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Mining Induced LULC Change Detection Study Using Landsat Satellite Data in Joda-Barbil Region of Kenojhar District, Odisha, India

D. BEHERA

Department of Earth Sciences, Sambalpur University, Jyoti Vihar, Burla – 768019

Email: dbeherasbp@gmail.com

Abstract: *Mining operations is essential for economic development of a country but it adversely affects the environment. All iron and manganese deposits of Keonjhar district are located in a hilly terrain that is thickly forested. Due to complex system of operation and a site-specific activity it directly responsible for Landuse and Landcover changes over an area in due course. The process of landuse and landcover change starts at the commencement of the mining operation due to need of development of approach road and unplanned land use for ancillary activities. During the mining operation and post processing phases, nearby area being dumped with rock waste, tailings etc which modify the Landuse pattern. This is due to rampant and unscientific mining activities; as a result it created various geomorphological features. Remote Sensing and GIS techniques can help for Landuse/ Landcover (LULC) mapping and change detection study which can provide appropriate and huge information to various field and decision making systems for natural resource management and sustainable development. Landsat satellite datas due to its free availability, it has extensive use in LULC change detection. Numbers of methodology and techniques like image processing, Principal Component Analysis (PCA), Image Ratio Method (IRM) and Normalise Difference Vegetation Index (NDVI) has been utilized in the present study. A detailed study has been undertaken by using Landsat satellite data and extensive field visits carried out to accomplish the landuse and landcover changes has been made in the study area due to mining activities.*

Keywords: *LULC change,GIS,PCA, image ratioing, NDVI*

1. Introduction

Mining operations is an important economic activity, which is necessary for the economic development of the society but at the same time it affects the environment variously. Incidentally iron and manganese ores deposits of Keonjhar district are located in a hilly terrain that is thickly forested. Since mining operation is a site-specific activity and especially opencast mining, due its complex system of operation where exploration, excavation and mineral processing takes place simultaneously. These activities are directly responsible for Landuse and Landcover changes over an area in the span of time. Land cover implies to any natural features like forest, water bodies, mountains, fallow lands, asphalt, trees, ploughed land etc. which covered the Earth's surface at the time of observation (Campbell, 2002).

Land cover is distinct from land use though they are very often used interchangeably; land use refers to how the land is being utilized for socio economic purposes, which involves full control of human beings over land for various purposes. A change in land use and land cover (LULC) is an emerging topic for research like environmental monitoring, planning and management. This LULC change represents how the land is being modified physically and biologically to obtain food and other essentials over a period of time.

Now a day's environment is getting deteriorated due to population explosion and its interference, over exploitation of natural resources, pollution, random land use for basic need and various other reasons (Satapathy et. al., 2007). Hence, it is very much essential to collect information about various changes occurring in landuse and land cover for different kind of studies. This information plays a vital role for various local and regional regulatory and governing bodies for macro level planning. Lack of information on rate of land use land covers changes posing problems to various planning and management agencies. The land-cover changes are natural process over the geological time but it is abrupt due to anthropogenic activities.

Since, ecosystems are dynamic in nature, LULC changes can be discussed in two ways, namely; "land cover modifications" and "land cover conversions" (Coppin et al., 2004, Henebry and Goodin, 2006). Coppin et al. (2004) explained that the land cover changes as "the complete replacement of one natural coverage by the other" and land cover modifications as "the slight changes that affect the nature of land cover without changing its overall classification". Land cover conversions are the results of urban sprawling, spreading out of agricultural field and wildfires whereas land cover modifications are happens due to climate changes, pollution, intra-

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annual cycles (Ahl et al., 2006, Lunetta et al., 2006, Telesca and Lasaponara, 2006). As a result, any types of land cover change have implications on various aspects of studies.

The landsat imagery data due to its continuous satellite based observatory system provides huge and longest information to the various researchers. For monitoring of regional and global changes of LULC occurred over the time, landsat is a precious resource and a principal source of medium spatial resolution Earth observation used for various policies and decision making (Chander et al., 2009; Fuller et al., 1994; Townshend et al., 1995; Goward and Williams, 1997; Vogelmann et al., 2001; Woodcock et al., 2001; Cohen and Goward, 2004; Goward et al., 2006; Masek et al., 2008; Wulder et al., 2008). Remote sensing has proved to be very vast useful for survey of natural resources/mineral resources and monitoring the environment especially, when fast and repeated observations are required (Satapathy et al., 2009). Land use land cover changes can be determined by digital process since it can analyse the geo-referenced multitemporal remote sensing data. It helps in identifying change between two or more dates which can be distinguished from normal variation.

1.1. Methodology and Data used:

Numbers of pixel analysis based methods have been used for change detection studies by various authors (Coppin et al., 2004; Deer, 1995; Ilsever and Ünsalan, 2012; Lu et al., 2004; Singh, 1989; Chengming et al., 2009; Di Giacomo et al., 2012; Robila and Varshney, 2003; Robila and Maciak, 2009; Qaoud, 2014). A pixel based methods and statistically derived landuse/ landcover mapping algorithm has been adopted in the present study to determine the changes that has been made over the time. In the electromagnetic spectrum the wavelength of the sensor of Landsat TM and ETM+ ranges from the visible to the thermal-IR portion. The spatial resolution of TM is of 30 meters for bands 1 to 5, and band 7, and 120 meters for band 6. In addition the ETM+ has panchromatic band with 15 meters spatial resolution. At first the Landsat satellite images has been orthorectified using RPC polynomial method. Then satellite metadata based conversion method is used to convert the raw DN values to reflectance value. After image calibration the mapping method is applied to the image and landscape changes has been identified. The methodology flow chart is given in fig.1. The details of the images used for this study are given in Table-1.

To undertake the landuse and landcover mapping around Joda-Barbil region different image processing methods like Principal Component Analysis (PCA) and Rational Polynomial Coefficients (RPC) orthorectification process has been adopted to correct various geometrical errors from the landsat datasets. In all, 40 DGPS ground control points (GCP) have been collected from the field for georeference of the imagery.

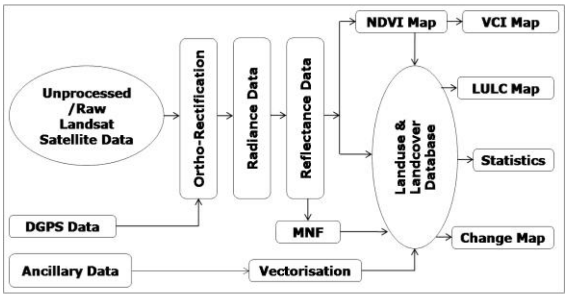

Fig.1. *Flow chart showing the overall methodology followed to complete this study*

Table 1: *Details of satellite datasets used for the study*

Name of the Satellite	Name of the Sensor	Path and raw	Date of acquisition
Landsat - 5	TM	P 140/R 45	01.11.1995
Landsat - 7	ETM+	P 140/R 45	26.10.2000
Landsat - 7	ETM+	P 140/R 45	05.10.2005
Landsat - 7	ETM+	P 140/R 45	10.12.2010

2. About the study area:

Joda-Barbil region, the area under study is bounded by latitude $22^0\ 00^{/}\ 00^{//}$ N to $20^0\ 10^{/}\ 00^{//}$ N and longitude $85^0\ 15^{/}\ 00^{//}$ E to $85^0\ 30^{/}\ 00^{//}$ E (Fig.2). Joda-Barbil region of the Kendujhar district is bestowed with vast mineral resources. The importance of this region has increased in recent year due to the rise in demand of iron and manganese metals in the domestic as well as global market. The region exhibits a rugged topography formed by a cluster of hills and valleys. The highest elevation of the area is 918m (the Thakurani hill top) and the lowest elevation is 400 m (near Kumudi) from MSL. Perennial nalas and rivers like Karo, Kundra, Baitarani and Koina constitute the drainage system of the area. The river Karo runs from the north western part towards north. Kundra nala lies in the southeastern part of the region and flows by the side of Joda town towards east. The river Baitarani is in the southeastern corner of the region and flows towards east.

3. Change detection techniques:

Numbers of change detection methods are in used for various researches. Mostly they can be studied in three ways namely spectral characteristic analysis, vector analysis of spectral changes and time series data analysis (Shaoqing and Lu, 2008; Maiti et al., 2014). For the purpose techniques like image processing and image classification has been adopted. In the image processing different errors reflected in the Landsat Image related to atmospheric, radiometric, and topographic corrections, geometrical rectification and image registration can be rectified which has been done in the pre- processing stage of landsat image data. To prepare a landuse land cover map accurate geometric registration is needed between multi-temporal images which can avoid replication of false changes due to image displacement in the scene. Errors caused by the various factors like sensor variation characteristics, atmospheric condition, solar angle, and sensor view angle can rectify by radiometric corrections to maintain the radiometric consistency. Later some sub-pixel level geometrical registration accuracy is needed to eliminate the image displacement error when analyzing multi temporal satellite image.

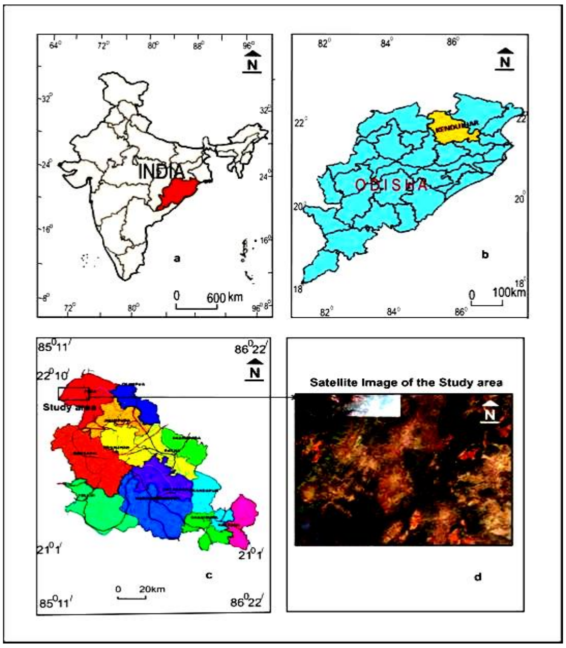

Fig. 2. *Map showing location of the study area (a). Map of India with position of Odisha, (b). Map of Odisha showing Keonjhar district, (c). Map of showing the position of the study area in the Keonjhar district, (d). Satellite image of the study area*

To undertake the landuse and landcover mapping of Joda-Barbil region, RPC orthorectification process has been adopted to correct various geometrical errors from the landsat datasets. By orthorectification method reduce the effects like image perspective (tilt) and relief (terrain) to generate a planimetrically corrected image. The ensuing orthorectified image maintained scale consistency and features are represented in their 'true' positions. This facilitated to measurement accurate distances, angles, and areas. The process works on a pixel-by-pixel basis to provide correct ground locations.

In all, 40 DGPS ground control points (GCP) have been collected from the field for georeference of the imagery. Rational Polynomial Coefficients (RPCs) are easiest empirical mathematical models as far as image gap (line and column position) is related with reference to latitude (X), longitude (Y), and surface elevation (Z). This model is reflecting the ratio of two cubic polynomial expressions. In this process a single image analysed two such rational polynomials, one for computing line position and the other for the column position (Di Giacomo et al. 2012).

Metadata based Landsat Calibration method is used in this study to convert Landsat digital numbers to spectral radiance or exoatmospheric reflectance (reflectance above the atmosphere) using published post-launch gains and offsets.

The spectral radiance (L_λ) is calculated using the following equation: (Chander et al. 2009):

$$L_\lambda = LMIN_\lambda + \frac{LMAX_\lambda - LMIN_\lambda}{QCALMAX - QCALMIN}(QCALMAX - QCALMIN) \quad (1)$$

Where:

- QCAL is the calibrated and quantized scaled radiance in units of digital numbers.
- LMINλ is the spectral radiance at QCAL = 0
- LMAXλ is the spectral radiance at QCAL = QCALMAX
- LMINλ and LMAXλ are derived from values published in Chander et al. 2009.
- QCALMIN is the minimum quantized calibrated pixel value (corresponding to LMINλ) in DN.
- QCALMAX is the maximum quantized calibrated pixel value (corresponding to LMAXλ) in DN. Valid values are 127, 254, or 255. When metadata is not available to determine the appropriate values, QCALMAX is set by default to 255 (TM and ETM+) or 127 (MSS).

The reflectance (ρ_p) is calculated using the following equation: (Chander et al. 2009):

$$\rho_P = \frac{\pi . L_\lambda . d^2}{ESUN_\lambda . \cos\theta_s} \quad (2)$$

Where:

- L_λ is the spectral radiance
- *d* is the Earth-Sun distance in astronomical units
- $ESUN_\lambda$ is the mean solar exoatmospheric irradiance.
- θ_s is the solar zenith angle in degrees.

3.1. Image Classification:

Image classification is an conceptual illustration of the state in the ground using well-defined analytical criteria:. It added the logical skeleton with the names of the different classes and methods used to differentiate them, it also correlate the relation between classes (Jansen and Di Gregorio, 2004). A practical based spectral classification technique called spectral angle mapper (SAM) has been used in this study for LULC classification of Joda- Barbil area. According to Chengming et al., 2009 this technique is an n-Dimensional angle and used to match pixels for reference spectra. The algorithm defines the spectral resemblance between two spectra by scheming the angle between the spectra. The angles are treated as a vectors in a space with dimensionally equal to the number of bands. This procedure when applied for calibration of reflectance data in relatively insensible to elucidation and albedo effects. SAM correlate the angle created between the endmember spectrum vector and each pixel vector in *n*-Dimentional space (Chengming et al., 2009). Slighter angles represent nearer matches to the reference spectrum. Pixels further gone than the precise maximum angle threshold in radians are not classified. In this study, the angle of 0.01 has been taken into consideration. In the given two *n*-dimensional vectors x and y, the spectral angle can be defined as (Keshava 2004):

$$SA(x,y) = \arccos\left(\frac{\langle x,y\rangle}{\|x\|_2\|y\|_2}\right) \text{(Robila and Maciak 2009)}$$

Where, <x,y> represents the dot product of the vectors and x_2,y_2 represents the Euclidean norm.

The spectral angle is always invariant to the scalar multiplication. The calculation is used in hyper spectral data processing as a technique for mapping the spectral resemblance of image spectra to the reference spectrum (Kruse 1993). It was also used for distance calculation in classification (various classes are viewed as being made of pixel vectors that make small angles) (Robila 2003).

4. Change detection Methods:

The LULC change detection methods applicable for multi-spectral satellite image data can be classified as: spectral type characteristic analysis, spectral changes vector analysis and time series analysis (Shaoqing and Lu, 2008; Maiti et al., 2014). The objective of spectral type characteristic analysis is to confirm the allocation and feature of changes on the basis of classification and calculation of spectral characteristic of different time series images. This method comprises the stacking of multi-temporal images, change detection by algebraic algorithm, change detection of the important image components and change detection after classification. The vector analysis of spectral changes method can reveal the strength and direction character of changes based on radicalization changes of images of different time particularly analyze the differences of all band. The time series analysis method can analyze the process and trend of changes along with monitoring of ground objects with the help of remote sensing repeated surveillance data. To derive the changes occurred over time in the Joda-Barbil region, the image ratioing method and the method of change detection after classification has been used to undertake this study.

4.1 Image Ratio Method:

In the image ratio method a pixel value of a different time series images divides the analogous pixel of a further time image. In this method, the ratio of corresponding pixels in each band of two images of different time periods after image registration will be calculated (Shaoqing and Lu,2008; Maiti et al., 2014). The formula is:

$$Rx^k{}_{ij} = x^k{}_{ij}(t_1)/x^k{}_{ij}(t_2) \qquad (3)$$

If the corresponding pixels of each image have the same gray value, namely $Rx^k{}_{ij} = 1$, then there is no changes has been occurred over the time.

$$NRx^k{}_{ij} = Int[Rx^k{}_{ij} \times 127 + 1] \qquad (4)$$

1 / 255 to 1 of the ratio would be transformed to 128~ 255 by the following linear transformation:

$$NRx^k{}_{ij} = Int[128 + Rx^k{}_{ij} / 2] \qquad (5)$$

A threshold value is required to demarcate the outline where considerable changes region found in the ratio image. After that the ratio image will be transformed to different change images like a simple change occurred image or no change image or positive change / negative change image which reflect the distribution and size of the changes. The selection of entry value must be based on the characteristics of the regional investigation targets and the surrounding environment. In this case the threshold values are variable for different regions, different times and different images (Fig. 3). The threshold value boundary of "change" and "no change" pixels can be selected from the histogram reflected in the ratio image.

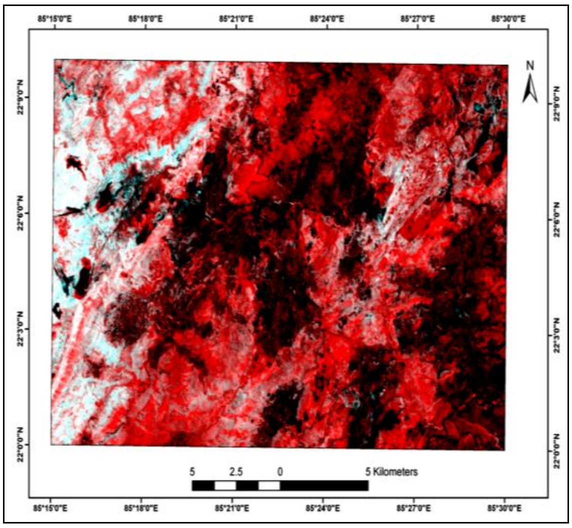

***Fig. 3**. Image showing the change (red coloured area) map from 1995 to 2010*

4.2 Normalized difference vegetation index (NDVI):

This change detection technique is a most widely used where the green biomass transformation is taking place. Normalized difference vegetation index (NDVI) is an image ratioing technique can map forest area change in most accurate and precise way (Fig. 4). The NDVI index is mainly based upon the reflectance characteristics of the vegetation in different wavelengths. In the electromagnetic spectrum red wavelength is absorbs by the chlorophyll present within the vegetation. In the other part the mesophyll reflects back the infrared segment. By using these specific wavelengths, we calculate the NDVI index by (Naveena Devi and Wilsen Jiji 2015).

$$NDVI = (\rho_{NIR} - \rho_{RED})/(\rho_{NIR} + \rho_{RED}) \qquad (6)$$

Where ρ_{NIR} refers to the near infrared reflectance and ρ_{RED} refers to the red band reflectance. After computation of the vegetation index for different time series data a standard pixel based approaches like differencing or rationing can be applied to determine the difference vegetation changes occurred over the time (Nelson, 1983; Singh, 1986; Naveena Devi and Wilsen Jiji 2015). The equation will give a value ranging from -1 to +1 and it is clear that the value closer 1, the larger the amount of vegetation biomass and –ve value will indicate bare coverage of vegetation.

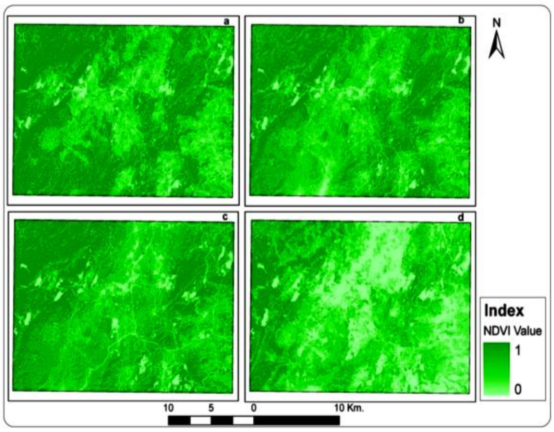

Fig. 4*. NDVI map of the study area for the year a) 1995, b) 2000, c) 2005 and d) 2010*

5 .Change detection after classification:

Change detection after classification is a very simple classification. This technique most widely used in LULC change detection study. In this technique a comparison can be done for different time series data after registration, including a classification step and a comparing step. Separate classifications are needed for each multi-temporal image then the classified resultant images are compared. If the analogous pixels have the same reflectance value in two different time series data, the pixel has not been changed, or otherwise the pixel has been changed where changes are occurred. There are two classification methods like supervised classification and non-supervised classification methods can be applied for the purpose. But non-supervised classification is most appropriate for the present study. Non-supervised classification can analyse point cluster. That is the process of searching and defining the natural spectrum cluster group in the multi-spectral image. Artificial selection of training point is not necessary for non-supervised classification. In few the cases some artificial initial input is needed, otherwise the computer can automatically composes the cluster group according to pixel values or spectral space. Then after each group and the reference data will be compared and can divide into different categories. For preparation of classification image at least two different time series images are needed and are classification are to done separately. The change image is made by comparing each pixel. The type of change of each changed pixel is determined by the change detection matrix (Shaoqing and Lu, 2008). These aforesaid two methods are being adopted in this study to monitor the landscape changes.

6. Results and Discussion:

Landuse and landcover cover mapping is a basic exercise that provides an essential and informative data set for natural resource management and planning. Change detection and its subsequent monitoring can be done by using numerous multi-date images. Since, these images can evaluate the differences in LULC due to different environmental conditions and human interference between the date of acquisition of images (Singh, 1989) (Fig. 5). Satellite remote sensing can successfully use for LULC change detection depending upon the adequate knowledge of landscape features, imaging systems and methodology employed in relation to the aim of the analysis (Yang and Lo, 2002). Various remote sensing data products over the time have frequently been integrated into historical land use information (Acevedo et al. 1996; Clarke et al., 2002; Meaille and Wald, 1990).

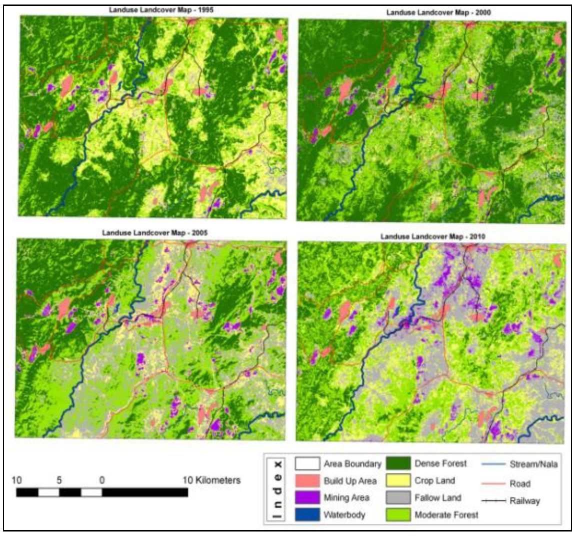

Fig. 5*. Map showing the LULC classes for the year from 1995 to 2010*

Joda-Barbil region, the study area covering 476 sq. km. has been classified into 8 classes namely built up area, mining, dense forest, moderate forest, fallow land, crop land, water body and road and railway (Table-2 and Fig. 6.). Total four number of landsat images with a time span of 15 years (1995-2010) has been classified. The forest land cover Groups such as dense forest and moderate forest showed a severe conversions and modifications as compared to other classes. It has been seen from the below classification area statistics table that the forest cover is rapidly vanishing from the study area due to unscientific rampant mining activities, pollution, climate change and human encroachment in forest land for fire wood.

Table 2. *LULC area statistics of Joda-Barbil region from 1995 - 2010*

Class Name	1995 Area (Sq. Km.)	2000 Area (Sq. Km.)	2005 Area (Sq. Km.)	2010 Area (Sq. Km.)
Dense Forest	226.49	144.31	121.73	89.04
Moderate Forest	130.58	173.09	153.68	139.85
Mining	8.90	9.74	11.42	32.18
Water body	0.69	0.86	1.03	1.17
Crop Land	70.51	59.99	56.99	42.92
Fallow Land	34.11	81.25	122.46	160.46
Road	0.32	0.54	0.73	0.92
Settlement	4.80	6.69	8.36	9.86
Total	476.40	476.47	476.40	476.40

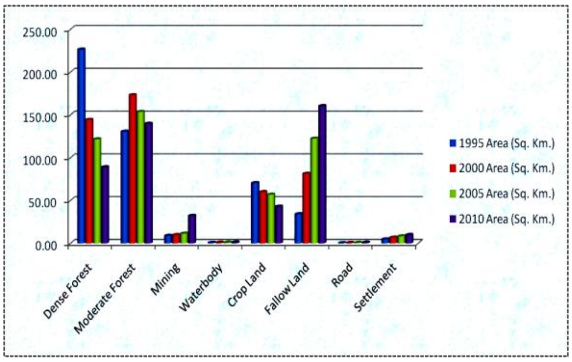

Fig. 6. *Showing the Bar diagram of LULC classes for 1995 to 2010*

Fig. 7. *Graph showing the trend lines of LULC classes for 1995 to 2010*

In 1995, the forest area is 357 sq. km, almost 75 % of the study area but in 2010 the forest area is only 228 sq. km, 47%. It is also depicted that the fallow land is increasing rapidly from 34.11 sq. km. (7.16 %) in 1995 to 160.46 sq. km. (33.68 %) in 2010. Basically, the mining activities transformed a forest bio-diversity rich area to a degraded fallow land (Fig. 7). The procedure of open-pit extraction of the mineral implies the excavation and extraction of important volumes of clearing materials using explosives. The explosives and the intense use of big machinery opened the process of massive reallocation of material and the change of the landscape. The large changes in forest cover could trigger abrupt, irreversible and harmful changes, these include regional climate change. Effective implementation of forest management plans, monitoring and enforcement is essential to safeguard the natural vegetation's, which serve as a key of life. Due to this rapid deforestation the ecosystem of the study area is destroying increasingly.

Two types of forest cover loss is depicted in the result, the first one is direct loss due to mining activities, which is about 23.28 sq. km. area when calculating from 1995 to 2010 and the second one is indirect loss of forest cover due to mining induced pollution, rock waste dumping etc. The indirect loss is about an area of 105 sq. km (Table-3 and Fig. 8). Air pollution has been deeply affected the forest cover of this region. The original greenish tone of forest has changed to blackish in natural color composite due to a large sponge-iron unit near Rugudi village. It is also highlighted in the MNF map as red color of the year 1995

Table 3. *Showing the area statistics of forest loss due to mining*

Year		1995-2000	2000-2005	2005-2010
Area of Forest Cover in Sq. Km.	Direct Loss	0.84	1.68	20.76
	Indirect Loss	39.67	41.99	46.52

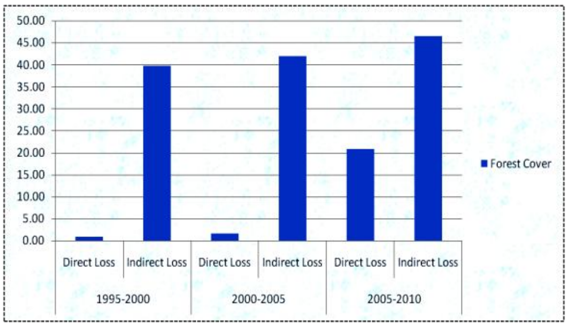

Fig. 8. *Bar diagram showing the forest loss for the year from 1995 to 2010*

The most important issue in landuse/landcover mapping using remote sensing data products are the measure of map accuracy. An accuracy assessment has been done and more than 85% overall accuracy has been achieved in mapping. The Kappa Coefficient is 0.7919. It means the Kappa accuracy is more than 79 %. The Error matrix is tabulated below.

Further a trend analysis has been done to see the future trends (Fig. 9). It has been seen from the trend that within 2040 the area covering dense forest is totally converted to mining and fallow land. The picture of trend analysis is given below –

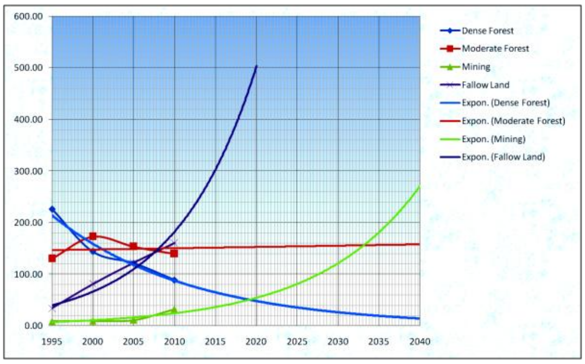

***Fig. 9**. Forecasting of LULC classes up to the year of 2040*

7. Conclusions

LULC Change mapping in the Joda- Barbil region helped in enhancing the capacity of local government to implement an ecosystem management plan to protect the forest cover from rampant mining activities. The method of change detection after classification is very useful in this study. The advantages of this method are – (1) it is very easy to interoperate the features. (2) It better handles calibration (including sun angle, shadow and topography impact) errors. The uses of the multi-temporal satellite images are gaining momentum in mapping Land use/land cover features. The remote sensing data products shows there credibility of change monitoring and vegetation stress measurement. Further, it was cost-effective, because it utilized free available remote sensing data sets.

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