

([1]Research Scholar, [2]Assistant Professor)

Overburden burden dumped area as well as mine voids which ultimately changes the soil strata (Bandyopadhyay and Maiti, 2019), diminishes biotic diversity and altered the structure and dynamics of ecosystems which has an effect on the region's water, air, and nutrient dynamics (Matson *et al.,* 1997; Almas *et al*., 2004; Ghose, 2004).

Sustainability in coal mining may be achieved by developing and integrating practices that lower the impacts of mining on the environment (Saini *et al*., 2016) and this can be achieved through vegetation development in the area. On these mine spoils process of natural succession is very slow due to adverse physicochemical properties of mine spoils (Kar and Palit, 2016). Overburden deteriorated soils have several barriers to plant growth in terms of physical, chemical, and biological qualities and it also contains heavy metals that hinder nutrient intake, plant growth, and microbial populations (Bohre and Chaubey, 2014). Mine spoils soil is deficient in major nutrient content especially organic carbon, available nitrogen, and available phosphorus which is essential for plant growth (Yaseen *et al.,* 2012). Therefore, ecological restoration of this degraded mine site is vital for bringing back its original land condition as well as it is also the best measure for reducing air pollution(Maiti and Banerjee, 1992; Maiti, 1993, 1998; Abbasi *et al.,* 2001). The Society for Ecological Restoration International (SERI, 2004) defined Ecological restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed".For the implementation and success of an effective ecological restoration project of an area vegetation composition and dynamics play an important role.

Remotely sensed data are used to detect the ongoing change in landscape structure (Mishra *et al.,* 2020; Pirnazar *et al*., 2018). Now a day remote sensing is a popular tool used for environmental monitoring in various aspects of ecosystems at local, regional, and global scales (Latifovic *et al.,* 2005). Change in vegetation dynamics is the most important indicator for detecting the change in environmental conditions of an area. It also helps in analysing the impact of current activities on the surrounding ecosystem. (Li *et al.,* 2021; Ji *et al.,* 2003). The studies of the geo-spatial method of coal mining area may be used to monitor land use/land cover change which helps in understanding the causes and consequences of change in vegetation structure and dynamics (Wu *et al.,* 2008). Various types of Vegetation indices are used as an important biological and physical measure for evaluating environmental change in degraded regions. One of the most important Vegetation indexes which are widely used for vegetation analysis is NDVI (Normalised Difference Vegetation Index). The data obtained from NDVI analysis is usually used as a popular tool for assessing and monitoring the vegetation health of an area (Mather and Koch, 2010). It is one of the band ratios whose values ranges from -1 to +1. The value near +1 shows that there is a high possibility of dense and healthy vegetation while values near zero or negative show the area doesn't consist of any vegetation or there is no vegetation.

Hence, the main objective of the study is to understand the vegetation dynamics of the area through geospatial temporal change detection over a period of time. The study helps in obtaining information about the tree composition and diversity of the mining area and the data obtained from NDVI gives the vegetation health status as well as the area degraded by the mining activity from 2001 to 2022. Land-use / land cover change detection through remote sensing data helps in analysing the possible impact of mining areas on the environment and usesit for future restoration management plans.

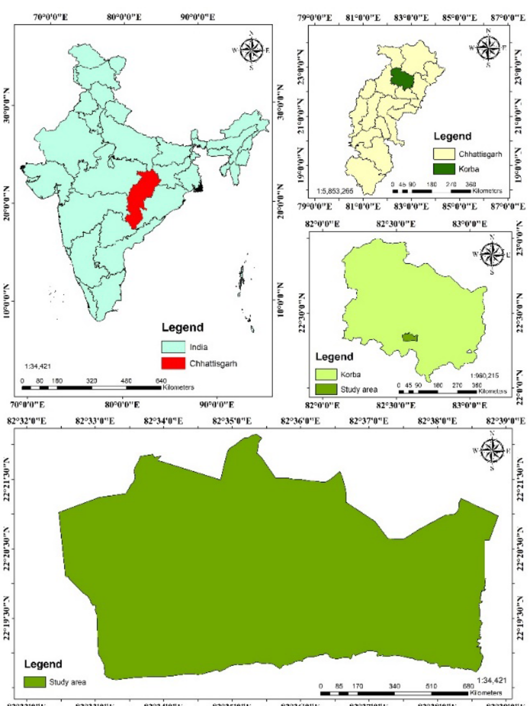


Fig. 1. Location Map of Study Area

Materials and Methods

Study area

Gevra open cast (OC) mine of Korba Coalfield of South Eastern Coalfield Limited (SECL) India lies at 22°22′7.52"N to 22°18′43.39"N latitude and 82°32′28.04"E to 82°38′53.15"E longitude (Fig. 1). It is the largest OC mine in the region, with a 4781.798 Ha total leasehold area and a 70 MT annual production capacity. The coal excavating activity started in 1981, while the process of restoring the land started in 1986.

Tree Species composition and diversity indices analysis

A survey was conducted on restored overburden dump areas by using the quadrat method to analyse vegetation and diversity. A totalof 60 quadrats of the size 10 m X 10 m (100 sq. m) have been laid in the different biologically reclaimed areas to quantify biodiversity and tree composition. The Importance Value Index (IVI) of tree species and the Family Importance Value Index (FIVI) of an individual family was determined by summing up relative density (RD), relative frequency (RF) and relative abundance (RA) (Misra, 1968).

IVI= RD + RF + RA

Diversity indices like species diversity (H¢)was calculated by using the Shannon-wiener index (Shannon and Weaver, 1949); Concentration of Dominance (D) was calculated through Simpson's index (Simpson 1949); Species Evenness (E) (Pielou 1966) and species richness (R) by Margalef's index (Marglef 1968).

Shannon-wiener index (H¢)

$$H' = -\sum_{i=1}^{S} pi \ln pi$$

Here, $pi = ni/N$

Simpson's Index (D)

$$D = \sum_{i=1}^{S} (pi)^2$$

Species Evenness (E)

$$E = \frac{H'}{H^{max}}$$

Here, $H^{max} = \ln(S)$

Margalef's Index (R)

$$R = \frac{S-1}{\ln(N)}$$

Where N= Total number of Individuals
ni= total number of a particular (i^{th}) species
S= Total number of species
ln= natural log

The generic coefficient of the biologically restored site was also calculated as: -

$$\text{Generic coefficient} = \frac{\text{No of Genera}}{\text{No of species}} \times 100$$

Spatial-temporal change analysis

The land use/land cover (LULC) change pattern of the study area has been analysed by using LANDSAT 8 and LANDSAT 5 satellite imaginary of path 142 and rows 44 & 45 for the years 2022 and 2001 respectively. The imaginary was obtained from the USGS earth explorer website (http://glovis.usgs.gov/) with a cloud cover of less than 10 %. Data from the same season were used to reduce seasonal variation and to choose uniform spectral and radiometric attributes. A base map of the research area was created using Survey of India (SOI) toposheets at a scale of 1:50,000, and all images were geometrically rectified. ArcGIS 10.4 software was used for digital processing and supervised maximum likelihood classification of satellite images into primary LULC classes.

Normalised Difference Vegetation Index (NDVI) for the years 2021and 2001was prepared by using LANDSAT 8 and LANDSAT 5 data of 30^{th} October2021 and 31^{st} October 2001; which indicates the vegetation health status over a particular period of time. For calculation of NDVI, the difference between the near-infrared (NIR) and red (R) reflectance is divided by their sum.

$$NDVI = \frac{(NIR - R)}{(NIR + R)}$$

These raster data that resulted were separated into fundamental intervals ranging from -1 to 0.1no vegetation, 0.1–0.2 bare soil, 0.2–0.4 sparse vegetation, 0.4–0.6 medium vegetation, and 0.6–1 dense vegetation (Kuzevic *et al.*, 2022).

Results and Discussion

Tree species composition and diversity Index

Various native and exotic species have been introduced to reclaim the mine area, which performs well, in order to reduce environmental impact of mining activities (Sheoran *et al*., 2010; Gudadhe and Ramteke, 2012). Native tree species are now being emphasized more for recovering the degraded area. Green cover generation in mining areas depends on the species used for reclamation and site conditions (Hazarika *et al*., 2006). Atotal of 48 tree species belonging to 40 genera and 20 families were recorded in the study area, in which most of the trees were

Table 1. IVI and FIVI of tree species growing at different overburden dump areasof Gevra.

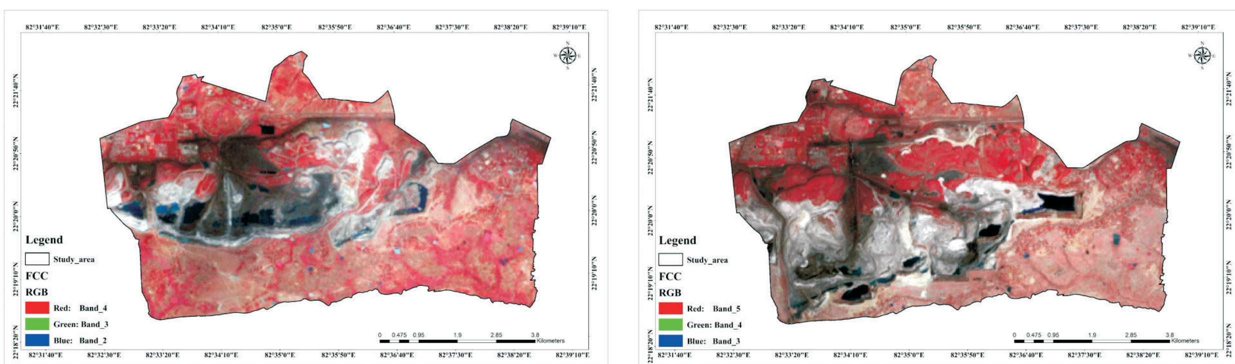
S.No.	Common Name	*Botanical Name*	*Family*	IVI	FIVI
1.	Mango	*Mangifera indica*	*Anacardiaceae*	3.15	5.57
2.	Satvan	*Alstoniascholaris*	*Apocynaceae*	2.87	5.21
3.	Arjun	*Terminalia arjuna*	*Combretaceae*	4.08	11.51
4.	Harra	*Terminalia chebula*	*Combretaceae*	1.76	
5.	Badam	*Terminalia catappa*	*Combretaceae*	1.46	
6.	Behra	*Terminalia bellirica*	*Combretaceae*	3.69	
7.	Sal	*Shorearobusta*	*Dipterocarpaceae*	9.78	17.07
8.	Amla	*Phyllanthus emblica*	*Euphorbiaceae*	5.14	8.85
9.	Sissoo	*Dalbergia sissoo*	*Fabaceae*	46.28	143.3
10.	Karanj	*Millettia pinnata*	*Fabaceae*	14.64	
11.	Subabool	*Leucaena Leucocephala*	*Fabaceae*	13.52	
12.	Black Siris	*Albizia lebbeck*	*Fabaceae*	17.66	
13.	White Siris	*Albizia procera*	*Fabaceae*	5.99	
14.	Cassia samea	*Senna siamea*	*Fabaceae*	6.67	
15.	Peltophorum	*Peltophorum pterocarpum*	*Fabaceae*	35.64	
16.	Ganga Imli	*Pithecellobium dulce*	*Fabaceae*	13.5	
17.	Prosopis	*Prosopis juliflora*	*Fabaceae*	3.3	
18.	AustalianBabool	*Acacia auriculiformis*	*Fabaceae*	4.97	
19.	Khair	*Senegalia catechu*	*Fabaceae*	2.8	
20.	Gulmohar	*Delonix regia*	*Fabaceae*	2.89	
21.	Imli	*Tamarindus indica*	*Fabaceae*	3.27	
22.	Babool	*Acacia nilotica*	*Fabaceae*	2.44	
23.	Kachnar	*Bauhinia variegate*	*Fabaceae*	5.33	
24.	Mangium	*Acacia mangium*	*Fabaceae*	7.97	
25.	Palash	*Butea monosperma*	*Fabaceae*	1.95	
26.	Raintree	*Samanea saman*	*Fabaceae*	3.33	
27.	Amaltash	*Cassia fistula*	*Fabaceae*	1.76	
28.	Teak	*Tectona grandis*	*Lamiaceae*	5.3	9.31
29.	Semal	*Bombax ceiba*	*Malvaceae*	2.1	3.81
30.	Neem	*Azadirachta indica*	*Meliaceae*	10.25	17.39
31.	Banyan	*Ficus benghalensis*	*Moraceae*	1.76	7.86
32.	Peepal	*Ficus religiosa*	*Moraceae*	2.36	
33.	Gular	*Ficus racemose*	*Moraceae*	2.06	
34.	Jamun	*Syzygiumcumini*	*Myrtaceae*	8.52	16.76
35.	Eucalyptus	*Eucalyptus spp*	*Myrtaceae*	2.96	
36.	Guava	*Psidium guajava*	*Myrtaceae*	1.46	
37.	Karra	*Cleistanthuscollinus*	*Phyllanthaceae*	2.99	2.12
38.	Bamb**oo**	*Bambusa spp.*	*Poaceae*	2.59	4.71
39.	Ber	*Ziziphus mauritiana*	*Rhamnaceae*	2.06	3.78
40.	Kadam	*Neolamarckiacadamba*	*Rubiaceae*	2.44	4.4
41.	Mundi	*Mitragyna parviflora*	*Rubiaceae*	1.15	
42.	Bel	*Aegle marmelos*	*Rutaceae*	2.45	6.16
43.	Lemon	*Citrus limon*	*Rutaceae*	2.99	
44.	Mahua	*Madhuca longifolia*	*Sapotaceae*	3.48	6.19
45.	Maharukh	*Ailanthus excelsa*	*Simaroubaceae*	3.52	10.34
46.	Simaroma	*Simarouba glauca*	*Simaroubaceae*	4.83	
47.	Chirol	*Holoptelea integrifolia*	*Ulmaceae*	5	8.61
48.	Khamhar	*Gmelina arborea*	*Verbenaceae*	3.95	7.03

native. A research by Malakar and Joshi (2020) on the Ranigunj coalfield found 10 tree species in a natural forest close to the coalfield and 30 tree species in various overburden dumps while Safronova *et al.* (2018) recorded 40 species belonging to 35 genera and 18 families. *Dalbergia sissoo* (46.28) was found the most dominant and important tree species in all the communities which only accounts for 15.43 % of the area (Table 1) which showed resistance to the adverse climatic condition of mining areas resulting in sustainable reclamation of area (Juwarkar and Singh, 2007) while the lowest IVI value (1.15) wasfor *Mitragyna parviflora.*

The FIVIvalue indicates that the most dominant family were *Fabaceae* (143.30) while *Meliaceae* (17.39) and *Dipterocarpaceae* (17.07) are the next most dominant families. Kar and Palit, (2016) get a similar observation with the family *Fabaceae* in Ranigunj mine area, which has the ability of nitrogen-fixing leads to vegetation development by tolerating the adverse soil and environmental condition in mine areasthat have been previously reported (Ekka and Behera, 2011; Biswas *et al.*, 2014). Shannon-wiener index (H¢), Concentration of Dominance (D) (Simpson's index), Species Evenness (E) and species richness (R) of the study site were 2.72, 0.127, 0.70 and 6.38 respectively. The study area's generic co-efficient was 83.33, indicating that the area is genetically diverse. It gives an indication of a Floristic organization's microclimatic state trend (Roy and Mukherjee, 2014)

Spatial-temporal change analysis

The use of remotely sensed data in the study area provides useful information about the vegetation dynamics and trends of deforestation or reclamation in the mining landscape. Land use land cover change detection helps in analysing the change that occurs during a time period. Data reveal from land use land cover classification during the year 2001 and 2022 (Table 3) shows that vegetation cover decreases while sparse tree/ scrub and grassland increases due to intensive plantation activity done on backfill and dump areas by SECL (Fig. 3). Mining areas consist of the active mining areas and barren over dump or backfill areas also increased from the period 2001 to 2022 by 5.42 % due to rapid industrialization. Agricultural land (including both Cropland and Fallow land) shows decreasing trend due

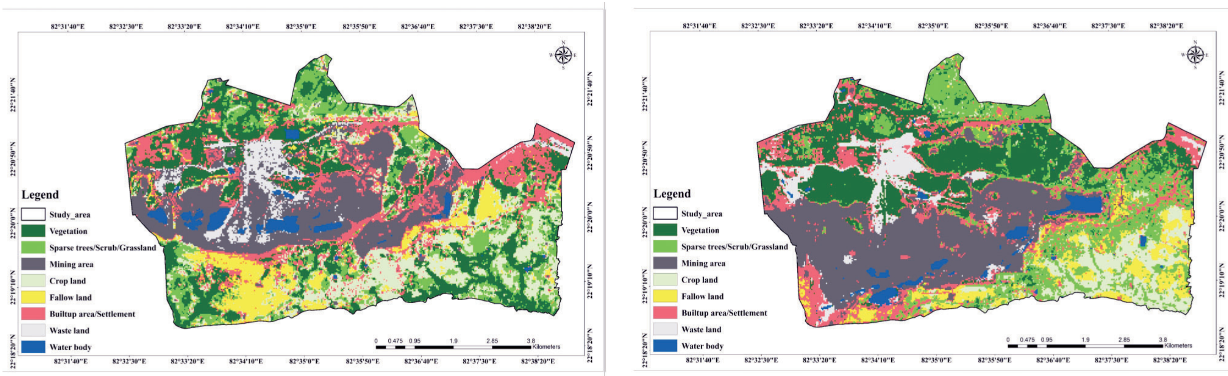


(a) (b)

Fig. 2. Showing False Colour Composition (FCC) Map of study area for the year (a) 2001 (b) 2022

Table 2. Land use/ Land cover Changes

Land use/ Land Cover Classes	LULC – 2001		LULC – 2022	
	Area (Ha)	Area (%)	Area (Ha)	Area (%)
Vegetation	1063.44	22.30	1042.11	21.85
Sparse trees/Scrub/Grassland	592.56	12.42	834.75	17.50
Mining area	926.91	19.43	1185.57	24.86
Crop land	727.2	15.25	351.63	7.37
Fallow land	350.01	7.34	282.87	5.93
Builtup area/ settlement	768.33	16.11	683.37	14.33
Waste land	230.49	4.83	275.85	5.78
Water body	110.88	2.32	113.67	2.38
Total	4769.82	100	4769.82	100



(a) (b)

Fig. 3. Showing LULC Map of study area for the year (a) 2001 (b) 2022

to an increase in the mining area. Due to the increase in coal extraction, the existing settlements and villages were relocated to other's places which shows a decreasing trend in built-up areas or settlements during the period. The results also show a slight increase in the wasteland and water bodies in the study area. Fig 4 gives the graphical representation of the change detection during the specific period.

Fig. 4. Change detection between year 2001 and 2022

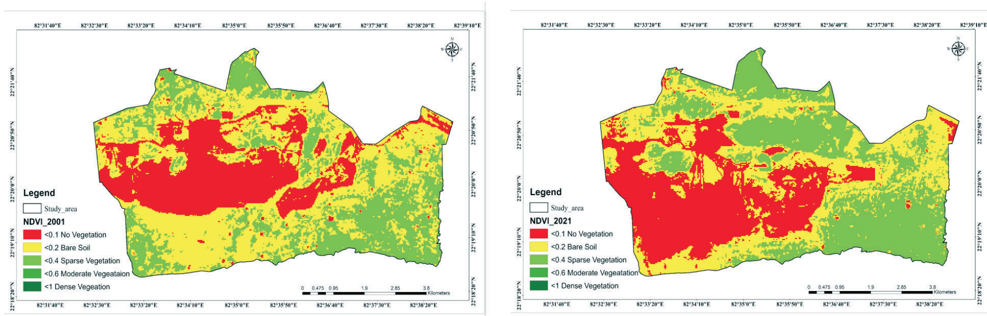
A study conducted in the mining area of Slovakia shows the change in the spatial distribution of individual land cover classes in a 6520.10 ha area between the years 1990 and 2018. The results show an increase in the discontinuous urban fabric and mineral extraction sites (Kuzevic *et al*., 2022). At the same time, the area is also technically and biologically reclaimed every year through plantation activity. Normalized Difference Vegetation Index (NDVI) shows high values for vegetation parameters such as green leaf biomass, green leaf area, and percentage of green cover, hence it is a considerable value for vegetation discrimination (Joshi *et al.*, 2006). The result shows that maximum value of NDVI for the years 2001 and 2021 is 0.358209 and 0.38548 respectively which shows that the change in vegetation cover is very low. The result shows that areas with no vegetation and sparse vegetation is increases during the period while bare soil shows declination, due to the ecological restoration of degraded land (Table 4).

Conclusion

Extraction of mineral resources especially through open-cast mining, degrade the land by changing its physio-chemical property. This land should be properly restored to improve the soil environment. Vegetation analysis of this ecologically restored site is very important for future management plans. The

Table 4. NDVI index

S. No.	NDVI Value	Class	NDVI (2001)		NDVI (2021)	
			Area (in Ha)	Area in %	Area (in Ha)	Area in %
1	< 0.1	No vegetation	1306.62	27.39	1515.06	31.76
2	0.1 - 0.2	Bare Soil	2122.74	44.50	1610.73	33.77
3	0.2 - 0.4	Sparse Vegetation	1340.46	28.10	1644.03	34.47
4	0.4 - 0.6	Moderate Vegetation	0	0	0	0
5	0.6 – 1	Dense Vegetation	0	0	0	0



(a) *(b)*

Fig. 5. Showing NDVI Map of study area for the year (a) 2001 (b) 2021

result of the present study indicates that the area consists of a good diversity index and species richness. Land use/ land cover change detection shows that the area degraded by the mining activity is reclaimed properly at the same time which resulted in even though increase in mining area very little or negligible change is detected in the vegetation cover. NDVI index helps in accessing the landscape condition in the coal mine area. There is no dense forest area recorded in the study area. The combination of vegetation analysis and remote sensing data helps in providing a cost-effective tool for evaluating the ecologically restored site of the coal mine over a period of time.

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