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Spatio-temporal dynamics of mines in Singrauli, India: An analysis using geospatial technology

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Abstract: Forests are at present facing threat because of various reasons. One such reason is the blooming of mining industry. It has many adverse impacts on the forest environment, water resources and wildlife habitat. Evaluation of such impacts time to time and controlling the negative aspects to promote sustainable living would benefit the nation and the people.The present study is an attempt to evaluate the spatial and temporal expansion of mines near Singrauli district (Uttar Pradesh and Madhya Pradesh border) since 1976. Amidst the dry tropical forests, the mines are prevalent since 1980s and are now a threat to the health of these forests. Satellite remote sensing data have the potential to observe large areas at regular intervals. Further, in GIS domain, area statistics can be computed which help in quantifying the actual loss or gain in various LULC classes. The temporal datasets for the present case were from Landsat (1976, 2002, 2010 and 2015). After the image processing and classification, the expansion of mines and transformation of various LULC classes were observed. The loss of forests and conversion to other land use was analyzed between different time periods. It was observed that the annual increase in mines area is 4.25 times higher when compared with the period (2010-2015) to (1976-2002). Continuous losses in the annual forest cover was due to increase in the mining area between the study periods (1976-2015) was observed.

Keywords: Geographic Information System (GIS); Land Use Land Cover (LULC), Mining, Remote sensing data, Satellite imagery

1. Introduction

Natural resources like oils, minerals, water, forests and fertile land have been the backbone of human existence by providing the necessities of life such as food, fodder, medicines and fuel. Over the years, they have been exploited immensely for economic gains. Increasing population and the quest for power has led to extraction of minerals, especially coal, to meet the ever increasing demand. Mining and its related activities in forested region are responsible for a change in the land use/ land cover (LULC) and have a profound effect on the forest ecosystems (Greenpeace, 2011).

India is a country which has large reserves of minerals. It is the third largest producer of coal (565.6 MT) and has the fifth largest coal reserves (of 301.6BT) in the world (Energy statistics 2016). The Government of India has facilitated and favored the mining sector by increasing the lease period. The enforcement of the MMDR [Mines and Mineral (Development and Regulation) bill, 2015] has given an opportunity to dig more and for longer time periods. In light of these mining dominated environment, it is necessary to monitor the status of the forests and water bodies in proximity to such areas.

There are many states in India which harbor rich mineral deposits within their forest cover. One of them is the Singrauli area situated at the border of Uttar Pradesh (near Sonebhadra district) and Madhya Pradesh (Sidhi and Surguja districts) and is known as the energy capital of India with rich reserves of coal. It is the largest industrial area of the South east Asia. The presence of GovindBallabh Pant Sagar (which came into existence in 1960s) in the vicinity has facilitated the establishment of many thermal power plants. Some of them are like National Thermal Power Plant in 1977, National Coalfields Limited in 1986, Singrauli Super Thermal Power Plant in 1982 and Vindhyachal STP in 1987 (Pandey, 2005). Some of the coal blocks are Jayant, Chilkadand, Dudhichua, Basi and JogiChaura.

By the year 2009, Singrauli was declared as one of the critically polluted areas in an analysis conducted by Central Pollution Control Board and MoEF in collaboration with IIT, Delhi. It ranked ninth among the list of 14 critically polluted areas with an index of 81.79 (CPCB, 2009). As a result, a temporary moratorium was imposed in January, 2010, when no new mining lease was sanctioned and expansion was halted. The ban was lifted in July, 2011. The “no –go” areas did not allow mining within its premises while the “go” areas were permitted after 2009. The expansion of mines and leases sanctioned to upcoming mines was more prevalent after 2008-2009 and a rapid expansion of mines is observed in between 2010-2015. The new mines are finding place in the Moher basin on the left side of the present existing blocks. As analysed by Singh (2014), it was seen that mining area was lowest in 2000 between the study periods analysed by him (1991-2011).

It has also decimated the growth of the tropical dry deciduous forests and has been singled out as an Eco sensitive zone (Singh et al., 2003). Further, this region is characterized by hot summers, erratic and scanty rainfall and moisture stress conditions. Deforestation, conversion of forest to agricultural farmlands and subsequently losing it to urbanization has become the norm of the dry tropical deciduous forests. Thus the fragile ecosystem is now on the verge of desertification (Singh et al., 1991). The mines operating in Singrauli are open cast mines (Chopra, 2011).

Spatio-temporal analysis of LULC patterns are required to understand the impacts of minig activities on the environment. In this endeavour, satellite remote sensing provides the suitable data which can be processed and interpreted in a precise manner. The availability of satellite data at various resolutions and time period helps to study the situation at various spatial scales and time periods.

Singrauli has been the focal point for research by many enthusiasts. Areendran et al. (2013) have analysed LULC changes using multidate satellite data. Changes were quantified using landscape metrics and using Markov transition matrix.They noted that dense forests decreased from 1978 to 2010. In another study by Khan and Javed (2012), a comparative analysis of LULC was done for 2001 and 2010 using post classification comparison. The study concluded that before industrialization and mining, this area was covered with tropical dry deciduous forests. Forest has been destroyed to make way for infrastructure establishment and various industries.

Changing landscape patterns were analysed by Viswakarma et al. (2016) in Singrauli using Landsat data of 1991, 2000 and 2014. They noted that the rate of deforestation is more from 2000-2014 than 1991-2000. The mines have increased rapidly in between 2000-2014 and many forest patches have either disappeared or got converted to other land use. In all these studies it was observed that progress of mining activities has caused forest loss and much transformation in LULC patterns. Towards this, the present study focusses on the impact of mining on the forests and LULC pattern using satellite remote sensing data and GIS. It analysed the spatio - temporal changes related to mines and its expansion over the years 1976, 2002, 2010 and 2015 along with simultaneous forest loss.

2. Study area

The study area is located at the border of the two states that is Uttar Pradesh and Madhya Pradesh. It extends between latitude $24^{0}00' 31.39''$ N to $24^{0}16' 14.98''$N and longitude $82^{0}27' 58.05''$ E to $82^{0}50' 19.16''$ E. (figure 1). The Sonbhadra and Mirzapur districts of Uttar Pradesh form the eastern and the northern boundary. The topography is distinctly characterized by undulating terrain with altitude ranging from 243m to 640m above mean sea level. The climate of this region is mainly tropical to semi-arid. It is marked by three distinct seasons in a year. The summer season begins in March/April till June, the rainy season is from July to September and winter season is from October to February/March. The mean annual maximum and minimum temperatures are 37°C and 20°C, respectively. The soils in the study area vary from loamy sand to clay. Alluvium soil exists in the plain areas; colour varies from red to yellow.

3. Materials and methods

3.1 Data acquisition and preprocessing

The required Landsat satellite imagery of years 1976, 2002, 2010 and 2015 were downloaded from the USGS Earth explorer database and the specifications are given in table 1. The scenario before the start of mining activity and after can be studied in these years.

All the datasets belong to the December month, when the vegetation is in good condition. Tropical dry deciduous forest has a characteristic phenology marked by leaf fall during the dry season. Each dataset was found to be cloud free and was radiometrically and geometrically corrected. The image processing and interpretation for delineation of mining area and other LULC classes was performed in ERDAS Imagine software. The generated maps were studied and analyzed to detect the expansion of mines temporally and spatially. The detailed methodology is given through a schematic flowchart (Figure 2).

Table 1: Details of the satellite data acquired

Years	Satellite	Sensor	Spatial resolution	Dates
1976	Landsat	MSS	60 meter	22/12/1976
2002	Landsat	ETM+	30 meter	21/12/2002
2010	Landsat	TM	30 meter	03/12/2010
2015	Landsat	OLI	30 meter	01/12/2015

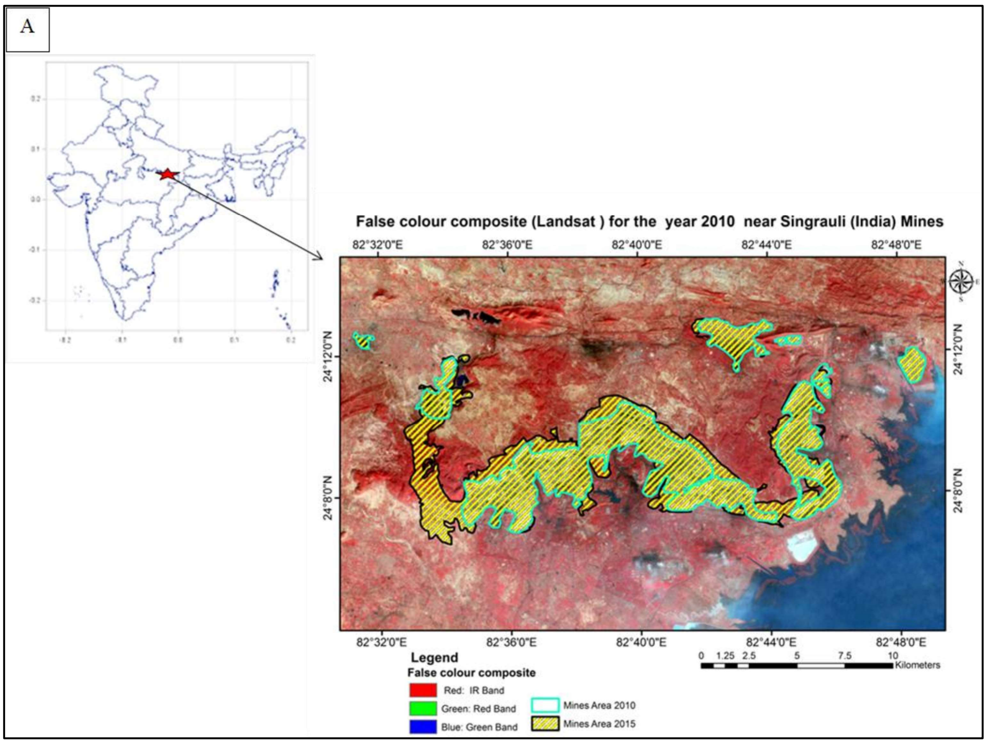

Figure 1: A) Map of India; B) FCC showing the location of Singrauli coal fields and overlay of mines boundary for the year 2010 and 2015

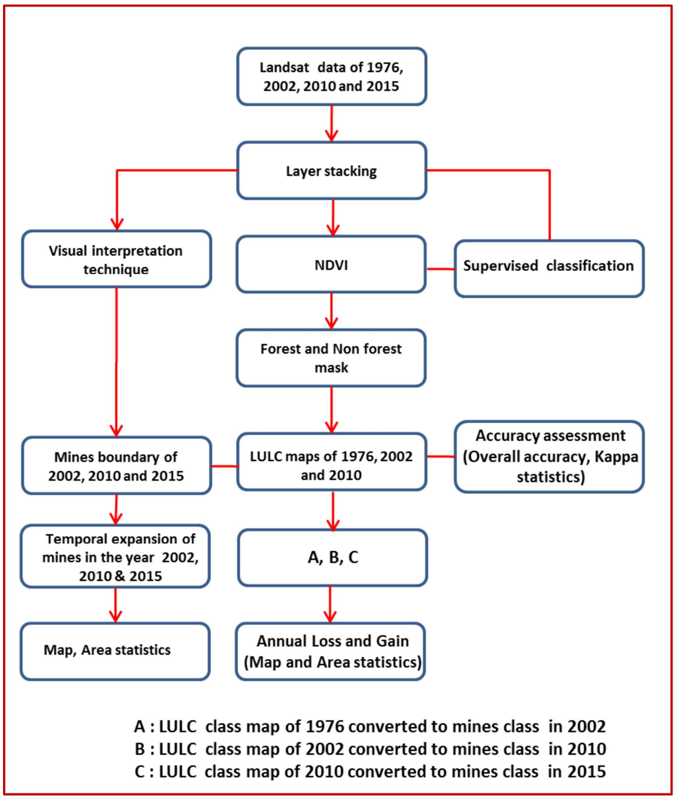

Figure 2: Schematic flowchart for analyzing the expansion of mines

3.2 Image processing and classification

Each of the satellite images was first enhanced to increase its visual interpretability. The boundary of the mines was visually interpreted on the false colour composite (FCC) and extracted from each of the datasets of time periods 2002, 2010, 2015. In the year 1976, no such mining area was visible as the mines were not established by that time. To explain the contribution of each year in expansion, it has been elaborated briefly below.

2015 mining area= 2002 mining area +(expansion from 2002-2010) mining area +(expansion from 2010-2015) mining area
2010 mining area = 2002 mining area +(expansion from 2002-2010) mining area
2002 mining area = zero (no mines was visible in 1976 Image) + (expansion from 1976-2002) mining area.

The individual shape file of the boundary of mines for 2002, 2010 and 2015 were brought in ArcGIS and integrated for generating the shape file of mines expansion between the period 1976-2002, 2002-2010 and 2010-2015.

The Landsat imagery for the year 2015 was not classified but only used to generate the boundary of mines visually because the objective of our study was to see the mines expansion till the year 2015.
For the datasets of 1976, 2002 and 2010, Normalized Difference Vegetation Index (NDVI) was executed to delineate vegetation. Further, by visual interpretation, the derived vegetation was utilized to generate two masks viz forest and non-forest.

The supervised classification technique (maximum likelihood) was performed on each data set to delineate different LULC classes viz., dense forest, open forest, water, other class. The training sets were given (9-10) for each class distributed uniformly throughout the image. Non forest mask was used to extract the other vegetation class. Finally all the LULC classes were integrated in model maker of ERDAS Imagine to obtain a single classified dataset. A brief description of each class is given in the table 2.

Accuracy assessment was executed for each classified dataset1976, 2002 and 2010 years for evaluating the quality of classification. Random sampling points were generated for various classes of the classified dataset. Confirmation was based on ground truth. Other ancillary and literature sources also assisted in confirming that the classified data matched with the ground truth. The generated shape file of mines expansion for the period of 1976-2002, 2002-2010 and 2010-2015 was used to subset classified output from 1976, 2002 and 2010 respectively for further analysis.

Table 2: Description of various LULC class

LULC class	Description
Dense forest	Canopy > 40%
Open forest	Canopy 10-40%
Water	Reservoirs, ponds, dam, lakes, water logged area
Others class	Areas with no vegetation cover, Waste land, Barren land, fallow, settlement and Uncultivated agricultural lands
Other vegetation	Vegetation outside the forest boundary such as trees, gardens, parks and playgrounds, grassland, agricultural lands and crop fields

The statistics for the mining area for the years 2002, 2010 and 2015 were generated and its annual expansion was calculated. Temporal change of LULC with respect to preceding time frame due to mining in 2002, 2010 and 2015 was examined. Subset of the classified LULC output of mines expansion for the period of 1976-2002, 2002-2010 and 2010-2015 was used to generate area statistics. Further, changing patterns of LULC class categories during period 1976-2002, 2002-2010 and 2010-2015 were evaluated.

4. Results

LULC maps for four study time periods were prepared. Changing patterns of LULC class categories during period 1976-2002, 2002-2010 and 2010-2015 were evaluated (see figure 3). The results are presented,

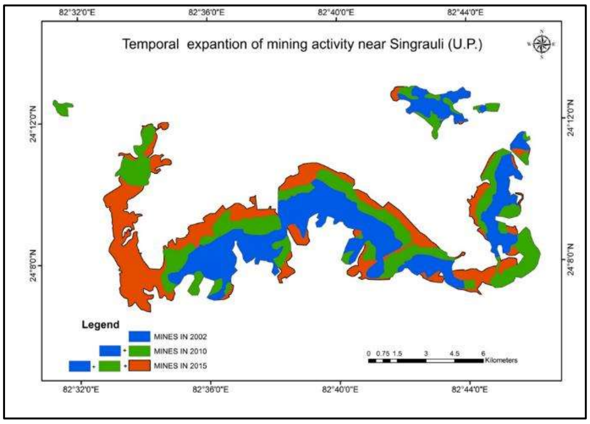

Figure 3: Temporal expansion of mines

4.1 Classification accuracy assessment

No image classification is complete until an assessment of accuracy has been performed. The overall accuracy and the Kappa statistic were also calculated and tabulated on the classified output (Table 3).

Table 3: Overall accuracy and Kappa statistic for LULC analysis

Years	% Overall Accuracy	Kappa statistic
1976	92	0.89
2002	94	0.91
2010	92	0.88

4.2 Spatial and temporal expansion of mining activity

The mining area for years 2002, 2010 and 2015 were 3515.4, 6433.92 and 9305.46 ha, respectively. Annual increase in mining area was found to be 135.2ha, 364.8ha and 574.3 ha during the period 1976-2002, 2002-2010 and 2010-2015, respectively. It was observed that the annual increase in mines area during 2010-2015 was 4.25 times higher compared with 1976-2002.

4.3 Temporal analysis (Change detection)

As the mines got established many activities related to it evolved. This resulted in changing the LULC. The boundary of mines as delineated in the present case when overlaid over the preceding classified data clarifies visually which all classes were converted at the expense of mines (Figures 4, 5 and 6). During the period 1976 -2002, it was observed that all the four LULC classes of the year were converted to one class that is mines for the year 2002 (Figure 4). The loss of dense forest, open forest, other vegetation and other class during this period were 1234.44, 930.96, 90.72 and 1259.28 ha respectively (see figure 7). The annual loss in dense forest, open forest were 47.48, 35.8 ha respectively (see figure 8).

During the period 2002 – 2010, it was noted that the loss of dense forest, open forest, other vegetation, other class and water during this period were 466.2, 369.72, 419.67, 1662.48 and 0.45 ha respectively (see figure 7). The annual loss in dense forest, open forest were 58.28, 46.22 ha respectively (see figure 8).

During the period 2010 – 2015, it is seen that the loss of dense forest, open forest, other vegetation, other class and water during this period were 526.41, 520.38, 163.98,1660.59 and 0.18ha respectively (refer figure 7). The annual loss in dense forest, open forest was 105.28, 104.08 ha respectively (refer figure 8).

From the above results, it is clear that the trend of the annual forest loss is increasing gradually due to mining activity over the whole study period (1976-2015). The annual gain in the mining area also shows an increasing trend.

5. Discussion

The coal reserves are abundant in the dry tropical forests of this region. The presence of Rihand reservoir made this place quiet suitable for locating thermal power plants as they require a continuous supply of water and coal to generate electricity. Within few years, mines as well as thermal power plants got established and later expanded during 1976 - 2000. By this time, they started polluting the air and water resources which occurred concurrently with the loss of forest cover. After the year 2000, more rapid increase in the number of mines was noticed. Around the year 2006, five super thermal power plants, namely DainikBhaskar, Essar, Hindalco, Jaypee and Reliance were set up under the private-public partnership. After 2010, it is seen that the new mines have paved way through the Moher basin. The forest land was diverted to facilitate them and more such diversions are expected in the coming days (Chakravartty, 2011). So, Singrauli hosts about 10 thermal power plants with aggregate capacity of 13,200 MW and 14 coal mines with potential production of 83 million tonnes per annum (Junega, 2012).

The Singrauli district was once dominated by tropical dry deciduous forests before the advent of mines. The forests were dense and formed a part of the Vindhyan mountain ranges (Munshi, 2013; Khan and Javed, 2012). They provided habitat to a number of wild animals. The commercially important tree species found were Acacia catechu, Diospyrosmelanoxylon and Dendrocalamusstrictus. Other economically important tree species are Anogeissuslatifolia, Butea monosperma, Bassialatifolia, Lagerstroemia parviflora, Terminalia bellirica, Boswelliaserrata, Holarrhenaantidysenterica (Singh, 2007). These were a source of livelihood to the people of this area. Due to anthropogenic pressure like mining, agriculture expansion, illegal logging etc., the dry tropical forests are being converted to open secondary forests or savannahs and native tree species fail to establish further (Singh et al., 1991; Sagar and Singh, 2004). Further, Singh (2012) conducted a study to record the plant species growing on mine spoil in Singrauli coal fields. He noticed that the flora was dominated by members of family Poaceae, Fabacea and Asteracea. Only three native tree species like Butea monosperma , Acacia catechu and Zizyphus were found.

Plantation activity was undertaken by some private companies towards the south of the present study area. Mainly *Eucalyptus* species were planted. Some of the activities were undertaken by Northern Coalfields Limited in a programme called “Green Gold”, NTPC undertook plantation programme in the townships and colonies. Monoculture plantations have yielded less significant results as native tree species failed to establish themselves in the changed environment.

Besides, the air and water in the surroundings is highly polluted with traces of Mercury, arsenic and fluoride. Water is contaminated with mercury and so is fish, which is now not worth consuming. People are suffering various ailments. Now, Singrauli is also known as “India’s Minimata” and “A coal curse” (Junega, 2012).

Mining is not a natural phenomenon; it depends upon the number of leases commissioned by the Government. Many companies flout the norms and do not maintain standard emission rates. Such impacts should be monitored at regular intervals and negative impacts should be mitigated urgently. Accordingly, laws and policy decisions should be taken.

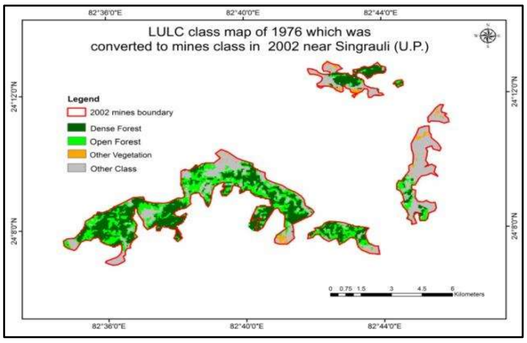

Figure 4: Temporal expansion of mines (1976-2002)

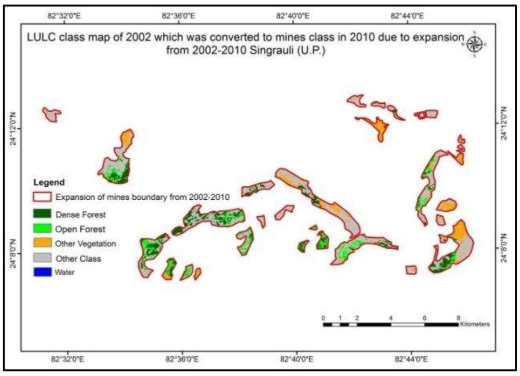

Figure 5: The expansion of mines (2002-2010)

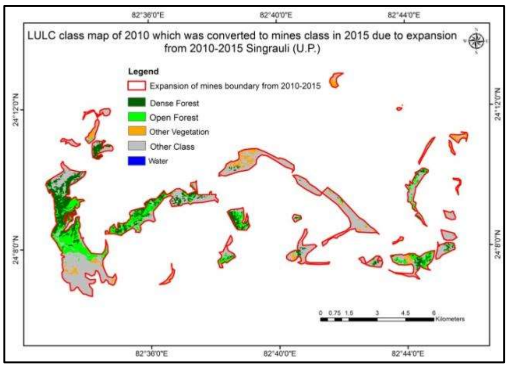

Figure 6: The expansion of mines (2010-2015)

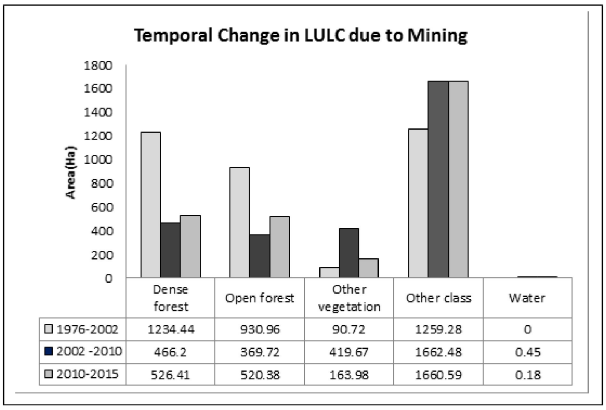

Figure 7: Graph to represent temporal change in LULC due to mining

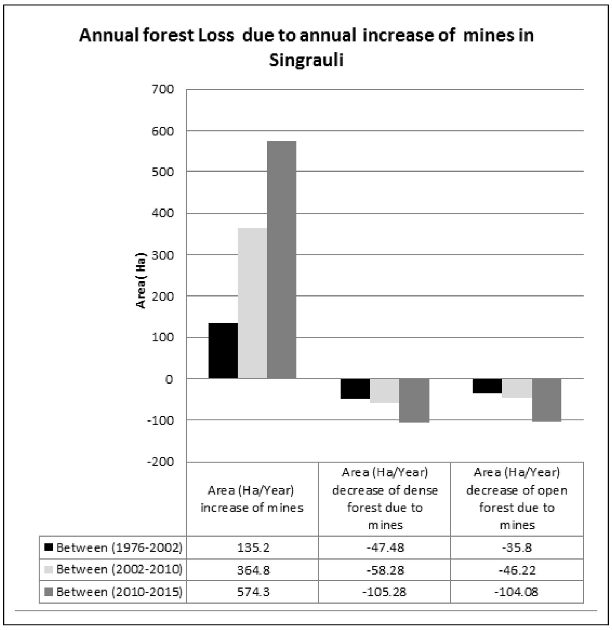

Figure 8: Graphical representation of annual forest loss

6. Conclusion

The study emphasizes that the satellite remote sensing data can be succesfully utilized for studying the spatial and temporal changes in LULC with respect to the mining activities. It is very helpful in monitoring at regular intervals such that the adverse impacts be identified and further appropriate steps should be taken to mitigate them. Such data is useful for staekeholders who operate the mines as well as forest officials to assist them in decision making such that they ensure that sustainability of forest ecosystems and healthy environment is maintained.

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