DOI 10.1515/pesd-2017-0020 PESD, VOL. 11, no. 1, 2017

GEOSPATIAL TECHNOLOGY PERSPECTIVES FOR MINING *VIS-A-VIS* SUSTAINABLE FOREST ECOSYSTEMS

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Keywords: Biodiversity, mines, deforestation, reclamation, satellite data, geospatial

Abstract Forests, the backbone of biogeochemical cycles and life supporting systems, are under severe pressure due to varied anthropogenic activities. Mining activities are one among the major reasons for forest destruction questioning the survivability and sustainability of flora and fauna existing in that area. Thus, monitoring and managing the impact of mining activities on natural resources at regular intervals is necessary to check the status of their depleted conditions, and to take up restoration and conservative measurements. Geospatial technology provides means to identify the impact of different mining operations on forest ecosystems and helps in proposing initiatives for safeguarding the forest environment. In this context, the present study highlights the problems related to mining in forest ecosystems and elucidates how geospatial technology can be employed at various stages of mining activities to achieve a sustainable forest ecosystem. The study collates information from various sources and highlights the role of geospatial technology in mining industries and reclamation process.

Introduction

Forests play a vital role in balancing biogeochemical cycles and life supporting systems and at present, are under severe pressure due to varied anthropogenic activities. In the current scenario, conversion of large tract of natural forest into agricultural lands, and subsequently for the construction of settlements, has changed the landscape beyond repair (Prasad et al., 2010; Pongratz et al., 2008; Ranade, 2007; Bell et al., 2001; Dhar et al., 1991; Rathore & Wright, 1993; Ghosh, 1989). In addition, mining activities are one among the major reasons for forest destruction since most of the mining locations are situated inside the dense, interior and biodiversity rich areas of the forests and near to fresh water bodies (Richards &

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Houston, 2004). The exponential growth of the mining sector within the forest areas not only shrinks the forested area, but also has its impact on the biodiversity by destroying or reducing their habitat, polluting the environment and finally questioning the survivability and sustainability of flora and fauna existing in that area (UNESCO, 1985; Parks et al., 1987; Bisht & Kothyari, 2001; Goretti, 1998; Singh, 2007; Songara & Rai, 2010; Kumar & Pandey, 2013). Moreover, the heavy equipment used in the open mining disturbs both ecological and hydrological balances within a short span of time (Koruyan et al., 2012). Besides, they also have a social impact by displacing the human population mainly the poor and tribal, who still sustain on forest produce for their livelihood (CSE, 2008). However, mining is inevitable as it defines the economic prospects of a country (Mondal et al., 2014). Thus the mining industry needs to address issues and mitigate the social and environmental impacts to achieve sustainability.

1. Mining Industry in India:

The Indian economy holds significant contributions from the mining industry as many states in India harbor rich mineral deposits (Mehta, 2002; Tripathy et al., 2012, Mondal et al., 2014). About 18% of total forest cover is observed in the districts of these mineral producing states (Areendran et al., 2013). The country had four major biogeographic zones 1) The Himalayas 2) Eastern Ghats 3) Western Ghats and 4) The Vindhyans of the central India (Murthy et al., 2003). All these zones are rich in forest biodiversity and have been exploited for minerals over the years, thus threatening the fragile ecosystems and making them vulnerable to forest fragmentation and degradation. Some of them are hubs for mining such as the Kudremukh for iron-ore (Karnataka), Dhanbad for coal (Jharkhand) Jharia and Raniganj coal fields (Jharkhand and West Bengal), Dehradun-Mussoorie for limestone (Uttarakhand), Singrauli (Madhya Pradesh and Uttar Pradesh border), Meghalaya and Assam in the northeast of the country. Chhattisgarh is the most vulnerable state that has lost its forest cover to mining actions, either closed or open mining activities (Figure 1).

The problem has alleviated because of government sanctioning more leases (based on fraudulent environmental impact assessments) and also directing forest land (biodiversity rich and wildlife corridors) towards such mining projects (Behar et al., 2005; Goparaju, 2014). Further, studies suggest that mining is the primary driver of forest changes with less percentage of forest conversions to agriculture (Kissinger et al., 2012). Another serious concern is many illegal mines operating in the forest area without any forest clearance or environmental clearance which is necessary as per rules and regulations laid down by the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India (GOI). Illegal mining is extensive in many states of India (ex. Karnataka, Andhra Pradesh, Orissa etc.,) and checking those areas is necessary as they contribute to economic loss and also pose severe environmental threat.

Figure 1. Major mining States of India (Discussed in the current study)

Geospatial technology has been well recognized in the mining sector in India.

Of late government and private sector industries are looking for a platform which will provide answers to public and ensure accountability. The GOI has started incorporating geospatial technology in combating various irregularities. For example, Saranda forests are the dense forests in the hilly region of West Singhbhum district of Jharkhand, India. They form a part of the core zone of the Singhbhum elephant reserve. In the Saranda forest of Jharkhand the government has asked the mining authorities to come up with a plan in the GIS (Geographic Information System) domain by preparing a DEM (Digital Elevation Model) and overlaying all the operational data in the proposed mining lease area. Further, a clockwise progressive mining and reclamation plan on DEM in GIS domain needs to be explored for future monitoring of mines (Ramanathan, 2014).

Thus, monitoring and managing the impact of mining activities on natural resources at regular intervals is necessary to check the status of their depleted conditions, and to take up restoration and conservative measurements. It is better to environmental threats. Furthermore, since mining is a temporary process, once the resources get exhausted the mining area is abandoned. (Jha & Singh, 1992; Singh et al., 2002; Sarma, 2005; Du et al., 2007).Then the focus should be on a restoration or reclamation process with suitable rehabilitation measures such as topographic and soil reconstruction, sediment and flood control to prevent runoff and erosion, planting pollution tolerant and fast growing species that can adapt to new environmental conditions and in scrapped top soil (Sahu & Dash, 2011; Bhattacharya, 2005; Rani & Ghosh, 1999).

In view of above context, the present study highlights some of the problems related to mining in forest ecosystems and elucidates how geospatial technology can be employed at various stages of mining activities to achieve a sustainable forest ecosystem.

2. Geospatial Technology – Mining Industry

The mining industry needs to be aided with a technology that ensures optimum benefit (Phifer, 2012). Geospatial technology (constituting remote sensing satellite data and GIS) plays a vital role in environmental monitoring and reclamation of mining areas covering large geographic areas in different time periods and for inaccessible areas (Parks et al., 1987; Rathore & Wright, 1993; Singh et al., 1997; Schmidt & Glaeser, 1998; Felink et al., 1998; Mouflis et al., 2008; Koruyan et al., 2012; Senthil Kumar et al., 2013). Geospatial technology can be effectively utilized in monitoring the impact of mining activities on forest ecosystem, in all phases of operation, beginning from selection of suitable mine sites, exploration and extraction, closure and reclamation (Bauer, 2000).

The changes that can be assessed include loss or removal of vegetation and important species, reduction in the wildlife in correlation to loss of habitat and forest fragmentation, acidic water discharge and change in land cover types (Dhar, 1990; Jamal et al., 1991). The technology also helps in analyzing severe land disruption and degradation caused by surface or subsurface /open pit mining (Koruyan et al., 2012). It also provides information about overburden of coal mines, mill tailings and indiscriminate disposal of waste materials into the nearby water bodies that harm the surrounding environment and its biodiversity (Koster & Slob, 1994; Schejbal, 1995).

3. Satellite remote sensing data – Availability:

The prerequisite for any satellite remote sensing analysis is the selection of proper satellite data. Satellite remote sensing data with varied spatial, spectral, radiometric and temporal resolutions is described in Table 1. This will help the experts to choose an ideal satellite data and offers the scope and potential to solve various mining related issues since it is cost–effective, accurate and saves time. Also, satellite remote sensing data have been made available in the public domain,

Table 1: Resolutions of satellite imagery

Spatial resolution: defines the pixel size of satellite images acquired. The ability to distinguish two closely spaced objects in an image. It is described as the geometric properties of the imaging system, known as instantaneous field of view (IFOV). It is the maximum angle of view in which a sensor can effectively detect electro-magnetic energy.	High spatial resolution data has a resolution between: 0.6 – 4m. Examples GeoEye 1; World View -2; Quickbird; IKONOS; Cartosat 1; and SPOT 5. Medium spatial resolution data: 4-30m resolution, Low spatial resolution data: 30->1000m	Examples ASTER; LANDSAT 7 and CBERS -2.
Spectral resolution: it refers to the dimension and number of wavelength regions (or bands) in the electromagnetic spectrum to which the sensor is sensitive.	High spectral resolution: 220bands.Medium spectral resolution: 3-15bands.Low spectral resolution: 3bands.	Examples: IRS –P3 (1996) MOS- A – 4 bands; MOS-B – 13 bands and MOS- C – 1band
Radiometric resolution: is a measure of how many grey levels are there between pure black and pure white. It is measured in bits.1. 7bit (0-127); 2. 8bit (0-255); 3. 9bit (0-511; 4. 10bit (0-1023.		Examples: IRS -1A/1B (1988, 1991) measure images in 7 bits. Cartosat -2 (2007), produces images in 10 bit radiometric resolution. 16 bit images are obtained from IRS -P3 (1996) MOS –A, MOS –B and MOS – C
Temporal resolution: It is explained as the frequency of coverage of ground by the remote sensing system.	High temporal resolution - <24hrs – 3days.Medium temporal resolution – 4-16days.Low temporal resolution - >16days.	Examples are: Cartosat 2 (2007) has a frequency of 5 days; IRS 1A/1B, 1988 and 1991 LISS I – have a repitivity for 22 days;IRS-P4 (1999-OCM and MSMR) has a frequency of 2 days

by a group of scientist from the University of Maryland (2013). First high resolution global map of forest extent (time period 1999-2012), defining both the forest loss and gain have been prepared and the data is open to all. Another such attempt has been made by the World resource Institute, USA (2014), which launched the site www.globalforestwatch.org where satellite data is available along with other baseline maps. The interface is user friendly. Thus the potential of spatial analysis and open data has been recognized in improving the forest management and landscapes. Such databases can be used by stakeholder, ecologists and scientists for management issues.

4. Geographical Information System (GIS): Softwares to aid in mining sector

In GIS, there are many mining software available (commercial, free and open) which helps in assessing 'What if' scenarios. They have superseded the traditional means of analyzing the mines and their environment. Each mine is different with respect to the geographic location and environment. Geography, geology, mineral ore modeling, excavation plans, optimized pit design etc are specific to each mine. All such aspects can be analyzed using an appropriate resolution of satellite data, and modeled in the GIS environs (Devireddy, 2013). Software companies like ESRI have developed a package named Geosoft Arc GIS exploration workflow solutions. Geochemistry for Arc GIS extension has the capability to analyze geochemical data within a GIS environment (International mining 2009). It is also feasible to see cross section diagrams portraying 3D data on 2D maps which depict the vertical section of the Earth’s crust (Meritt, 2012). The challenges required to be faced by the GIS software’s in dealing with the problems related to mining are gaining momentum (Samant & Datta, 2014). Further, the use of geospatial technology by BRICS countries (Brazil, Russia, India, China and South Africa) to achieve sustainable mining is an example set for others to follow (Datta, 2014).

5. Data sharing and access

Further, the huge data collected by big multinational companies must be made available to small companies for the benefit. This is possible in GIS environment. Small countries and companies can thus use the historical data for their purposes. Similar to an attempt made by Barrick Gold Corporation, world’s largest gold mining company, which created an online mapping portal with a large collection of online base maps. This exercise has made the availability of spatial data to a broader audience. Security features within ArcGIS keeps a check on users, ensuring that confidentiality is maintained. Decision makers are able to interact with the data and get a better understanding of global issues (Arc North News; Spring, 2013).

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7. Applications of geospatial technology in various stages of Mining activity

7.1 Identification of illegal mines*:* The use of different satellite data mostly moderate to high resolution data like AWIFS (Advanced Wide Field Sensor), Landsat MSS (Multi Spectral Scanner), TM (Thematic Mapper) & ETM (Enhanced Thematic Mapper), LISS (Linear Imaging Self Scanner) II, III & IV, can be used to map the extent of mining areas, precisely delineating the boundaries of the area given under the contract of lease (Srivastava & Sinharoy, 2001). Underground or closed mining activities usually result in the subsidence of the area which can be suitably detected using Synthetic Aperture Radar (SAR) data and Differential Radar Interferometry techniques (Mondal et al., 2008; Srivastava et al., 2012). The government can have a georeferenced database of leased mine areas assigned to different companies and can trace out illegal mines and their activities through temporal satellite data (Suresh & Jain, 2013). Presently, to curb illegal mining, the mining and geology department of Uttar Pradesh is considering the utilization of satellite remote sensing data (News, Geospatial World 2014). Also, the advanced technology of DGPS (Differential Global Positioning System) in addition to high resolution satellite data, aids in solving boundary disputes between leasing mine areas and their adjacent areas (agriculture, forest etc.,) with sub-centimeter accuracy. Curbing the growth of illegal mines in the vicinity of forest area would reduce the unnecessary pressure and damage to the biodiversity and wildlife existing.

7.2 Identification of suitable sites: Proposed mining area boundaries can be created in the GIS domain using geology, soil, hydrology and topographic maps. Remote sensing satellite data aids in the generation of forest cover map along with other land use and land cover (LULC) classes (Kaliraj & Malar, 2012). The delineated mining boundaries are overlaid on LULC (forest cover) map and spatially analyzed to select a site with low destruction of forest cover preserving the primary intact forest (Gangopadhyay, 2011). Further, while leasing the forest area to mining activities, areas of high biodiversity and endemism or protected areas should be avoided. Areas with low biological richness should be chosen for the mining activities to minimize the loss to forest strata. This can be done by the use of biological richness maps produced using satellite data in conjunction with field derived biodiversity information (Prasad et al., 2008). Flora and fauna data of every single forest patch is not available, but it may still hold a number of species or be a habitat for some wild animals. These small patches are important ecologically, socially, culturally and historically (WGEEP 2011). Corridors for animal movement can also be identified and excluded as far as possible. It is observed that most mining leases exist in proximity to forest area and wildlife sanctuaries (WLS). For example, in Goa, 31 leases lie within 2 km distance of WLS, out which 7 are active, 13 leases are within 1 km of WLS. Within a time span of 9 years (1988-1997), 2500 ha of forest area was lost to mining (TERI, 1997). Forest Survey of India, (FSI) in 1999, in collaboration with Indian Bureau of Mines (IBM**)** had utilized GIS for analyzing the forest cover in leased area for mining in three states of India, Madhya Pradesh, Odisha and Bihar. It was found that 53,217 ha of the leased area is under forest cover, out of which 71% is dense forest and 29% is open forest. Jeopardizing the ecosystem without full scientific knowledge will lead to disasters, losing more than we gain from commercial purposes.

7.3 Fire detection and accident management*:* Utilizing the technology at the most Prakash et al. (1997) used SWIR (Short wave infra red) and TIR (Thermal infra-red) bands of TM to identify the surface and subsurface fires in the Jharia coal fields. Similarly, Gangopadhyay et al. (2006) utilized thermal bands of TM to identify the temperature variation in the Raniganj coal belt. Further, making a temporal analysis, Martha et al. (2010) used thermal band of ETM (2003) and ASTER (2006), to delineate coal fire areas in Jharia Coal filed. Their study observed eastern part of the coal fields are more prone to fires compared to the western side. Accidents and disasters like fires, explosion, and inundation are common during mining practices. These events not only result in the loss of lives of workers, but also damage surrounding mining areas if they are not controlled on time. Proper management steps to evacuate during such disasters can be designed using GIS. GIS tools help in identifying the shortest and safest path route during such events; also helps in development of mechanism that alert the workers to respond appropriately to escape from the dangerous site. Since the mines are usually located near the forests, it is necessary that such accidental fires are controlled. It will cause less harm to the forest environment.

7.4 Spatio –temporal assessment of Land use and Land cover Intensive mining activities change the LULC features in and around the mining areas. The use of temporal satellite remote sensing data helps in identifying these changes in the landscape structure in a given interval of time. Some examples have been noted across the country (major States) where forests have depleted (we considered only impact on forest due to mining activities), and using geospatial tools it is easy to study the changes both spatially and temporally (Figure 2).

Figure 2. Location of mining sites (Discussed in the current study)

In an example of Singrauli area, mined areas are visually identified (Figure 3) from a merged product of Landsat-TM and PAN, 2013 (source: http:/landsat.usgs.gov).

Further, showing the potential of geospatial technology in delineating LULC, Landsat TM (2010) satellite data covering a part of Singrauli area was classified using digital image processing techniques. As a first step vegetation classes were masked out using the Normalized Difference Vegetation Index (NDVI). The satellite data without vegetation class was visually interpreted to delineate classes like the mining area and ash ponds as they were quiet distinct in the image. Later the other classes including agriculture, fallow, settlement and water body were obtained by using unsupervised classification. All the classes were integrated in model maker of ERDAS Imagine software to generate LULC map of study area along with area statistics of each class (Figure 5). The accuracy of the LULC map, derived using hybrid approach, was assessed by computing overall accuracy and kappa statistic. The result showed an overall accuracy of 92.19% with Kappa value of 0.91 indicating accurate delineation of various LULC classes.

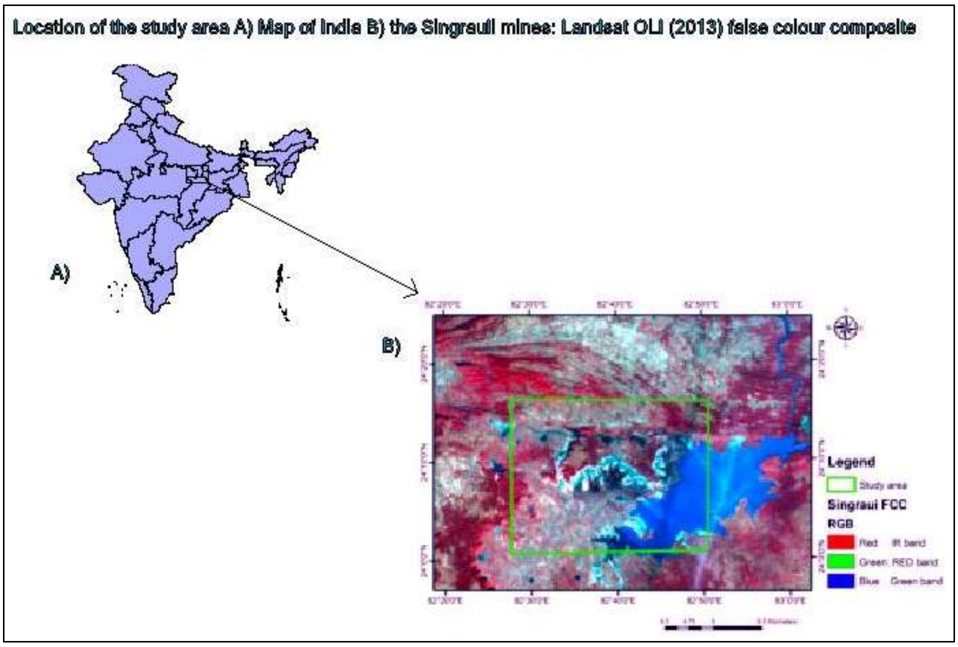

Figure 3 – Location of the study areaThe classified data of

In the Table 2 – It can be noted that the Singrauli mines (U.P. and M.P. border), Jharia and Raniganj mines (In Jharkhand) are the most studied. Thus, it is observed that increasing mining activities have reduced the forest habitat. Dense forests are depleted and open forests are more vulnerable to further degradation. In view of the above observations, dense forests must be "no-go" zones for mining. The open forest area must be protected such that further distortion is halted. Afforestation and plantation activities should take place in proximity to provide a buffering zone for forest biodiversity.

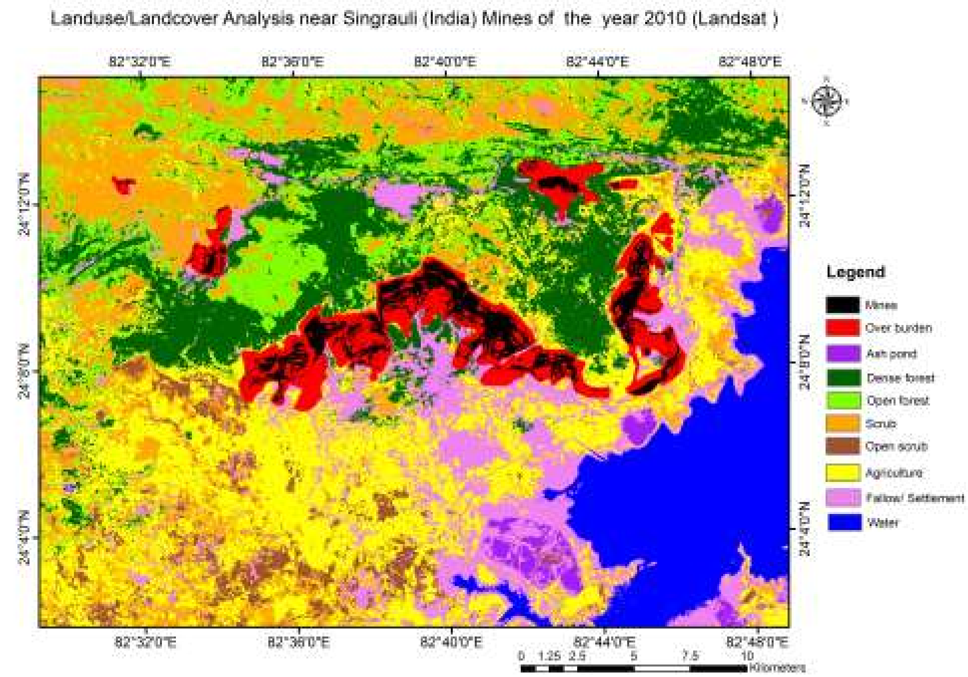

Fig. 4 Landuse/Landcover Analysis near Singraudi Mines in the year 2010 LANDSAT

7.5Identification of suitable afforestation sites around mining areas. In the GIS domain, buffer zones around the mining areas can be marked and possible areas to be affected can be assessed for the initiation of conservation measures to protect biodiversity. Since mining activities destroy forest areas, MoEF has made it mandatory to mining agencies to adopt compensatory afforestation programme. Towards this geospatial technology helps not only in identifying suitable sites for afforestation programme, but also aids in regularly monitoring the growth of these secondary vegetation time to time using temporal satellite data. The gas emissions and dust, pollutants released by vehicles and by mining blast, can be monitored by usingatmospheric remote sensing technology to assess the extent of aerosols present in the mining areas and their subsequent impact on surrounding floral and faunal biota. There by taking management actions like water spraying, creation of green belts by planting seedlings to subsidize the dust prevalence.

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Table 2 – Details of spatiotemporal study regarding mining in various states of India.

State	Data Used	Time period	Researcher	Remarks/comments
Jharia (Jharkhand) and Raniganj coal belt (West Bengal)	Landsat MSS, TM, LISS-I, and LISS II, SPOT (Satellite Pour l'Observation de la Terre), PAN (Panchromatic)	1925-27, 73-75, 88-89	Srivastava	It was observed that in the Jharia forest area decreased (vanished), along with an increase in scrub, settlements in addition to degradation of land and pollution of nearby rivers (ex. Damodar River). However no significant change has been observed in Raniganj.
South Karanpura coal fields of Jharkhand state.	1992 (ETM) 2004 and 2009 (LISS III)	1992-2004; 2004-2009	Kumar and Pandey (2013)	Increase in mining areas from 1992 – 2004 while a decrease during 2004-2009 (because of mineral depletion in the area) with significant loss in forest cover, in addition to crop land.
North Karanpura Coal fields limited,Ranchi (Jharkhand)	Satellite data analysis (TM 1992 & 2011)		Gaurav & Khan (2014	Loss of 10% of forest cover in the Dakra mining area, near Ranchi (Jharkhand) out of10%, 4% of deforestation is primarily due to mining activities.
Zawar group of mines in Udaipur, Rajasthan	IRS 1A,B, LISS II	1969-1997	Jhanwar,M.L.	Forests highly damaged in the leasehold as well as surrounding areas, mining area increased 0.24 km^2 in 1999, dense forests decline on the contrary in addition to the total disappearance of open forest.
Mining site in Jaintia hills of Meghalaya, India	Satellite remote sensing data of medium resolution like (MSS of 1975, TM of 1987, ETM+ of 1999 and LISS III data of 2007	1975 -2007	Sarma, 2005	Higher reduction in dense forest and increase in open forest owing to mining activities. It was observed that there was threefold increase in mining area (1975-2007), loss of 46.6 km^2 of dense forest. Later the abandoned mining area landscape is dominated by grassland and non-forest classes
Korba coal mines , Chattisgarh	MSS (1975), TM (1990), ETM (1999) and LISS III (2004)	1975-2004	Joshi et al (2006)	Significant decrease in forest cover due to mining operations.
Bailadila, Bastar district of Madhya Pradesh state	Pre mining LULC, he used aerial photos of 1966 & 1967 and for post mining MSS (1984), TM (1986) and	1966-1989	Venkatraman (MoEF Report)	Studied the change in terrain conditions (topography), surface drainage pollution in addition to LULC changes, in open cast iron ore mining areas, decrease in closed and dense forest area and an increase in area of degraded forest and mine area.

	LISS II (1989).			
Singrauli, (U.P. and M.P.border)	MSS (1975) and TM (1986 & 1999)	1975-1999	Singh et al (1997)	A decrease in agricultural lands and forest area because of mining and thermal power industry.
Singrauli coal mines (lying between the Singrauli district of Madhya Pradesh and Sonebhadra district of Uttar Pradesh)	LISS II (1993) and LISS III (2010),	1993-2010	Khan & Javed (2012)	Decrease in the dense forest (3.28% of the total in area from 2001-2010) due to mining activities.
Singrauli, (U.P. and M.P.border)	MSS (1978), TM (1991) and IRS LISS III (2010)	1978-2010	Areendran et al (2013)	Reported the loss of forest to cropland, settlements and mining areas. LULC change was quantified using landscape metrices. Further, using Markov change matrix they were able to infer about the rate of change. A correlation was found between decreasing forest cover and increasing mining in this area.
Salem district of Tamil Nadu	Landsat TM (1986); IRS 1A (1989) and IRS 1C 1996).	1986-1996	Saranatham et al., (2003	Observed that around 580 and 117 acres of land were converted into forest blank and degraded forest respectively. 290 acres of plantation was also converted to mining activities. The open cast mining in Chalk hill area is being carried out for decades.
Kudremukh (iron ore), Dehradun-Mussoorie (limestone mine belt), Korba and Talcher power plants.	three periods [1975 (MSS), 1985 (TM) 1988-89 (LISS II)]	1973-1989(Kudremukh) Dehradun (1972-1988). (1979-1987) Korba	Garg (MoEF Report	Mapped active and abandoned mining areas along with the influence of mining operations in the changing river course. It was observed that in the Kudremukh forest cover is reduced by 10.8 % for the time period 1973-1989. Grasslands were observed to increase by 2.8%. Dehradun, there was a loss of 2.8 km2 of forest cover. Similarly, significant reduction in the forest area was observed in Korba (25.2%) and in Talcher (34%), due to coal mining activities.

7.6 Monitoring invasive species. Once the mining areas are abandoned, they are encroached by invasive species or exotic species may be planted (Dutta & Agrawal, 2003). Monitoring and regulating these alien species is utmost important as they spread into nearby natural areas and threaten the native species (Kumari et al 2010). Using high resolution satellite imagery or hyperspectral imagery, these invasive species can be mapped with respect to their area of expansion and management actions can be planned accordingly to check their growth and spread. dust, pollutants released by vehicles and by mining blast, can be monitored by usingatmospheric remote sensing technology to assess the extent of aerosols present in the mining areas and their subsequent impact on surrounding floral and faunal biota. There by taking management actions like water spraying, creation of green belts by planting seedlings to subsidize the dust prevalence.

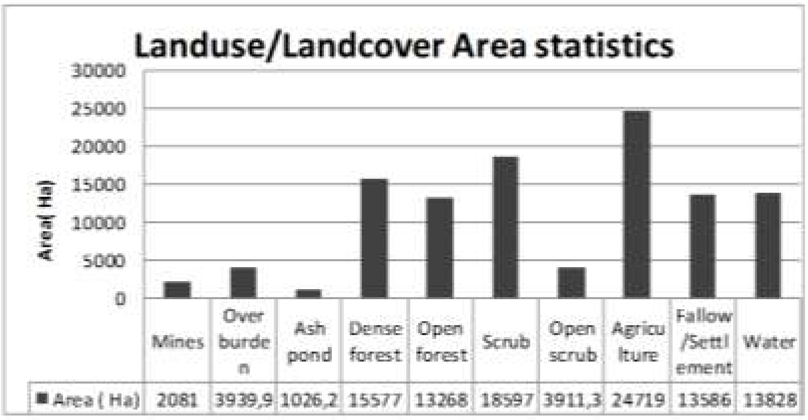

Figure 5 –Graphical representation

7.7 ***Reclamation of mining sites***. One step in the reclamation of the mining areas involves getting back the past ecological structure using back filling methods along with various topographical variables, especially slopes (Sahu & Dash, 2011). Digital Elevation Model (DEM) derived using different sources of varying resolution (ex SRTM, ASTER) will help in accurate estimations of the slope of the terrain. Arc GIS and geodatabase can be successfully utilized to study internal reclamation planning, mining permit reversion and renewals, annual compliance with various agencies. In Kayenta mine, NE Arizona, GIS was used to restore post mining topography approximately to that of pre mining topography (Huang et al., 2011/ 2012).

Singh et al (2011) used LISS IV and LISS III PAN merged temporal data having resolution of 5.8 m to monitor the reclamation of open cast coal mines of the country. The study showed that 79% of the mined land is reclaimed with the rest of the area (21%) under active mining. Out of the 79%, 52% of the area is already planted and 27% is back filled to prepare a bed for plantation activities. It was also reported that area under land reclamation increased from 192 km^2 (2008) to 225 km^2 (2009), because of the environmental protection steps initiated by coal companies in different projects of the country. Thus this kind of study successfully showed the utility of geospatial technology in assessing and monitoring reclamation activities in mining areas.

Conclusions

It is thus inferred that using satellite data of various resolutions it is possible to map and monitor different activities related to mining both spatially and temporally. Different remote sensing techniques are helpful. Geospatial technology can be used in extracting the information as desired by the user, combating the menace of illegal mines, monitoring LULC changes and also in reclamation of abandoned mines. Further, accidents can also be minimized and pollution levels can be monitored. The mining industry in India is flawed mainly because of irregularities and violation of laws. A large part of our population, tribes depend on forests for their livelihood. To provide a sustainable living to them, mining should be carried out in a planned manner. Environment managers and regulatory authorities should incorporate deductions from geospatial studies to ensure a better future of the mining sector, ensure forest sustainability and promote transparency.

Acknowledgements. We thank landsat.usgs.gov, for satellite data quoted as an example in the study.

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